ARMY RESEARCH LABORATORY

Human Research and Engineering Directorate, Major Laboratory Programs: Current Thrust Areas and Recent Research

by Bruce E. Amrein, Daniel N. Cassenti, Keryl A. Cosenzo, Andrea S. Krausman, Michael E. LaFiandra, Brent J. Lance, John F. Lockett, Kaleb G. McDowell, Kelvin S. Oie, Valerie J. Rice-Berg, Charneta L. Samms, and Jean M. Vettel

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14. ABSTRACT

The U.S. Army Research Laboratory's (ARL's) Human Research and Engineering Directorate conducts a broad-based program of scientific research and technology development directed into two focus areas: (1) enhancing the effectiveness of Soldier performance and Soldier-machine interactions in mission contexts and (2) providing the U.S. Army and ARL with human factors integration leadership to ensure that Soldier performance requirements are adequately considered in technology development and system design. This document provides an overview of the following thrust areas: human robot interaction, human system integration, neuroscience, and Soldier performance.

15. SUBJECT TERMS

human robotic interaction, human systems integration, neuroscience, social/cognitive network science, Soldier performance

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Contents

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1. Human Robot Interaction

The U.S. Army Research Laboratory (ARL) Human Research and Engineering Directorate (HRED) Major Laboratory Program Human Robot Interaction program seeks to enable the seamless integration of robots into military and related civilian activity. Our research premise is that to achieve this integration we need to fit the technology to the Soldiers and take into consideration a multitude of factors to include operating environments, tasks, user characteristics, and user preferences. We aim to determine how these factors affect states or actions such areas as decision making (both human and robot) and situation awareness. Army concepts for the robotic unmanned systems are varied. Platforms will range from large vehicles to smaller man-packable vehicles to micro systems. The level of autonomy will be variable across these platforms and will change depending on the size and function of the platform. The prevailing expectation is that autonomy will enable robots (i.e., air, ground, or sea) to function with minimal human intervention and that humans will be planners, controllers, and/or a supervisors. Additionally, humans will be the recipients, monitors, interpreters of the sensor information received by the robot, and will have role in communicating the sensor information to others.

As robots increase in capability and functionality, the operators will require appropriate enhancements to the displays and interfaces to task and control those robotic systems. The purpose of the human robotic interaction (HRI) research is to develop human factors technologies and design principles that enhance the Soldier interface with robots in order to reduce workload and improve Soldier-robot performance. This includes the investigation of supervisory control, automation, human-robot and robot-robot teaming, and interface technologies such as multimodal inputs and scalable interfaces. Our research program uses a multilayered approach, including modeling, simulation, laboratory experimentation, and field experimentation, to validate our HRI concepts. This approach allows us to evaluate HRI concepts in highly controlled environments and then transition those concepts to more military relevant environments. We have four main thrust areas within this Major Laboratory Program: Soldier-Robot Teaming, Supervisory Control, Intuitive Soldier Interactions, and Human-Inspired Robotics.

1.1 Thrust Area 1: Soldier Robot Teaming

Soldier-Robot Teaming is an important factor in the future use of robotic assets. Research has been and continues to be conducted in areas such as Team Characteristics, Supervisory Control, and Individual Differences. Team characteristics—size, member roles, and even asset types—can play a role in team success for various mission types. Important factors to consider with team characteristics include the use of heterogeneous robotic assets (i.e., UGVs and UAVs together), information integration techniques and personnel, and levels of automation. Research in Supervisory Control has a focus on an operator's ability to maintain situational awareness (SA) in a variety of operating conditions, ranging from full tele-op control to full autonomous vehicle operation. In addition, Supervisory Control investigates information sharing and the role that data flow can have in maintaining SA. The role of Individual Differences in Soldier-Robot Team performance includes the relationship of spatial ability to successful navigation, maintenance of SA, and successfully identification of potential targets; training retention to the amount of time needed to reach both competent and mastery levels of operational skill; and level of trust in automation to overall team effectiveness.

Note: Soldier-Robot Teaming research is lead by the University of Central Florida (UCF); all work completed by non-ARL employees is included in appendix D; ARL is currently developing a complimentary research program to the one continuing at UCF involving Soldier-Robot Teaming.

1.1.1 Research Area 1.1: Team Characteristics

- Research: 6.2%–100%
- Funding: 100% Collaborative
- Research Projects: 1
- Special Designators: SOURCE ATO
- Collaborations: University of Central Florida
- Keywords: Teaming, HRI, Heterogeneous Assets, RoboTech

Aim: The purpose of this area of research is to explore the relative effects of both team size and composition, as well as characteristics of human and robotic (e.g., for robots, homogeneous vs. heterogeneous) teammates, on the overall performance of the Soldier-Robot team. Of particular interest in this effort has been the use of a 'RoboTech' officer whose primary function is information integration and decision making and not robotic asset control.

Methods: This line of research is being completed using the UCF/Team Performance Lab (TPL) Scale MOUT Facility. Over the course of five experiments, participants have assumed team roles ranging from operator to 'RoboTech' and completed reconnaissance missions using interfaces designed for each specific team role. The initial study focused on team size in the form of operator-to-asset ratio and subsequent studies have further investigated the roles of each team member. Current and future studies are looking at the effects of varying asset automation roles. Primary performance measures for each of these studies are related to target recognition, with other measures such as workload and spatial ability used as covariates.

Progress: The continued collaboration with academic partners at the University of Central Florida has lead to many significant findings regarding team structure and roles. Specifically, the addition of the 'RoboTech' officer to integrate mission information has lead to increases in task performance and general team situation awareness.

Current Goals: Currently, this research is expanding beyond simple reconnaissance tasks and further investigating the role of automation in robot teaming, specifically, automation that allows assets to automatically reroute waypoints and share target identification information

1.1.1.1 Recent Publications:

Alban, J.; Cosenzo, K.; Johnson, T.; Hutchins, S.; Metcalfe, J.; Capstick, E. Robotics Collaboration Army Technology Objective Capstone Soldier Experiment: Unmanned System Mobility. In *Proceedings of the AUVSI Conference*, Washington, DC, CD-ROM, 2009.

Barnes, M. J.; Jentsch, F.; Chen, J. Y. C.; Haas, E.; Cosenzo, K. Five Things You Need to Know About Soldier-Robot Interactions. In *Proceedings of the 26th National Army Science Conference*, Orlando, FL, 2008.

1.1.2 Research Area 1.2: Shared Control of Heterogeneous Assets

- Research: 6.2%–100%
- Funding: 100% Collaborative
- Research Projects: 1
- Special Designators: SOURCE ATO
- Collaborations: University of Central Florida
- Keywords: HRI, Situation Awareness, Shared Control, Supervisory Control

Aim: The aim of this effort is to determing what factors contribute to increased or decreased situation awareness (SA) and how information is efficiently shared within the team when simulating collaboration among ground and aerial assets. As automation for unmanned vehicles (UVs) improves, there are fewer requirements for constant human supervision, presumably enabling operators to control heterogeneous assets; however, maintaining SA can become difficult for operators in this type of environment.

Methods: This line of research is being completed using the UCF/TPL Scale MOUT Facility. Five studies have been completed looking at variable levels of robot automation. Within these studies, the additional variables of shared information (i.e., map and RSTA camera views) and shared control (i.e., hand-off of asset control to second party) have been evaluated. In the current study, the robots will operate in one of two modes; Independent Operation or Team Collaborative, designed to investigate robot-robot collaboration effects on operator SA.

Progress: The continued collaboration with academic partners at the University of Central Florida has lead to many significant findings regarding supervisory roles in Soldier-Robot teams, especially in regards to the sharing of information and control and its effects on SA. Specifically, SA has shown to be positively influenced when operators share information (i.e., map and reconnaissance camera views) but that positive influence is then significantly decreased when UV control is shared between parties.

Current Goals: Currently, research along this line is looking to expand performance beyond simple reconnaissance tasks and will look to further investigate the role of automation in team SA. Specifically, automation will be implemented which allows assets to automatically communicate critical information with one another to pre-filter target data before it reaches the human supervisors, thus attempting to limit the confusion of redundant information. Additionally, some aspects of cueing will be investigated to determine any helpful effects on maintaining positive SA.

1.1.2.1 Recent Publications:

Chen, J. Y. C.; Clark, B. R. *UAV-UGV Teaming: UAV-Guided Navigation*; ARL-TR-4462; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2008.

Barnes, M. J.; Cosenzo, K.; Jentsch, F.; Chen, J.; McDermott, P. Understanding Human Robot Teaming Using Virtual Media. In *Proceeding of the NATO Conference on the Use of Virtual Media for Military Application*, West Point, NY, June 2006.

1.1.3 Research Area 1.3: Individual Differences

- Research: 6.2%–100%
- Funding: 100% Collaborative
- Research Projects: 2
- Special Designators: SOURCE ATO
- Collaborations: University of Central Florida
- Keywords: Individual Differences, Spatial Ability, Training Retention

Aim: The purpose of this area of research is to explore the relative effects of human team member individual differences on the overall performance of the Soldier-Robot team. Of particular interest in this effort has been spatial abilities and their effects on situation awareness (SA), route planning and way finding, as well as, information communication between team members (i.e., target location/orientation). In addition, the effects of training, shape memory, and inherent 'back-up' behaviors have been and continue to be investigated for potential effects on performance.

Methods: This line of research is being completed using the UCF/TPL Scale MOUT Facility and simulation. Over the course of all of the research experiments, participants have undergone a battery of assessments to evaluate individual difference among unmanned vehicle operators. These assessments have looked at spatial abilities from several aspects, as well as, evaluated the retention of training material including the robot interface controls and target knowledge. These factors have then been used as covariates in each study helping to further the understanding of performance outcomes. Current and future studies are continuing to look at these factors as they have proven time and again to be both relevant and significant. Primary performance measures for each of these studies are related to target recognition, with measures for spatial ability and training retention used as covariates.

Progress: The continued collaboration with academic partners at the University of Central Florida has lead to many significant findings regarding individual differences as they pertain to performance outcomes. Specifically, individual spatial ability plays a significant role in the ability to control, supervise and understand robot asset actions, as well as the ability to maintain mission SA. Training has shown to have a steep development curve leading to operator competency (i.e., only a few hours a training can make a competent robot operator), but much longer times (i.e., potentially hundreds of hours) to achieve mastery.

Current Goals: Currently, research along this line is looking to continue investigating the effects of individual differences as mission tasks expand into new areas. One of the potential areas for specific investigation is trust in automation, an area that has a deep history in aviation, but needs more attention when looking at Soldier-Robot teams in military context.

1.1.3.1 Recent Publications:

Chen, J. Y. C.; Durlach, P. J.; Sloan, J. A.; Bowens, L. D. Human Robot Interaction in the Context of Simulated Route Reconnaissance Missions. *Military Psychology* **2008**, *20* (3), 135–149.

Chen, J. Y. C.; Terrence, P. I. Effects of Imperfect Automation and Individual Differences on Concurrent Performance of Military and Robotics Tasks in a Simulated Multitasking Environment. *Ergonomics* **2009**, *52* (8), 907–920.

1.2 Thrust Area 2: Supervisory Control

Unmanned vehicles, including unmanned air vehicles and unmanned ground vehicles, are becoming an essential part of the battlefield, encompassing aerial, sea, ground, and subterranean applications. Battlefield collaborations will involve large numbers of robots, as well as an equal number of manned systems requiring novel techniques such as call center approaches, to monitor the unfolding decision environment. The complexity and sheer number of mixed assets in future operations will require increased autonomy and problem-solving capabilities for unmanned systems. However, as span of control increases, the operator's ability to task and manage the robotic assets may decrease if the control and interaction strategies are not effective. In this research thrust, we investigate human performance issues in supervisory control of multiple robots with regard to operator multitasking performance, trust in automation, situation awareness, and operator workload. We also investigate potential mitigation strategies such as intelligent agent and multimodal controls and displays.

1.2.1 Research Area 2.1: Supervisory Control of Multiple Robots and Robotic Swarms

- Research: 6.1%–100%
- Funding: Internal (DRIs) 100% Collaborative
- Research Projects: 2
- Special Designators: DRI
- Collaborations: (a) RoboLeader: Prof. Zhihua Qu (Dept. of Computer Science and Electrical Engineering, University of Central Florida); (b) Human-Swarm Interaction: Dr. MaryAnne Fields (ARL-VTD)
- Keywords: Supervisory Control, Swarm, Intelligent Agent, Multimodal Control

Aim: This research area investigates Supervisory Control of Multiple Robots and Robotic Swarms, which includes two research efforts: *RoboLeader* and *Soldier-Swarm Interaction*. *RoboLeader* is an intelligent agent that can help the human operator coordinate a team of robots, and its capability is being expanded to deal with dynamic re-tasking requirements for persistent surveillance based on various battlefield developments. A simulation experiment that investigates the effects of unreliable RoboLeader (false alarm-prone or miss-prone) on operator performance is also being conducted. In the research on *Soldier-Swarm Interface*, the effort focused on the design of algorithms and multimodal control and display devices that allow Soldiers to efficiently interact with a robotic swarm conducting a reconnaissance mission within convoy operations.

Methods: Both research efforts utilize human-in-the-loop simulations in their experimentation. There are three experiments conducted on RoboLeader and two experiments on Soldier-Swarm Interaction. The RoboLeader studies examines human operator performance when using RoboLeader to control four or eight ground robots to performance reconnaissance and the effects of RoboLeader reliability on operator performance and individual differences factors such as operator attentional control on his/her trust behavior. The user interface of RoboLeader incorporates ecological interface design to convey the constraints in the tasking environment to the human operator. For Soldier-Swarm Interface, a multimodal Soldier-swarm display containing visual, audio and tactile cues was developed to show swarm and convoy geospatial position; swarm health and communication; and convoy status information. The effectiveness of the interface was tested in a laboratory study and in follow-on research a multimodal speech and touch Soldier-swarm control interface was developed and tested.

Progress: As supervisory control strategies are developed and experimentally tested, we are working with computer scientists and roboticists to guide the development of the robotics intelligence architecture. It is the coupling of HRI with the robotic system development that will enable us to improve soldier robot interaction in the field.

Current Goals: User interfaces developed under these research efforts will be transitioned to MAST CTA, SOURCE ATO, and Joint ARL research with the University of Texas (Arlington), exploring the use of heterogeneous swarms containing ground vehicles and helicopters.

1.2.1.1 Recent Publications:

Chen, J. Y. C.; Barnes, M. J.; Harper-Sciarini, M. Supervisory Control of Multiple Robots: Human Performance Issues and User Interface Design. *IEEE Transactions on Systems, Man, and Cybernetics--Part C: Applications and Review*, under review.

Chen, J. Y. C.; Barnes, M. J.; Qu, Z. *RoboLeader: A Surrogate for Enhancing the Human Control of a Team of Robots*; ARL-MR-0735; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, February 2010.

Haas, E.; Fields, M.; Hill, S.; Stachowiak, C.; Pillalamarri, K. Extreme Scalability: Multimodal Controls for Soldier-Robotic Swarm Interaction; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, in press.

Haas, E.; Fields, M.; Hill, S.; Stachowiak, C. *Extreme Scalability: Designing Interfaces and Algorithms for Soldier-Robotic Swarm Interaction*; ARL-TR-4800; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2009.

1.2.2 Research Area 2.2: Mitigation Strategies for Managing Task Load

- Research: 6.2%–100%
- Funding: 100% Collaborative
- Research Projects: 3
- Special Designators: IMOPAT and SOURCE ATO
- Collaborations: University of Central Florida, George Mason University, STTC
- Keywords: Human Robotics Interaction (HRI), Adaptive Automation, Operator State Assessment

Aim: The ability to incorporate robot control with existing Soldier tasks will be an issue and the management of Soldier workload will be problematic. We are investigating several mitigation strategies for task load management. One such strategy is automation to support Soldier performance. Our aim is to develop effective mitigation strategies and transition that solution to a prototype system in which the Soldier is required to manage the workload of being a robotics operator in a complex environment.

Method: With multiple university partners we are investigating the multitasking constraints of the robotic environment. From this work we are evaluating several mitigations strategies to overcome performance bottlenecks. Our research efforts utilize human-in-the-loop simulations in their experimentation. The simulations are designed to represent an operator interface that is anticipated to be used by the Soldier and is reconfigurable to respond to any design changes. We are utilizing a multiple measure approach–objective performance, subjective workload, and physiological measurement to include eyetracking, ECG, and EEG for our research. Automation aids have included automated target recognition, vehicle autonomy, and multimodal cues.

Progress: We are currently pursuing the development of a hybrid automation approach which takes into consideration task load, operator state, and real time physiological measurement. We are assessing the use of different automations as well as invocation strategies. Our recent research results have shown some promise with the use of eye movement patterns as indices of operator state. We continue to pursue the application of multimodal signals for information displays about system status as well as means to control or communicate intent between the Soldier-robot team.

Current Goals: Our goal is to develop automation and cueing strategies for the dual task of tele-op driving and maintaining situation awareness. The triggers for this scheme will be task based with the intent to measure other behavioral parameters to guide future research.

1.2.2.1 Recent Publications:

Chen, J. Y. C.; Terrence, P. I. Effects of Imperfect Automation on Concurrent Performance of Military and Robotics Tasks in a Simulated Multi-Tasking Environment. *Ergonomic* **2009**, *52* (8), 907–920.

Chen, J. Y. C.; Durlach, P. J.; Sloan, J. A.; Bowens, L. D. Human Robot Interaction in the Context of Simulated Route Reconnaissance Missions. *Military Psychology* **2008**, *20* (3), 135–149.

Cosenzo, K.; Chen, J.; Reinerman-Jones, L.; Barnes, M.; Nicholson, D. Adaptive Automation Effects on Operator Performance During a Simulated Reconnaissance Mission With an Unmanned Ground Vehicle. *Accepted for presentation at the 54th Annual Meeting of the Human Factors and Ergonomics Society*, Human Factors and Ergonomics Society: San Francisco, CA, 2010.

Cosenzo, K.; Parasuraman, R. Automation Strategies for Facilitating Human Robot Interaction. Human-Robot Interactions in Future Military Operations Barnes; M. J., Jentsch, F., Eds.; 2010.

Cosenzo, K.; Parasuraman, R.; Pillalamarri, K. *Appropriate & Inappropriately Applied Automation for the Control of Unmanned Systems on Operator Performance*; ARL-TR-4933; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2009.

Fidopiastis, C.; Drexler, J.; Barber, D.; Cosenzo, K. Impact of Automation and Task Load on Unmanned System Operator's Eye Movement Patterns. In *Proceedings of the Human Computer Interaction International Conference*, San Diego, CA, CD-ROM, 2009.

Haas, E. C.; Stachowiak, C. C. Multimodal Displays to Enhance Human Robot Interaction on-the-Move. In *Proceedings of the Performance Metrics for Intelligent Systems (PerMIS) Conference*, 2007, 135–140.

Haas, E. C. Integrating Auditory Warnings With Tactile Cues in Multimodal Displays for Challenging Environments. In *Proceedings of the International Conference on Auditory Displays*, 2007, 127–131.

Parasuraman, R.; Cosenzo, K.; DeVisser, E. Adaptive Automation for Human Supervision of Multiple Unmanned Vehicles: Change Detection, Situation Awareness, & Workload. *Military Psychology* **2009**, *21*, 270–297.

Taylor, G.; Reinerman-Jone, L.; Cosenzo, K.; Nichoson, D. Integrating Multiple Physiological Sensors to Classify Operator State in Adaptive Automation Systems. *Accepted for Presentation at the 54th Annual Meeting of the Human Factors and Ergonomics Society*, Human Factors and Ergonomics Society: San Francisco, CA, 2010.

1.3 Thrust Area 3: Intuitive Soldier Interactions

Our interface research focused on four issues: (1) scalability, (2) dismounted and (3) mounted operations, and (4) display guidelines. (1) Scalability allowed a common picture of the battlefield to be disseminated to mounted and dismounted Soldiers while keeping the information content appropriate for different mission environments. (2) We examined various interface options to aid dismounted robotic operators allowing them to focus their attention on the current combat environment. We evaluated display options, tactile communications and navigation aids, and voice systems. In particular, we found that a small set of intuitive tactile patterns could be learned rapidly and used by robotic operators to locate hidden targets. True stereos displays using various technologies (polarity and split-eye presentations) proved to be efficacious for finding and manipulating IEDs as well as being effective for SUGV navigation. (3) For mounted operations, we demonstrated that tactile and 3-D audio multimodal displays improved targeting performance for robotic missions. Tactile decision support was found to be useful for alerting operators of threats near the mounted vehicle while they were conducting remote targeting with robots. However, because important individual differences were found, we argued that specialized training and display options are necessary to ensure enhanced performance for every Soldier. (4) Finally, our results were used to develop metrics and guidelines for interface design. In general, we demonstrated that the soldier's intuitive understanding of the battle field could be enhanced by using true stereo displays, tactile and audio augmentation, and target aiding in order to reduce workload and improve performance for robotic operators. We obtained the results using workload modeling, laboratory experiments, realistic simulations, and field exercises with active duty Soldiers controlling live robots. Our goal is to develop intuitive interfaces that aid Soldiers to overcome intentional deficits and increased workload typical of combat environments encountered by mounted and dismounted Soldiers conducting robotic missions. Methods and interfaces that allow the Soldier to use supervisory control technologies to monitor and to intervene when necessary for controlling multiple semiautonomous robots is envisioned.

1.3.1 Research Area 3.1: Dismounted Operations

- Research: 6.2%–100%
- Funding: Internal - 50% Collaborative - 50%
- Research Projects: 6
- Special Designators: Robotic Collaboration ATO and SOURCE ATO
- Collaborations: TARDEC, SPAWAR, Ben Gurion University (Israel), TNO Research Institute (Netherlands)
- Keywords: Infantry, Small Robot Control, Semi-Autonomy, Teleoperations, Human Robotic Interaction

Aim: Dismounted Soldiers must be able to carry the robotic controllers along with all their fighting and sustainment gear and must be able to engage in robotic control while simultaneously attending to other aspects of the dismounted environment. The aim of the research is to investigate effective techniques for scaling robotic interfaces (controls and displays) for use by dismounted Soldiers. Scaling interfaces ensures smooth transfer of training across interface systems and allows tailoring to specific tactical contexts.

Method: Each of the experiments in this research program was conducted in field settings that simulated the tactical environment and task demands of the dismounted Soldier. For each study, a robotic course was designed to evaluate the ability of Soldiers to perform a series of reconnaissance and navigation tasks using various controls and displays. Active duty Soldiers served as participants. Each experiment used a within-subjects design. The controls and displays were evaluated based on objective performance data, data collector observations, and Soldier questionnaire responses.

Progress: A number of findings have emerged from this line of research. Design guidelines have been developed for controls and displays that are scaled down to be easily portable by the dismounted Soldier and that provide an adequate interface for robotic navigation and reconnaissance. Such guidelines as when to use speech-control, how to tailor speech command language to the Soldier population, using tactile displays for navigation beyond line of sight, the minimum size for a driving display, the effects of goggle mounted displays on robotic control, methods for reducing controller size, techniques for operating a robot on the move, and the benefits of telepresence and autonomy for reconnaissance tasks have been developed and documented with objective data. Cooperative research has been accomplished with the Netherlands, SPAWAR, industry, Israel, other elements of ARL, and TARDEC. These experiments have been reported in seven ARL technical reports, one book chapter, six conference presentations, and six refereed journal submissions.

Current Goals: Current goals include documentation of the contribution of individual aspects of telepresence to the reconnaissance mission, a robotic workshop designed for researchers, industry, and academia to share accomplishments, investigation of omnipresence and long endurance autonomy with two different divisions of SPAWAR, and continuation of investigation into ways to reduce the robotic interface size for the dismounted Soldier. Findings from this research have already been used in the design of robotic interfaces and in requirement documents.

1.3.1.1 Recent Publications:

Coovert, M.; Elliott, L. Cognitive and Task Demands for a Prototypical Robot Operator: Specifications from O*NET. In *Proceedings of the Human-Robot Interaction*, Santa Monica, CA, 2009.

Elliott, L. R.; Redden, E. R.; Pettitt, R. A. Using a GPS-Based Tactile Belt to Assist in Robot Navigation. In *Proceedings of the 3rd Applied Human Factors & Ergonomics Intl Conference,* Orlando, FL, 2010.

Elliott, L. R.; van Erp, J.; Redden, E. S.; Duistermaat, M. Field-Based Validation of a Tactile Navigation Device. *IEEE Transactions on Haptics*, 29 January 2010. IEEE Computer Society Digital Library. http://doi.ieeecomputersociety.org/10.1109/TOH.2010.3.

Pettitt, R. A.; Redden, E. S.; Carsten, C. B. *Scalablity of Robotic Controllers: Speech-Based Robotic Controller Evaluation*; ARL-TR-4858; US Army Research Laboratory: Aberdeen Proving Ground, MD, 2009.

Pettitt, R. A.; Redden, E. S.; Carstens, C. B. *Scalability of Robotic Controllers: An Evaluation of Controller Options*; ARL-TR-4457; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2008.

Redden, E.; Carstens, C.; Pettitt, R. Intuitive Speech Based Robotic Control; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, in press.

Redden, E. S.; Elliott, L. R.; Pettitt, R. A.; Carstens, C. B. A Tactile Option to Reduce Robot Controller Size. In *Journal on Multimodal User Interface* **2010**, *2*, 205–216. http://www.springer.com/computer/user+interfaces/journal/12193.

Redden, E.; Elliott, L.; Pettitt, R.; Carstens, C. Scaling Robotic Systems for Dismounted Warfighters. In Special Issue on Improving Human-Robot Interaction Journal of Cognitive Engineering and Decision Making Special Issue on Improving Human-Robot Interaction, in review.

Redden, E. S.; Pettitt, R. A.; Carstens, C. B.; Elliott, L. R. Scaling Robotic Displays: Displays and Techniques for Dismounted Movement with Robots; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, in press.

Redden, E. S.; Petitt, R. A.; Carsten, C. B.; Elliott, L. R.; Rudnick, D. *Scaling Robot Displays: Visual and Multimodal Options for Navigation by Dismounted Soldiers*; ARL-TR-4708; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2009.

Redden, E. S.; Pettitt, R. A.; Carstens, C. B.; Elliott, L. R. *Scalability of Robotic Displays: Display Size Investigation*; ARL-TR-4456; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2008.

1.3.2 Research Area 3.2: Specialized Interfaces

- Research: 6.2%–100%
- Funding: Internal - 70%; Collaborative - 30%
- Research Projects: 2
- Special Designators: SOURCE and IMOPAT ATO
- Collaborations: Leonard Wood Institute, FCS funding
- Keywords: Robotics, Tele-operation, Vision, Manipulation

Aim: The aim of this line of research is to evaluate improvements to mission-based performance of robotic systems thru the development and evaluation of specialized display concepts including stereovision and multimodal interfaces.

Methods: Multimodal studies investigated the added utility of audio, voice and tactile systems for SUGV and UGV interfaces both in laboratory experiments and field exercises at Ft. Benning and Ft. Bliss. Initial studies for stereovision at Fort Leonard Wood focused on determining requirements and assessing performance for 3-D display, camera, and control systems as they relate to potential application in several military missions. Laboratory studies conducted at the ARL-HRED Field Element in Orlando were used to assess navigation improvements by comparing various stereovision systems.

Progress: The multimodal systems showed performance advantages in target alerting, navigation aids, and silent communications for both mounted and dismounted missions. A series of studies at Fort Leonard Wood aided in the development of a workable stereovision system that included a coordinated camera and controls for military robotic systems. The final product (developed by Polaris Sensor Technologies, Inc.) resulted in improved performance compared to 2-D camera views for multiple mission related tasks. Laboratory research at the ARL HRED Field Element in Orlando used stereovision technologies and showed 3-D superiority for navigation tasks relative to 2-D.

Current Goals: Our primary goals are to examine the capabilities and limitations of contemporary display technologies and to assess the synergistic relationship of this vision technology with other advanced human robotic interaction technologies. Future goals will focus on advanced interface concepts for supervisory control of semi-autonomous vehicles.

1.3.2.1 Recent Publications:

Bodenhamer, A.; Pettijohn, B.; Pezzaniti, J.; Edmondson, R.; Vaden, J. 3-D Vision Upgrade Kit for the TALON Robot System. In *Proceedings of Society of Photo-Optical Instrumentation Engineers Stereoscopic Displays and Applications Conference*, San Jose, CA, January 2010.

Chen, J. Y. C.; Haas, E. C.; Barnes, M. J. Human Performance Issues and User Interface Design for Teleoperated Robots. *IEEE Transactions on Systems, Man, and Cybernetics--Part C: Applications and Reviews* **2007**, *37* (6), 1231–1245.

Chen, J. Y. C.; Oden, R. V. N.; Kenny, C.; Merritt, J. O. Effectiveness of Stereoscopic Displays for Indirect-Vision Driving & Robot Teleoperation; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, in press.

Edmondson, R.; Vaden, J.; Morris, J.; Hyatt, B; Pezzaniti; Chenault, D.; Tchon, J; Barnidge, T.; Kaufman, S.; Kingston, D; Newell, S.; Pettijohn, B.; Bodenhamer, A. 3-D Vision Upgrade Kit for TALON Robot. In *Proceedings of SPIE, Unmanned Systems Technology XII*, Orlando, FL, 6–9 April 2010, Vol. 7692, Paper 7692–20.

Edmondson, R.; Vaden, J.; Morris, J.; Hyatt, B.; Pezzaniti; Chenault, D.; Tchon, J.; Barnidge, T.; Kaufman, S,; Kingston, D.; Newell, S.; Pettijohn, B.; Bodenhamer, A. 3-D Display for Enhanced Tele-Operation and Other Applications. In *Proceedings of SPIE, Display Technologies and Applications for Defense, Security, and Avionics IV*, Orlando, FL, 6–9 April 2010, Vol. 7690, Paper 7690B–44.

Haas, E. C. Integrating Auditory Warnings With Tactile Cues in Multimodal Displays for Challenging Environments. In *Proceedings of the International Conference on Auditory Displays*, 2007, 127–131.

Haas, E. C.; Pillalamarri, R. S.; Stachowiak, C. C.; Lattin, M. A. Audio Warning Cues to Assist Visual Search in Narrow Field-Of-View Displays. In *Proceedings of the International Ergonomics Association 16th World Congress on Ergonomics*, 2006.

Haas, E. C.; Stachowiak, C. C. Multimodal Displays to Enhance Human Robot Interaction on-the-Move. In *Proceedings of the Performance Metrics for Intelligent Systems (PerMIS) Conference*, 2007, 135–140.

Hutchins, S.; Cosenzo, K.; McDermott, P.; Feng, T.; Barnes, M.; Gacy, M. An Investigation of the Tactile Communications Channel for Robotic Control. *Proc Human Factors and Ergonomics Society Annual Meeting Proceedings*, 2009, *53* (4), 182–186(5).

Pettijohn, B.; Bodenhamer, A.; Kingston, D.; Newell, S.; Geulen, V. *3-D Visualization System Demonstration on the TALON Robot*; ARL-TR-4980; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2009.

1.4 Thrust Area 4: Human Inspired Robotics - Cognitive Robotics

The thrust area of cognitive robotics is devoted to the application of cognitive psychological principles and theory to the area of robot control and autonomy. Specifically, theories of human memory, attention, and intelligence are used as the basis for the development of new robotics control mechanisms and methodologies in order to improve robot control and autonomy. The primary foundation for the work on cognitive robotics within HRED has been the use of existing cognitive architectures as a foundation for current research. Cognitive architectures, primarily the Adaptive Control of Thought – Rational (ACT-R) and Soar, have been under continuous development for approximately four decades. These software architectures have been used extensively to model human behavior under a variety of different task situations. Research has continued to refine and update these two architectures in order to provide a foundation for a computational understanding of the human mind in a variety of different task situations.

As part of the cognitive robotics program at HRED, we used the general production system based theory of ACT-R as the foundation for a new robotics control mechanism called the Symbolic and Subsymbolic Robotics Intelligence Control System (SS-RICS). SS-RICS is a production system based, goal oriented, C++ architecture running in the Windows environment. The system is composed of two layers, the symbolic and subsymbolic layers. The symbolic layer is the production system layer, similar to ACT-R's or Soar's implementation of a goal based production system. This section of the system is responsible for directing goal based behavior and manipulating factual, declarative information in serial fashion. The lower layers are the subsymbolic layers, which run in parallel, and are responsible for manipulation of input data for perception and interpretation of the environment. The subsymbolic layers run as multiple threads in a distributed fashion similar to the perceptual systems in the human cognitive system. In contrast, the symbolic system is similar to the frontal lobes in the human cognitive system, which direct behavior in a goal oriented, serial manner.

1.4.1 Research Area 4.1: Perception

- Research: 6.1%–100%

- Funding: Internal - 25%; External - 75%
- Research Projects: 2
- Special Designators: Robotics DSI; Cognitive Object Recognition System (CORS) Small Business Innovative Research (SBIR) contract
- Collaborations: Towson University, Pennsylvania State University, Vehicle Technology Directorate (VTD), Sensors and Electronic Devices Directorate (SEDD)
- Keywords: Perception, Robotics, Cognitive Architectures

Aim: The aim of this research area is to develop perceptual algorithms for use within our robotics architecture, SS-RICS. Currently, robotics systems have difficulty identifying and classifying objects in their environment due to variations in object orientation, lighting, and scale. HRED has researched object identification and classification algorithms using the Adaptive Resonance Theory (ART) neural network architectures within SS-RICS. ART networks are especially useful as they can be trained adaptively, in real time, and do not suffer from the catastrophic forgetting problem as do some more traditional neural networks. We have also worked with the ARL Sensors Directorate to incorporate Principle Components Analysis (PCA) for dimensionality reduction and input to our various neural networks. We have also worked with Pennsylvania State University to develop pulsed neural networks which are useful for the analysis of perceptual data which has a temporal dimension. Finally, we are currently developing a Phase II Small Business Innovative Research (SBIR) contract with Utopia Compression to develop a 3-D, shape based, object recognition system. The system will be capable of recognizing most manmade objects using the psychologically plausible Geon theory, for classification. Finally, we have hired a doctoral candidate from Towson University to join our cognitive robotics program here at HRED.

Methods: Perception is a multifaceted process. First a candidate object must be segmented as an object of interest. We are using human theories of visual attention and foveation to help us with the initial stages of the segmentation process. Once segmentation is complete, initial features of the object must be indentified and processed (shape, texture, color). These features must then be combined and sent to a classifier for object identification. If the object is a new object, then the classifier must be updated to learn the new object. The classifier might be a simple template based matcher or something more complex that attempts to extract features in order to generalize across many different objects within the same category. We have been working to develop all aspects of the perceptual process. Internally, we have been working on template based systems for matching and have found these to be a useful first step for perception. Additionally, we have worked on different types of classification schemes (neural networks, nearest neighbor approaches, AdaBoost.) Finally, a shape-based and feature based classification system called the Cognitive Object Recognition System (CORS) is being developed through a Phase II SBIR.

Progress: We have worked to develop a variety of classification techniques using neural networks (traditional, pulsed, ART). We are currently in the Phase II SBIR development cycle for a shape based classification system called CORS.

Current Goals: Our goal is to develop a complete set of perceptual algorithms which are useful for the recognition of objects under a variety of different conditions. We hope to have our shape based system (CORS) developed as the Phase II SBIR completes. We will augment this system with other processes in order to recognize a variety of objects using other methods (i.e., not just shape).

1.4.1.1 Recent Publications:

Avery, E.; Kelley, T. D.; Davani, D. Using Cognitive Architectures to Improve Robot Control: Integrating Production Systems, Semantic Networks, and Sub-Symbolic Processing. In *Proceedings of 15th Annual Conference on Behavioral Representation in Modeling and Simulation (BRIMS)*, Baltimore, MD, 2006, 25–33.

Kelley, T. D.; Long, L. N. Deep Blue Can't Play Checkers: The Need for Generalized Intelligence for Mobile Robots. *Journal of Robotics*, in press.

Kelley, T. D. Developing a Psychologically Inspired Cognitive Architecture for Robotic Control: The Symbolic and Subsymbolic Robotic Intelligence Control System (SS-RICS). *International Journal of Advanced Robotic Systems* **2006**, *3* (3).

Long, L. N.; Kelley, T. D.; Wenger, M. J. The Prospects for Creating Conscious Machines. Presented at the *Toward a Science of Consciousness Conference*, Tucson, AZ, 2008.

1.4.2 Research Area 4.2: Human Robot Communication

- Research: 6.1%–100%
- Funding: Internal - 50%; External - 50%
- Research Projects: 1
- Special Designators: SOURCE ATO
- Collaborations: Towson University
- Keywords: Human Robotics Interaction (HRI), Robotics Control

Aim: The aim of this research is to explore the limitations and advantages of communication with an autonomous system using voice or manual control under different levels of workload. Additionally, we are interested in testing our internally developed robotics architecture, SS-RICS, for the control of robotic assets.

Methods: We are currently running a study in our Cognitive Assessment and Simulation Laboratory (CASEL) in which subjects are asked to manipulate a robot using different control modalities and under different levels of cognitive load. The three control modalities are manual control, limited voice, and extended voice. In the manual control condition the robot is manipulated with the keyboard only. In the limited voice condition, the robot is controlled using a limited set of voice commands (turn left, turn right). In the extended voice condition, the robot is controlled with the limited voice commands as well as additional voice commands (go down the hallway, go to the door, search the room). Each of the conditions is performed with and without additional workload. The workload is in the form of math problems, presented aurally, to each subject. The task is to search for a simulated bomb in a building. Our hypothesis is that the extended voice condition will show the best performance (task completion times, total area searched) under the workload condition.

Progress: We have completed running 14 subjects and hope to have the study completed by the end of April.

Current Goals: Our goal is to use the information gathered from the experiment to inform the development of autonomous systems. For the current experiment, the robot performs the extended voice commands as part of a scripted set of functions and cannot perform these tasks autonomously. We are interested in knowing if it is useful for human-robot performance to be able to perform certain tasks autonomously. For example, is it useful for the robot to "go through a door" autonomously, or to be able to "go down a hallway" autonomously? If we find that these are useful behaviors then these autonomous capabilities will be implemented as a behavior set to improve Soldier and robot performance.

1.4.2.1 Recent Publications:

Cassenti, D. N.; Kelley, T. D.; Swoboda, J. C.; Patton, D. J. The Effects of Communication Style on Robot Navigation Performance. In *Proceedings of the Human Factors and Ergonomics Society 53rd Annual Meeting*, Human Factors and Ergonomics Society: Santa Monica, CA, 2009, pp 359–363.

2. Human System Integration

The goal of Human Systems Integration (HSI) is to optimize total system performance, minimize total ownership costs, and ensure the system is built to accommodate the characteristics of the user population that will operate, maintain, and support it. The purpose of ARL's HSI program is to develop human performance modeling tools and techniques and analyses to represent system level mental and physical human performance tradeoffs at the system of systems level for Command, Control and Communication (C3), level of automation, interface modality, and workload. These tools and analyses support consideration of manpower requirements, workload, and skill demands collectively and systematically, avoiding information and physical task overload and taking maximum advantage of aptitudes, individual and collective training, and numbers of Soldiers for an affordable Future Force. The work involves an intimate knowledge of the Department of Defense, Army materiel acquisition system and working to develop efficacious means to influence it so that the human is considered. When necessary, ARL HRED mission funds are used to seed or augment HSI work to influence critical systems or open new business areas. Also note that Manpower Integration (MANPRINT) is the Army's programmatic implementation of HSI.

2.1 Thrust Area 1: Soldier Modeling and Simulation Tool Development

Within the Soldier Modeling and Simulation area, our focus is to develop and enhance human performance modeling tools that enable early, cost effective insertion of MANPRINT criteria into (DOD acquisition) pre-milestone A requirements to optimize Soldier-system performance and cost at the system of systems level. By using effective human performance modeling tools early in the acquisition process, potential performance problems can be identified and resolved sooner resulting in better designed systems for the Warfighter. We also work to extend the capabilities of MANPRINT tools and techniques by sponsoring and leveraging Small Business Innovative Research (SBIR) projects and through collaborative efforts with other organizations. These tools and techniques are transitioned to our ARL field element analysts and human factors specialists at various defense contractor organizations for the purpose of conducting essential analysis as early in the acquisition process as possible. Along with development, we also promote the use of MANPRINT techniques, tools, and technologies through training, technical support, marketing and usability enhancement.

2.1.1 Research Area 1.1: Improved Performance Research Integration Tool (IMPRINT) Development

- Research: 6.2%–100%
- Funding: Internal - 100%
- Research Projects: NA
- Special Designators: TPA no. DC-HR-2009-01, TO-HR-05-01, TO-HR-05-02
- Contractors: Pacific Science and Engineering Group, Alion Science and Technology, Design Interactive and Florida State University
- Keywords: Human Performance Modeling, MANPRINT, Human Systems Integration, IMPRINT, Mental Workload

Aim: The goal of this line of research is to continually enhance and develop IMPRINT to enable analysts to address new and existing analysis requirements efficiently, effectively and early in the system acquisition process. Since IMPRINT is an essential tool to supporting the goal of early, cost effective and comprehensive inclusion of MANPRINT criteria into the system development process, it is necessary that it remains sensitive to the needs of the analysts that use it.

Methods: IMPRINT enhancements fall into three categories: analytical capability – enhancements that support answering various analytical questions; modeling capability – enhancements that support building models more efficiently; and information assurance compliance – enhancements that ensure the software can be used on all user systems. Requests for enhancements are elicited from the users through our online user community and during training workshops and while providing user support.

Progress: Even with a reduction in available funding, IMPRINT development has been able to continue. Our FY10 release of IMPRINT Pro version 3.1 will include several analytical and modeling enhancements which include the addition of 2-D and 3-D animation to support visualization of analysis results; a chemical, biological, nuclear and radiological effects (CBRNE) environmental stressor that will allow analysts to examine the impact of CBRNE on system performance and the Multimodal Information Design Support Tool plug-in that will provide analysts with specific implementable design guidelines that could potentially mitigate mental overload identified during IMPRINT analysis. Since 2006, we have released three major versions of IMPRINT to the user community.

Current Goals: In addition to maintaining IMPRINT and supporting its user base, there are other development efforts that will yield analytical enhancements for IMPRINT. These include a training plug-in that will allow analysts to examine the effect of training media type on system performance and extensive improvements to the Forces module that will provide more flexibility and analytical power to analysts looking at the manning of large force units and the effects of fatigue on their ability to accomplish planned and unplanned activities.

2.1.1.1 Recent Publications:

Samms, C.; Jones, D.; Hale, K.; Mitchell, D. Harnessing the Power of Multiple Tools to Predict and Mitigate Mental Overload. *Engineering Psychology and Cognitive Ergonomics*, Springer Berlin: Heidelberg, 2009, 5639/2009: 279–288.

Samms, C. IMPRINT and Augmented Cognition: Reducing the Cognitive Demands of the Future Force. *Foundations of Augmented Cognition 2nd Edition*, 2006.

U.S. Army Research Laboratory. Improved Performance Research Integration Tool (IMPRINT). http://www.arl.army.mil/IMPRINT, 2008.

Wojciechowski, J. Q. *Development of a User-Defined Stressor in the Improved Performance Research Integration Tool (IMPRINT) for Conducting Tasks While in a Moving Vehicle*; ARL-MR-0659; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2007.

2.1.2 Research Area 1.2: Logistics Planning and Maintenance Manpower Decision Support Tools

- Research: 6.2%–100%
- Funding: Internal - 85%; External - 15% (not including SBIR funds)
- Research Projects: NA
- Special Designators: None
- Collaborations/Customers: ARL SLAD, PM PAWS
- Keywords: Logistics, Maintenance Manpower, Decision Support

Aim: This area of research and development is oriented toward the manpower, personnel and training (MPT) domains of human systems integration (HSI) to support resource decisions, acquisition programs, processes, and policy and doctrine pertaining to logistics and maintenance.

Methods: Explore human-computer interaction for development of logistics and maintenance systems to reduce support personnel and training demand. Identify subject matter experts for business processes and employ systems engineering techniques to develop software based applications. Leverage the Army's Small Business Innovation Research (SBIR) program for resources.

Progress: Developed a maintenance modeling tool to assess impact of current and future force employment, maintenance doctrine, technology/process change and resourcing strategies on dynamic Warfighter "Go-to-War" (GTW). The tool is called the Army Transformation in Logistics and Sustainment (ATLAS) and has been transitioned to U.S. Army's Aviation and Missile Life Cycle Management Command Integrated Materiel Management Center (AMCOM IMMC). The Logistic Site Planning and Operations (LOGSPOT) is a modeling tool developed to assist Army logisticians in positioning and managing the day-to-day operation of sustainment depots and transfer points in forward staging areas. LOGSPOT has been transitioned to PM Petroleum and Water Systems.

Current Goals: The Theater Distribution Planner for 4th Generation Warfare (TRIP-4GW) is a modeling tool being developed to support theater forward sustainment planning utilizing geospatial analysis techniques to mitigate terrain and insurgent risks to sustainment missions. TRIP-4GW is in Phase II of the SBIR program.

2.1.2.1 Recent Publications:

del Rosario, R. D.; Tom, K. F.; Mitchell, G.; Ruth, B. G.; Grazaitis, P. J.; Ferryman, T.; Scharett, D. E.; Toomey, C. J., Jr. *Underlying Technologies for Military Logistics Prediction and Preemption Capability*; ARL-SR-0166; Army Research Laboratory: Aberdeen Proving Ground, MD, 2009.

2.2 Thrust Area 2: Soldier Centered Analysis for the Future Force

This area is conducted with ARL 6.6 analysis mission funding and often augmented with customer funding. The purpose is to conduct human systems integration for systems being developed and where possible to improve the state of the art in conducting HSI. Traditionally our focus has been on early, rapid, cost effective and MANPRINT analyses (e.g., human engineering, manpower, personnel, training constraints) in support of requirements determination and validation to optimize soldier-system performance and cost. While those efforts continue, we have been working to improve the synergy among the research, development, testing and Warfighter communities. This includes HSI methodology development, consultation and evaluation support to the Army Evaluation Command (AEC). The vision is to identify potential HSI requirements early, ensure any issues are tracked and mitigated by the program manager, and finally to ensure those same issues will be tested and evaluated. Much of the work under this thrust area is supported by application of models and tools such as those developed under thrust area 1, Soldier Modeling and Simulation Tool Development.

2.2.1 Research Area 2.1: Human Performance Modeling in Support of System Development

- Research: 6.6%–100%
- Funding: Internal - 60%; Customer - 40%
- Research Projects: NA
- Special Designators: TO-HR-05-04
- Collaborations: Army Evaluation Center (AEC), PEO Integration
- Keywords: Workload Modeling, Human Figure Modeling, Mission Based Test and Evaluation (MBT&E)

Aim: Develop analytical techniques researchers can use early in the acquisition process, pre-milestone A, to evaluate the impacts of system requirements on Warfighter performance. The analytical techniques developed emphasize quantitative analyses of areas of human performance, such as mental workload that have traditionally been difficult to quantify. Quantifying Warfighter performance of a system pre-milestone A helps to avoid Warfighter information and physical task overload which lead to increased injury, fratricide, and decreased mission performance.

Methods: Early application of human performance and human figure modeling tools in the development of Soldier-focused requirements to shape technology for Army Transformation. Design analyses, constructive simulations and Soldier-in-the-loop assessments to help ensure that manpower requirements, workload and skill demands are considered, avoid information and physical task overloads, and take optimum advantage of aptitudes, individual and collective training, and numbers of Soldiers for an affordable Future Force.

Progress: Researchers working within this thrust area have developed a technique for applying the experimental design process to predicting Warfighter mental workload with human performance modeling tools. Their analyses resulted in changes to the requirements for several Future Combat System (FCS) Program Manned Ground Vehicles (MGVs), including the Mounted Combat System (MCS), Non-line-of-sight Cannon, and Reconnaissance and Surveillance Vehicle and contributed to Soldier workload becoming the top issue during the preliminary design review for the FCS MGVs. The Soldier workload analyses completed for the FCS MGV program were used by the Ground Combat Vehicle (GCV) Program to support a three-Soldier GCV design requirement.

Current Goals: The researchers are enhancing the analytical techniques they have developed and applying them to a major Joint Acquisition Program, the Joint Light Tactical vehicle. In addition, they are continuing to quantify Warfighter performance for the revised FCS program, Brigade Combat Team Modernization. In FY11, they will to apply the techniques to evaluate the conceptual designs for the GCV.

2.2.1.1 Recent Publications:

Animashaun, A. F. *A Human Factors Engineering Assessment of the Buffalo Mine Protection Clearance Vehicle Roof Hatch*; ARL-TR-4272; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2007.

Havir, H.; Kozycki, R. *An Assessment of the Emergency Egress Characteristics of the U.S. Army Airborne Command and Control System (A2C2S)*; ARL-MR-635; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2006.

Hicks, J. S.; Durbin, D.; Kozycki, R. An Overview of Human Figure Modeling for Army Aviation Systems; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, in press.

Hsiao, H.; Badler, N.; Chaffin, D. B.; Yang, K. H.; Lockett, J. F. Digital Human Modeling Goals and Strategic Plans: Key Note Panel. In *Proceedings of the SAE Digital Human Modeling Conference*, SAE: Warrendale, PA, Pittsburgh, PA, 2008, paper no. 2008-01-1933.

Lockett, J. F.; Archer, S. G. Impact of Digital Human Modeling on Military Human-Systems Integration and Impact of the Military on Digital Human Modeling. In Duffy, Ed.; *Handbook of Digital Human Modeling*, Taylor and Francis: London, 2008.

Mitchell, D. K. Abrams V2 SEP Crew Workload Analysis: Impacts of Two Proposed Technologies; customer report in press.

Mitchell, D. K. Analysis of Soldier Workload and Performance for Alternative Reconnaissance (RECCE) Vehicle Designs; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, in press.

Mitchell, D. K. Successfully Changing Conceptual System Designs Using Human Performance Modeling. In *Proceedings of Human System Integration Symposium*, 2009.

Mitchell, D. K. *Workload Analysis of the Crew of the Abrams V2 SEP: Phase I Baseline IMPRINT Model*; ARL-TR-5028; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2009.

Mitchell, D. K. United We Stand: Using Multiple Tools to Solve a Multi-dimensional Problem. In *Proceedings of the 52nd Meeting Human Factors Society*, 2008.

Mitchell, D. K. *Predicted Impact of an Autonomous Navigation System (ANS) and Crew-Aided Behaviors (CABs) on Soldier Workload and Performance*; ARL-TR-4342; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2008.

Mitchell, D. K. *Verification and Validation of the IMPRINT MCS Analyses Utilizing Omni Fusion 06 Part 1 Data*; ARL-TR-4027; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2007.

Mitchell, D. K.; Abounader, B.; Henry, S.; Animashaun, A. *A Procedure for Collecting Mental Workload Data During an Experiment that is Comparable to IMPRINT Workload Data*; ARL-TR-5020; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2009.

Mitchell, D. K.; Brennan, G. *Infantry Squad Using the Common Controller to Control an ARV-A (L) Soldier Workload Analysis;* ARL-TR-5029; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2009.

Mitchell, D. K.; Brennan, G. *Infantry Squad Using the Common Controller to Control a Class 1 Unmanned Aerial Vehicle System (UAVS): Soldier Workload Analysis*; ARL-TR-5012; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2009.

Mitchell, D. K.; Brennan, G. *Infantry Squad Using the Common Controller for Small Unmanned Ground Vehicle Control: Soldier Workload Analysis*; ARL-TR-5003; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2009.

Mitchell, D. K.; Chen, J. Impacting System Design With Human Performance Modeling and Experiment: Another Success Story. In *Proceedings of the 50th HFES Conference*, San Francisco, CA, 2006.

Mitchell, D. K.; McDowell, K. Using Modeling as a Lens to Focus Testing. In *Proceedings of the 2008 Symposium on Collaborative Technologies and Systems*, 2008.

Mitchell, D.; Samms, C. Predicting Soldier Workload and Performance Using Human Performance Modeling. Human Robotic Interaction in Future Military Operations, in review.

Mitchell, D. K.; Samms, C. L. An Analytical Approach for Predicting Soldier Workload and Performance Using Human Performance Modeling. *In Human-Robot Interactions in Future Military Operations*, Barnes and Jentsch, Eds.; Ashgate Publishing: London, UK, in press.

Mitchell, D. K.; Samms, C. L. Using a Holistic Analytical Approach to Meet the Challenges of Influencing Conceptual System Design. In Savage-Knepshield, P., Martin, J., Lockett III, L., Allender, Eds.; *Designing Soldier Systems: Current Issues in Human Factors*, in draft.

Mitchell, D. K.; Samms, C. L. Workload Warriors: Lessons Learned from a Decade of Mental Workload Prediction Using Human Performance Modeling. In *Proceedings of the 53rd Meeting of the Human Factors Society*, 2009.

Mitchell, D.; Samms, C. Please Don't Abuse the Models: The Use of Experimental Design in Model Building. In *Proceedings of the 51*st *Annual Meeting of the Human Factors and Ergonomics Society*, 2007, Vol. 51 (4), pp. 1454–1457.

Mitchell, D. K.; Samms, C.; Kozycki, R.; Kilduff, P.; Swoboda, J.; Animashaun, A. *Soldier Mental Workload, Space Claims, and Information Flow Analysis of the Combined Arms Battalion Headquarters Command and Control (C2) Cells*; ARL-TR-3861; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2006.

Mitchell, D. K.; Samms, C.; Wojcik, T. System-of-Systems Modeling: the Evolution of an Approach for True Human System Integration. *2006 BRIMS Conference*, Baltimore, MD, 2006.

Pomranky, R. A.; Wojciechowski, J. Q. *Determination of Mental Workload During Operation of Multiple Unmanned Systems*; ARL-TR-4309; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2007.

Samms, C. Challenges to Conducting System of Systems Analysis from a Warfighter Performance Perspective. In *Proceedings of the Defense Analysis Seminar XIV*, Seoul, Korea, 2008.

Samms, C. L.; Animashaun, A. F. *Mental Workload Analysis of the Reconnaissance and Surveillance Vehicle*; ARL-TR-3835; U.S. Army Research Laboratory, Aberdeen Proving Ground, MD, 2006.

Savage-Knepshield, P.; Martin, J.; Lockett, J.; Allender, L., Eds.; book proposal accepted by publisher. Designing Soldier Systems: Current Issues in Human Factors.

Wojciechowski, J. Q. Modeling Human Performance with Environmental Stressors: Case Study of the Effect of Vehicle Motion. In *Proceedings From the Human Factors and Ergonomics Society 51st Annual Meeting*, Human Factors and Ergonomics Society: Producer and Distributor, 2007.

Wojciechowski, J. Q.; Karna, V.; Dorney, L. A. *Analysis of the Light Brigade Combat Team Reconnaissance Capability Gap With the Use of a Human Performance Model of the Joint Chemical, Biological, Radiological, and Nuclear Dismountable Reconnaissance System (JCDRS)*; ARL-TR-4340; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2007.

2.2.2 Research Area 2.2: System Assessment in Support of Test and Evaluation

- Research: 6.6%–100%
- Funding: Internal - 50%; Customer - 50%
- Research Projects: NA (no. of programs we support)
- Special Designators: TO-HR-05-03
- Collaborations: Memorandum of Agreement with Army Evaluation Center (AEC)
- Keywords: MANPRINT evaluation, business enterprise systems, maneuver situational awareness, effects-based operations

Aim: Improve the frequency and rigor with which Human Systems Integration issues are tested and evaluated during acquisition of Army and DOD systems.

Methods: We have leveraged and when necessary extended human factors analytical approaches, methodology, and techniques to meet the time and resource constraints typical in test and evaluation. Some of the efforts include questionnaire development and administration, interviews, workload and situation awareness probes, and modeling. Consultation and evaluation support have been provided primarily to program management offices through the Army Evaluation Command (AEC). We have leveraged findings from human performance research to inform identification of HSI issues as well as metrics and methodologies for testing the issues.

Progress: In 2009, ARL established a Memorandum of Agreement with the Army Evaluation Command with the goal of better quality, more-timely, and more cost-effective evaluation products for AEC and the Government acquisition decision maker. We have also increased HSI involvement in enterprise/business process systems (e.g., GFEBS and GCSS-A are new software-based systems for conducting financial transactions) and see this as a growth area. We have developed an Assessment Framework for Effects Based Operation in support of Joint Forces Operations and have expanded HSI involvement net-centric applications across DOD. This includes development of instruments specially tailored to large scale C3 test events in the field (such as those conducted at the National Training Center).

Current Goals: Develop a Situation Awareness (SA) Assessment Tools for Network Enabled Command and Control Field Evaluations to quantify the ability of C4ISR Net Centric Systems to provide individual and staff SA to our Soldier and units. Expand the Effects Based Operations data base and develop collaborative tools based on internet applications for composing and vetting generic tasks, effects and assessment metrics across diplomatic, military, social and economic domains. The need exists to develop metrics to quantify human characteristics and aptitudes that are necessary to achieve optimal system performance as net-centric technology expands.

2.2.2.1 Recent Publications:

Grynovicki, J. O. Metrics for Evaluating Digitization for U.S. Army Battle Command Capability Sets. *U.S. Army Conference on Applied Statistics*, October 2010, in press.

Grynovicki, J. O. System Engineering Framework for Evaluating the Human Dimension of Network Centric Warfare. *U.S. Army Conference on Applied Statistics*, October 2008.

Maceo, M.; Grynovicki, J. O. Operational Test Agency Evaluation Report (OER) for the General Fund Enterprise Business System Release 1.3 Initial Operational Test. U.S. Army Evaluation Center, 2010.

Branscome, T. A. Human Factors Assessment; Manpower, Personnel and Training Assessment and Soldier Survivability Assessment for the 60,000-Btu/hr Improved Environmental Control Unit (60K IECU). U.S. Army Evaluation Command, 2009.

Maceo, M.; Grynovicki, J. O.; Operational Test Agency Milestone Assessment Report for the GFEBS Release 1.2 Limited User Test. U.S. Army Evaluation Command, 2009.

Grynovicki, J. O. NECC Program – Manpower and Personnel Integration (MANPRINT) Evaluation Approach. *White paper for the NECC Joint System Team*, 2009.

Kim, J. B.; Grynovicki, J. O. Capabilities and Limitations Report for the Multilateral Interoperability Programmed (MIP). U.S. Army Test and Evaluation Command, 2009.

Grynovicki, J. O. System Engineering Framework for Evaluating the Human Dimension of Network Centric Warfare. U.S. Army Conference on Applied Statistics, 22 October 2008.

Geduldig, T.; Grynovicki, J. O. Operational Test Agency (OTA) Abbreviated Operational Test Agency Report (AOTAR) for Full Materiel Release (FMR) of the Battle Command Sustainment Support System (BCS3). U.S. Army Test and Evaluation Command, 2008.

Grynovicki, J. O. MANPRINT Evaluation of Persistent Surveillance System of Systems. U.S. *Army Conference on Applied Statistics*, 2007.

Hollister, C.; Kim, S.; Grynovicki, O. System Assessment of the Command Post of the Future; ATEC- 2006-OA-C3E;Version 3.2, August 2006.

Grynovicki, J. O. MANPRINT Assessment -Tactical Ground Reporting Network (TIGRNET). Army Test and Evaluation Command, 2006.

2.3 Thrust Area 3: Performance With Systems

Optimizing Soldier-system interaction is essential for developing and fielding highly complex military systems that enhance Soldier's capabilities while minimizing the system's negative effects on Soldier performance. Soldiers in the modern and future battle field will be faced with the need to interact with highly complex military systems. For instance, technology in a new weapon site may make it possible for the Soldier to accurately engage targets at higher ranges. Bench level and laboratory testing may prove the new weapon site increases Soldier performance. However, when the weapon with the new site is carried by the Soldier through rough terrain, the site may become loose and thereby lose accuracy, ultimately resulting in decreased performance. This research thrust focuses on evaluating the ability of Soldiers to use new equipment compared to their ability to use legacy equipment, and on determining if the capabilities of the new equipment meet Army needs. The first area focuses on how information is visually displayed, specifically, this year the focus is on the emerging technology of flexible displays. New flexible display technology was compared to standard displays. The second research area focuses on the interaction of Soldiers and weapons, and will report on several weapon studies conducted for specific project managers. New or modified small arms weapons were compared to current small arms weapons designed for similar use. The final research area describes collaboration between HRED and the Louisiana Immersive Technology Enterprise (LITE) which was an effort to further the advanced design and evaluation of immersive environments for conducting research on issues relevant to dismounted operations. Specifically, the research reported centers on the integration of an Omni-Directional Treadmill (a device that enables the user to move through the environment in a natural way) with immersive visual and auditory displays to provide a more realistic physical workload while traversing through a simulated environment.

2.3.1 Research Area 3.1: Immersive Simulations

- Research: 6.2%–100%
- Funding: Congressional - 100%
- Research Projects: 3rd Generation Omni-Directional Treadmill
- Special Designators: Congressional
- Collaborations: University of Louisiana at Lafayette
- Keywords: Immersive, Simulation, Mobility Platform

Aim: The overall goal of this effort is to further research in the advanced design and evaluation of immersive environments for conducting research on issues relevant to dismounted operations. Specifically, the project centers on the integration of an Omni-Directional Treadmill (a device that enables the user to move through the environment in a natural way) with immersive visual and auditory displays to provide a more realistic physical workload while traversing through a simulated environment.

Methods: (1) Build the software infrastructure to integrate the Omni-directional treadmill into an improved immersive simulation environment; (2) develop techniques for the rapid creation of scenarios, terrains, targets, and other elements that define the battlefield; and (3) conduct research taking into account the effects of the physical as well as the cognitive load on the performance of the dismounted soldier.

Progress: The software infrastructure is nearly complete. Improvements have been made to the visual quality, dynamics and performance. Simplified methods for automating terrain generation while still providing the flexibility to customize features have been developed. A series of research topics have been defined, examining issues involving attentional resources and motor control, wayfinding and collaboration under stress, attentional blink, and recovery from refractory period.

Current Goals: A possible solution to allow stereo projection for the visual scene without creating interference with the IR cameras for the motion tracking system is being tested. Hardware modifications to weapon mock-ups are being made to allow for wireless communication to capture trigger pull, firing mode, and reload of ammunition. Improvements to the weapon calibration methods are being explored to provide greater aiming accuracy. Terrain generation program is being further refined per ARL-HRED's requests. Research protocols are being developed in preparation for conducting experiments using the ODT.

2.3.2 Research Area 3.2: Weapons

- Research: Customer
- Funding: Customer - 100%
- Research Projects: 3
- Special Designators: None
- Collaborations: Individual Weapons Program Managers (Customer)
- Keywords: Weapons, Individual, Shooting Performance, System Integration

Aim: Evaluating the effect of new individual weapons and other weapon accessories on Soldier Performance. Many times equipment developers do not consider the user of their equipment; it is therefore HRED's responsibility to consider the Soldier when evaluating various weapon systems. The Soldier and equipment is crucial for the success of the Soldier-System.

Methods: Typically, when the small arms community has an improvement of an existing product for evaluation they will contact HRED. Soldiers from active U.S. Army units are often used as Subject Matter Experts due to their field or combat experience, and the new equipment is compared to the current by having Soldiers use it in militarily relevant field studies. These studies are designed such that data gathering during these field evaluations is based on sound statistical principles, training issues are addressed, and both objective (shooting performance, obstacle course completion times, etc.) and subjective data (typically questionnaire and/or After Action Review) are gathered. HRED has the resources to gather shooting performance data such as number of shots fired, number of targets hit, which round hit the target, time a round was fired, time a target was hit, and x and y coordinates of projectile impacts on the target or miss around the target accurate to within 5 mm.

Progress: In the near and midterm, our SPEAR facility and Shooter Performance Facility are undergoing upgrades. In the far term, our Shooter Performance Facility is being updated to be portable so we can collect highly accurate shooting data anywhere in the world – saving the government and tax payers the expense of shipping Soldiers to APG for data collection.

Current Goals: Expand the data collection during these studies to include more objective data (i.e., metabolic cost) and to further educate the customer on the need and importance of this data.

2.3.2.1 Recent Publications:

Ortega, S.; Garrett, L.; Burcham, P. *Soldier Performance with the M240E6 Lightweight Machine Gun - Phase II*; ARL-TR-4561; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2008.

2.3.3 Research Area 3.3: Flexible Display Technology for Soldiers and Vehicles

- Research: 6.2%–100%
- Funding: ATO-R - 100%
- Research Projects: 1
- Special Designators: ATO no. R.IS.2008.02
- Collaborations: ARL, Flexible Display Center, Arizona St. Univ., NSRDEC
- Keywords: Flexible Displays, Emissive Technology, Reflective Technology

Aim: The U.S. Army's Flexible Display Program's primary objective is to speed the development of flexible display technology for the Soldier. Flexible displays have reduced weight and are inherently rugged with ultra-low power electro-optic technologies as compared to traditional liquid crystal glass based displays. This ATO-R will develop the processes and technologies that will enable the demonstration of lightweight, rugged, low volume flexible displays. The purpose of ARL-HRED's participation is to develop human factors parameters for systems using flexible displays.

Methods: HRED has conducted studies to evaluate various aspects of display functionality, system form factor, system interface, informational needs of Soldiers using flexible display systems.

Progress: HRED has evaluated handheld and body-worn display concepts specifically to obtain user field evaluation responses for the display prototypes and to guide device specifications by assessing physical form factor features. A preliminary human factors investigation was also completed to evaluate viewing and readability of the flexible display demonstrators under different lighting conditions including indoor light, outdoor sunlight, and under darkness. Soldiers generally agreed that the display sizes of the concepts were reasonable and effective (about a 3-in diagonal for the body-worn concept and the handheld concept about a 6 in-diagonal). Soldier participants also commented that the flexible display concepts could potentially serve as an information display device that is easily transported when dismounted.

Current Goals: There are several transition goals for the flexible display program mainly to support the human dimension of flexible display system interfaces. ARL has also submitted a Technology Transition Agreement (TTA) of the Flexible Displays to the Program Manager Common Controller to define technology deliverables from the FDC through the prototype integration and support of U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC). As the technology development continues, projects will be coordinated with human factors evaluations to optimize design tradeoffs.

2.3.3.1 Recent Publications:

Elliott, L. R.; Wilson, R.; Forsythe. (ARL Tech Pubs). User-based Evaluation of Two Reflective Flexible Display Prototypes.

Wilson, R.; Elliott, L. R.; Cosenzo, K. A.; Forsythe, E. W. User Evaluation of Soldier Flexible Display Technology Demonstrators: Future Combat System Common Controller Spiral 1 Excursion, in review.

3. Social/Cognitive Network Science

The Social/Cognitive Network Science Major Laboratory Program is directed at improving distributed collaboration and decision-making in complex network-enabled operations using cognitive science, computer science, and social network innovations. The research contributes to the development of theory, measures, models, and understanding of social networks and the cognitive implications of those networks. Ultimately it will guide the design of human-team-system interaction and feed future operational systems. Research facilities being used range from networked simulations in a laboratory environment to field exercises. An applied cognitive system engineering approach is used employing cognitive work analysis and the newly developed dynamic social network tools. Key themes include trust in automation, the unique workload and information properties associated with networked environments, measurement of team performance and situation awareness, and methods to drive the information and communication networks with dynamic social network information for real time support for the Soldier/decision maker.

3.1 Thrust Area 1: Multicultural Communication

Joint, interagency, intergovernmental, and multinational distributed, network-enabled operations are, by their nature, exercises in multicultural communication for U.S. Army native English speakers. These multicultural communications occur across nations, as well as between military and Non-Governmental Organization (NGOs), joint services, and military branches. An additional factor is distributed network-enabled operations offer less opportunity for establishing shared context since physical presence and much of the information contained in verbal, behavioral, and cultural cues are removed during network-enabled operations making it difficult to calibrate the reliability and accuracy of information coming from various contexts, including levels of expertise, situation awareness, and proximity to ground truth. We have been investigating multicultural communications by leveraging multinational exercises hosted by the Battle Command Battle Lab, Fort Leavenworth (BCBL-L). In the first research area, Miscommunications and Context we are examining the issue of misunderstanding due to miscommunication, as an attempt to address information load and improving shared understanding. The focus of the research, to-date, has been on exploring variations in language and language use between U.S. and UK Soldiers due to cultural and contextual differences. The goal is to discover effective ways of minimizing miscommunication and to discern how communication of contextual knowledge can improve shared understanding during coalition operations. In a second research area, collaborative coalition planning, we are developing a US/UK Collaborative Planning Model (CPM), a multilevel plan representation that captures cultural differences in US/UK planning processes.

3.1.1 Research Area 1.1: Miscommunications and Context

- Research: 6.1%–100%
- Funding: Internal - 10%, Indirect - 40%, Collaborative - 10%
- Research Projects: 1
- Special Designators: ITA, ATO
- Collaborations: CISD, BCBL-L
- Keywords: Coalition Operations, Miscommunications, Context, Linguistic Variation, Cultural Differences

Aim: The objective of this research is to understanding sources of miscommunication among native U.S. and UK English speakers. The underlying tenet is that cultural differences between U.S. and UK are mainly manifested within language usage. We have observed that a shared common understanding of the context forms a foundation for successful communication and misunderstanding frequently results when it is lacking. Potential military applications include Battle Command during network-enabled multinational coalition operations.

Methods: Initial methods included gathering anecdotal information during semi-structured interviews with Infantry Soldiers at the Division and Brigade. This progressed to leveraging network-enabled multinational coalition field exercises hosted by the Battle Command Battle Lab, Fort Leavenworth (BCBL-L) to gather self-report data. Data collection includes unobtrusive observations, questionnaires, and semi-structured interviews during three consecutive years of this field study. Current analysis suggests that miscommunications are largely pragmatic in nature, not just involving lexical and grammatical differences but indicating differences in the way the two cultures use the "common" language.

Progress: Numerous peer reviewed conference papers and presentations have been completed based on work with BCBL-L. We plan to use the Talon Strike/OmniFusion10 (TS/OF10) field exercises at BCBL-L this year to gather data on miscommunications and context awareness. TS/OF10 is a distributed network-enabled exercise in a Joint, Interagency, Intergovernmental, and Multinational Operations/Operation Enduring Freedom context used to identify interoperability solutions enabling a 2010 UK Brigade to operate as part of a U.S. Division in 2010 and the implications for battle command concepts and capability in 2010 and 2017. In addition, we are planning a smaller, controlled experiment to examine several mitigation strategies relative to language usage and context awareness.

Current Goals: The goal of this work is to identify mitigation strategies to minimize miscommunication errors that can be quite expensive and even fatal within network-enabled coalition operations.

3.1.1.1 Recent Publications:

Allen, J.; Mott, D.; Bahrami, A.; Yuan, J.; Giammanco, G.; Patel, J. A Framework for Supporting Human Military Planning. In *Proceedings of the Annual Conference US/UK International Technology Alliance in Network and Information Sciences*, London, 2008.

Mott, D.; Giammanco, C. The Use of Rationale in Collaborative Planning. In *Proceedings of the Annual Conference US/UK International Technology Alliance in Network and Information Sciences*, London, 2008.

Poteet, S.; Giammanco, C.; Patel, J.; Kao, A.; Xue, P.; Whiteley, I. Miscommunications and Context Awareness. In *Proceedings of the Third Annual Conference of the International Technology Alliance*, MD, 2009.

Poteet, S.; Patel, J.; Giammanco, C.; Whiteley, I.; Xue, P.; Kao, A. Words Are Mightier Than Swords … and Yet Miscommunication Costs Lives! In *Proceedings of the Second Annual Conference of the International Technology Alliance*, London, 2008.

Poteet, S.; Xue, P.; Patel, J.; Kao, A.; Giammanco, C.; Whiteley, I. Linguistic Sources of Coalition Miscommunication. In *Proceedings of the NATO Research and Technology Organization, Human Factors and Medicine Panel Symposium on Adaptability in Coalition Teamwork*, Denmark, 2008.

3.2 Thrust Area 2: Human-Team-Network Interaction

Increased access to information and network technologies is transforming military capabilities and can potentially act as a force multiplier at the tactical level; however, information technology advances have not been fully harnessed to augment the warfighter's ability to integrate networked knowledge for collaboration and decision making in distributed operations. Information systems are not always aligned with the cognitive capabilities of the warfighter. A host of factors contribute to this misalignment, including the sheer volume of information, network bandwidth and other hardware/software constraints, information loss or drop-outs, mis-directed attention, or mis-calibration of trust in the information received. In the first research area, Network Information Requirements/Interactions, we address three parts of the problem within the Tactical Human Integration of Networked Knowledge Army Technology Objective (THINK ATO): identification of mission-contextual information and knowledge requirements, social networking and Warfighter training, and development of data aggregation and alert capabilities based on mission context.

3.2.1 Research Area 2.1: Network Information Requirements/Interactions

- Research: 6.2%–100%
- Funding: Internal - 100%
- Research Projects: 1
- Special Designators: ATO, TPA, ITA
- Collaborations: BCBL-L, ARI, CERDEC
- Keywords: Cognitive Performance, Information Sharing, Collaboration, Decision Making, Battle Command

Aim: The aim of ARL HRED's portion of the Tactical Human Integration of Networked Knowledge—Army Technical Objective (THINK-ATO) (a collaborative effort with ARI and CERDEC) is to enhance warfighter cognitive performance for collaboration and decision making in a complex dynamic net-centric environment. Model-based work and information flow analyses, context specific cognitive networked knowledge requirements, automation reliance guidelines, and methods/tools to train, improve, and assess information sharing, decision making, and collaboration will be developed.

Methods: Methods include behavioral observations, questionnaires, Cognitive Work Analysis, semi-structured interviews with US Army Division and Brigade Combat Team Soldiers in net-centric environments. Findings will be used in model-based work and information flow analysis, to establish networked knowledge requirements, to validate those requirements in subsequent laboratory experiments/field studies, and to develop data aggregation and alert capabilities. Future methods will include social network analysis of electronic message traffic from lab/field studies.

Progress: Findings from OmniFusion09, a multinational coalition exercise exploring interoperability issues and division and brigade Battle Command concepts and capabilities, are published in the Battle Command Battle Lab, Fort Leavenworth (BCBL-L) final report.

Current Goals: We plan to implement our current methodologies at the BCBL-L during Talon Strike/OmniFusion10, a net-centric exercise in a JIIM Operations/Operation Enduring Freedom context to identify interoperability solutions enabling a 2010 UK Brigade to operate as part of a U.S. Division in 2010 and the implications for battle command concepts and capability in 2010 and 2017. We are developing a Command, Control, and Communications - Techniques for the Reliable Assessment of Concept Execution (C3TRACE) model of information flow and operator performance for select cells within the division and brigade combat team as part of a model-test-model paradigm for lab experiments.

3.2.1.1 Recent Publications:

Giammanco, C. Invited Panel: Tactical Ground Reporting System (TIGR) Cognitive Performance and Trust. U.S. Military Academy TIGR User Workshop, 2009.

Giammanco, C. Invited Panel: Understanding Cyber Terrorism. U.S. Military Academy Network Science Workshop, 2009.

Giammanco, C. Invited Panel: Network as an enabler for coalition operations. Tactical Integration of Networked Knowledge Army Technology Objective (THINK ATO) overview. *Knowledge Systems for Coalition Operations (KSCO) Conference*, 2009.

Kilduff, P.; Swoboda, J.; Katz, J. *A Platoon-Level Model of Communication Flow and the Effects on Operator Performance*; ARL-MR-0656; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2006.

Scielzo, S.; Strater, L. D.; Tinsley, M. L.; Ungvarsky, D. M.; Endsley, M. R. Developing a Subjective Shared Situation Awareness Inventory for Teams. *Human Factors and Ergonomics Society Annual Meeting Proceedings*, 2008, *53* (4), pp 289–293.

Smart, P.; Engelbrecht, P.; Braines, D.; Strub, M.; Giammanco, C. The Network-Extended Mind. Verma, D., Ed.; Network Science for Coalition Operations; Hershey: IGI Global Publishing, 2009.

Swoboda, J. C3TRACE: Modeling Information Flow and Operator Performance. Savage-Knepshield, P., Lockett, J., Martin, J., Allender, L., Eds.; Designing Soldier Systems: Current Issues in Human Factors, in press.

Swoboda, J. FY09 Alternative FCS-Approved Reconnaissance Platoon Models. Unpublished Customer Report, 2009.

Swoboda, J. FY08 FCS-Approved Reconnaissance Platoon Modeling Effort. Unpublished Customer Report, 2008.

3.2.2 Research Area 2.2: Network Degradations – Lag, Information loSs

- Research: 6.1%–50%; 6.2%–50%
- Funding: Internal - 50%; Collaborative - 0%
- Research Projects: 2
- Special Designators: DSI
- Collaborations: None
- Keywords: Social/Cognitive Network Science, Network-Enabled Communication, Team Effectiveness, Communication Delay, Team Trust, Shared Awareness

Aim: The aim of this research area is to gain an understanding of team communication and coordination in network-enabled environments and to influence system design or tactics, techniques, and procedures for use. In network-enabled environments, teams rely heavily on networked communication technologies to communicate and coordinate their efforts; however, technology factors such as the type of communication technology (audio, video, and text), limitations in bandwidth, and communication delays, etc., can have adverse affects on the ability of a team to communicate and collaborate, and subsequently on team performance. Operational factors such as the need to perform tasks in a highly dynamic and stressful environment may compound the issue. Organizational or network structures may also impede performance and degrade teamwork. This research will explore the impact of technological, operational and organizational factors on team performance in a network-enabled environment.

Methods: A laboratory study will be conducted using small teams (dyads) performing a collaborative problem solving task. Team members will be distributed and will communicate and share information with one another, verbally, over a network, using either audio or video communication technology. Communication will be delayed at three levels (0, 500, and 1000 ms). Four experimental sessions will be conducted to assess how team members utilize strategies to adapt to communication delays over time. Dependent measures include task accuracy, task completion time, shared awareness, trust, and conversational parameters. The simulation study will use first-person shooter PC-based game and customize it to study the effects of key variables on the decision making of small groups. We will incorporate a capability that degrades the network at various levels while conducting a mission scenario designed for a fire-team, and measure the impact on SA and performance.

Progress: For the laboratory study, a protocol is close to completion, with initial pilot data collection planned for the summer 2010. Concept formulation and experimental design are underway for the simulation project.

Current Goals: Our current goal is to understand how communication variables such as delays or jitter impact team performance, shared awareness, and team trust and examine what ommunication strategies emerge as teams interact over time. Our ultimate goal is to maximize team performance in network enabled environments.

3.2.2.1 Recent Publications:

Krausman, A. Distributed Team Collaboration: Impact of Communication Delay on Team Performance, Shared Awareness, and Trust, in preparation.

Wiley, P. W.; Scribner, D. R.; Harper, W. H. Evaluation of Wearable Information Systems During Route Reconnaissance and Assault Missions Using Commercial Games. In *Proceedings of the 14th Annual International Conference on Industrial Engineering Theory, Applications and Practice,* Anaheim, CA, 18–21 October 2009.

Wiley, P. W.; Scribner, D. R.; Harper, W. H. Manipulation of a Commercial Game to Provide a Cost Effective Simulation to Evaluate Wearable Information Systems. In *Proceedings of the 13th Annual International Conference on Industrial Engineering Theory, Applications and Practice*, Las Vegas, NA, 7–10 September 2008.

3.3 Thrust Area 3: Social Interaction in Simulations

The research in this area focuses on developing a means of enhancing distributed collaboration such that groups of users can collaborate from their desktops as effectively as if they were face-to-face. This effort will contribute to the development of virtual humans that recognize the user’s speech, intent, and gestures. Consequently, this will guide the design of authoring tools and the creation of animations that enable user flexibility accounting for factors like, native language and cultural background. The research entails improvement in simulated real-life interactions inside the virtual world. The research will guide the development of dialogues and cultural protocols between both human participants and “socially intelligent virtual agents.”

3.3.1 Research Area 3.1: Using Virtual Worlds for Collaboration

- Research: 6.2%–100%

- Funding: Internal - 10%; Collaborative - 90%
- Research Projects: 1
- Special Designators: THINK ATO
- Collaborations: Carnegie Mellon U., U. of Edinburgh, U. of Virginia, Perigean Tech., ARI, JFCOM
- Keywords: Distributed Collaboration, Virtual Worlds, Crisis Response

Aim: The aim of this research is to investigate the effect of using a virtual environment for collaboration and explore the potential benefit to communication, trust, and uncertainty for crisis response. Crisis response situations require collaboration across many different organizations with different backgrounds, training, procedures, and goals. Distributed collaboration among such diverse organizations has proven extremely challenging (e.g., Hurricane Katrina). This research involves generating a virtual collaboration environment to investigate how distributed collaboration may be improved for military, government, and non-government organizations in crisis situations.

Methods: A cognitive work analysis (CWA) was conducted to what fundamental functions of distributed collaboration should be supported within the virtual collaboration environment. Social network analysis (SNA) was used to assess and identify the current expertise within the crisis response community across its military, government, and non-government members. Two collaboration experiments were conducted that were driven by a pandemic H1N1 related outbreak near U.S. military bases. Each experiment was conducted virtually and in a distributed nature.

Progress: The virtual collaboration environment (VCE) has been designed and created that supports both synchronous and asynchronous collaboration efforts. Three workshops have been conducted using the VCE to introduce the effort, form an online crisis response community of interest, and prepare for the experiment series. The two experiments have been completed and data analysis is in progress. The VCE design efforts and preliminary lessons learned have been presented at one conference, accepted to another, and one under review with several other publications in progress. The VCE won second place in the Federal Virtual World Challenge contest in 2010.

Current Goals: The primary goal is to examine how distributed collaboration can be improved among very diverse individuals and organizations with different but relevant backgrounds and expertise for complex crisis response planning and action efforts. Areas of intended improvement include patterns of communication, levels of trust and uncertainty, and planning efforts. Phase I is complete of this project and funding is being pursued for Phase II.

3.3.1.1 Recent Publications:

Tate, A.; Hansberger, J. T. Open Virtual Collaboration Environment for the Whole of Society Crisis Response Community. In *Proceedings of the Knowledge Systems for Coalition Operations 2010 Conference*, Vancouver, British Columbia, in progress.

Hansberger, J. T. Supporting Crisis Response Planning in Virtual Environments. In *Proceedings of the Human Factors and Ergonomics Society 54th Annual Conference*, San Francisco, CA, under review.

Moon, B.; Hansberger, J. T.; Tate, A. Concept Mapping in Support of Collaborative Crisis Response Planning. *Applied Concept Mapping: Theory, Techniques, and Case Studies in the Business Applications of Novakian Concept Mapping*, in progress.

Hansberger, J. T.; Tate, A. Supporting Crisis Planning With Virtual Worlds. In *Proceedings of the Federal Consortium for Virtual Worlds Conference 2010*, Washington, DC, 2010.

Hansberger, J. T.; Tate, A.; Moon, B.; Cross, R. Cognitively Engineering a Virtual Collaboration Environment for Crisis Response. In *Proceedings of the 2010 ACM Conference on Computer Supported Cooperative Work*, Savannah, GA, 2010.

Hansberger, J. T. Understanding Distributed Collaboration Within Virtual Worlds. In *Proceedings of the Sunbelt XXX Social Network Analysis Conference*, Trento, Italy, 2010.

3.4 Thrust Area 4: Computational Representations

Computational representations of social/cognitive networks can include task-level models, models of information flow, deep cognitive models, and advanced techniques for representing networks generally. The focus here is to exercise and extend current modeling approaches in conjunction with field and laboratory experimentation. The models include task-level information flow modeling techniques used in the C3TRACE (Command, Control, and Communication: Techniques for Reliable Assessment of Concept Execution) tool and a more purely mathematical, Bayesian approach. Specific models will portray the limits in information processing and decision making of the Soldiers, with the intent of affecting system design or implementation.

3.4.1 Research Area 4.1: Effects of Information Flow on Operator Performance

- Research: 6.2%–100%
- Funding: Internal - 100%
- Research Projects: 2
- Special Designators: ATO, TPA
- Collaborations: None
- Keywords: C3TRACE, Information Flow, Operator Performance

Aim: The aim of this research effort is to model the communications between key individuals within the Division Command Group, Division Maneuver Group, and the Infantry Brigade Combat Team, noting patterns of information flow among key decision-makers and the subsequent effect on performance.

Methods: The C3TRACE tool, Command, Control, and Communications – Techniques for the Reliable Assessment of Concept Execution) is used to model representations of command and control C2 tasks and functions performed by key individuals at the division and brigade level; various types of communication and information technologies are modeled in this environment. Military Subject Matter Experts (SME's) are used to gather information for model development to include scenario development and task network design. Two projects are being conducted in parallel: one uses the C3TRACE model (Swoboda); the other studies decision making under uncertainty (DMUC) conditions by applying a quantitative conditional probability approach based on Bayesian statistics and Partially Observable Markov Decision Processes (Middlebrooks).

Progress: Baseline model runs using both approaches were recently completed on a recon platoon level scenario. A next effort using C3TRACE modeled the effects of Platoon Leader equipment attrition in a similar scenario with the same personnel configuration.

Current Goals: The primary goal of the current efforts is to establish a baseline task network model detailing the information flow between key individuals at the Battalion and Brigade command level. For the C3TRACE model, initial interviews with SME's have helped to determine the key individuals from the Brigade and Battalion staff who will be the focus of our modeling effort. The development of communication task networks for each operator is in progress. It is our intent to then replicate the model conditions in a controlled experiment in the CASEL facility, where the aforementioned key individuals of the Brigade and Battalion staff will play out a simulated scenario. At this point, actual message traffic data, to include voice, digital, and face-to-face communications, will be collected and used in future model runs. This model can then be used to conduct "what-if" analyses to support future year's experimentation. The DMUC model will be applied on data collected at the 2010 OmniFusion experiment conducted at the Battle Command Battle Lab, Fort Leavenworth.

3.4.1.1 Recent Publications:

Kilduff, P.; Swoboda, J.; Katz, J. *A Platoon-Level Model of Communication Flow and the Effects on Operator Performance*; ARL-MR-0656; Army Research Laboratory: Aberdeen Proving Ground, MD, 2006.

Middlebrooks, S. E. Evaluating the Effect of Organizational Structure on Tactical Decision-Making Performance of the Reconnaissance Platoon Leader Using the Decision-Making Under Uncertainty (DMUC) Model.

Swoboda, J. C3TRACE: Modeling Information Flow and Operator Performance. Savage-Knepshield, P., Lockett, J., Martin, J., Allender, L., Eds.; Designing Soldier Systems: Current Issues in Human Factors, in press.

Swoboda, J. FY08 FCS-Approved Reconnaissance Platoon Modeling Effort. Customer report, 2008.

Swoboda, J. FY09 Alternative FCS-Approved Reconnaissance Platoon Models. Customer report, 2009.

4. Neuroscience

4.1 A Strategic Research Initiative That Has Developed Into a Major Laboratory Program

The U.S. Army Research Laboratory's Strategic Research Initiative in Neuroscience* seeks to enable revolutionary advances in Soldier-system performance by integrating modern neuroscience with human factors, cognitive science, and engineering to both enhance our understanding of Soldier function in complex operational settings and develop novel and effective means to enhance systems design. ARL's neuroscience efforts focus on the scientific study of the brain and mind. Increasingly, the connection between psychological experience and its biological bases are the foundation upon which we come to understand how we perceive and interact with the external world. As Army operations continue to move into future battlefields that are more dynamic and complex, such understandings will become increasingly critical in the design and development of systems that capitalize on the Soldier's cognitive abilities to meet the demands of these environments, ensuring mission effectiveness and maximizing Soldier survivability. ARL's neuroscience goals are to foster the translation of neuroscience research across a broad spectrum of military-relevant domains with a specific goal of augmenting Soldier performance. We have three main research thrust areas to accomplish these goals. The first is on neurocognitive performance, and currently eleven research projects across three sub-areas aim to uncover brain-environment-task interactions with a goal of providing fundamental understandings for translation. The second thrust is on advanced computational approaches, and currently eight internal projects across two sub-areas focus on advancing our capability to measure and interpret brain-environment-task interactions with a goal of providing advanced tools. The third area, neurotechnologies, is the most nascent of the thrusts and currently three internal research projects across three sub-areas aim to integrate the understanding and tools

* The U.S. Army Research Laboratory's efforts in neuroscience currently span five directorates and the U.S. Army Research Office. This document focuses on only those efforts in which Human Research and Engineering Directorate personnel are involved at the level of co-authorship.

developed under the more instantiated thrusts with novel technologies to develop neuroscience-based technologies that enhance Soldier-system interactions. Across all three of our three research areas, ARL seeks advances, both in the knowledge base and in related technologies, which will move neuroscience out into operational environments in order to quantify the capabilities and limitations of the nervous system, and will then use these metrics to modify and refine systems design and development. Ultimately, this effort, which is comprised of three thrust areas, envisions a process of systems design and implementation that exploits the capabilities of nervous systems to radically improve and optimize Soldier and system performance.

4.2 Thrust Area 1: Neurocognitive Performance

The recent advances in our scientific understanding of the capabilities and limitations of the human nervous system present a remarkable opportunity for improving Soldier-system technologies. However, our recent understanding of human brain function has been mostly derived within highly-controlled laboratory environments using tasks that often do not capture either the scope or the complexity of tasks performed in the real world. Results from these highly-controlled environments may not generalize given the complexity and marked moment-to-moment variability of human brain dynamics as well as the brain's central role in optimizing the outcome of our behavior when eyes and limbs can move freely about a perceptually-rich scene of sensory information. In short, the dynamic, complex nature of Army operational tasks and environments is likely to have dramatic influences on human nervous system functioning. Consequently, a major emphasis of on-going research projects is aimed at understanding the translation of laboratory-derived neurocognitive concepts to human performance in more naturalistic tasks and environments. The first research area emphasizes the collaborative ride-motion simulation-based research that we have conducted over the past several years with the Tank and Automotive RDEC as well as laboratory-based studies of complex, Army-relevant tasks. These five research projects examine Soldier-system performance under stressors such as time and multitasking pressure, high levels of environmental and mission complexity, vehicle vibration, and threat of bodily harm. Research in the second research area on multisensory integration was highlighted at the 2009 TAB review, and current projects investigate how sensory inputs from different perceptual modalities (e.g., vision and audition) interact with one another under variable task demands, emphasizing the complexity of perceptually-rich environments and the interaction of processing at different levels of the nervous system. Finally, the third research area represents a newly proposed area for us in structure-function coupling that we submitted for funding through the FY11 Director's Strategic Initiative. This area focuses on how the interaction between brain structure and brain function influences human behavior and performance, with a special emphasis on network-based analyses as a way to characterize neural function and/or behavioral performance. In short, all three research areas aim to uncover brain-environment-task interactions with a goal of providing a fundamental understanding from which operationally-relevant neurotechnologies, Soldier-system interactions, and Soldier protection technologies can be optimized.

4.2.1 Research Area 1.1: Neural Behavior Under Operational Stressors

- Research: 6.1%–50%; 6.2%–50%
- Funding: Internal - 10%; Collaborative - 90%
- Research Projects: 5
- Special Designators: ATO, TPA, TO
- Collaborations: TARDEC, U. California - SD, U. Wisconsin
- Keywords: Neuroscience, Vision

Aim: The aim of this research is to investigate neurocognitive and behavioral performance of Soldiers as they perform operationally-relevant tasks such as driving a vehicle, scanning a complex environment for threats, making threat-engagement decisions, and controlling robotic assets. In addition to employing these Army tasks, these studies also manipulate the task difficulty and/or the amount of stress to investigate how these factors modulate neural processing and performance.

Methods: These studies capitalize on unique Army experimental testing facilities that increase the realism of the experimental scenario while still providing experimental precision of a laboratory environment in order to obtain neurophysiological measures for Army-relevant tasks and scenarios. In a shooting task study (Kerick et al., 2007), Marines were tested in an M-range shooting simulation at HRED where they used a demilitarized M16A2 rifle that was instrumented for realism with an electromechanical recoil system and digitized sounds of gunshots. A series of on-going studies have used a large-scale ride motion simulator at the Tank and Automotive RDEC in Michigan that utilizes a six degree-of-freedom motion platform to simulate the vibrations and movements of manned ground vehicles while still providing a mechanism for tight control and manipulation of the motions that participant's experience. These unique experimental paradigms are then combined with the progressive analysis approaches discussed in section 2.1 to advance our capability to understand neural processing in complex, operational environments.

Progress: A recent publication used independent component analysis (ICA) for the identification and removal of artifacts and ERSP was examined in alpha (8–10 Hz, 11–13 Hz) and theta (4–7 Hz) frequency bands to identify task-related frequency changes in a group of warfighters during shooting in a enemy/friendly target discrimination shooting task (Kerick et al., 2007). The results revealed that cortical dynamics in theta and alpha frequencies provide unique but complementary information about different cognitive demands imposed on the

Soldiers during threat engagement decision shooting. That is, an early (~1000 ms) parietal theta peak was associated with stimulus encoding (identifying enemy vs. friendly targets) and decision making (decision to shoot or not shoot), whereas a later (~1200 ms) progressive increase in left temporal/central alpha was associated with motor response processes observed during the aiming period in response to enemy, but not friendly targets. In the past year, we have also collaborated with the Tank and Automotive RDEC and conducted our first two experiments on the large-scale ride motion simulator that have collected both behavior and physiology (EEG, heart rate, respiration, eye-tracking) data concurrently. Analyses of these data are still on-going. The experimental design for a third collaborative study is currently being developed, and the plan is to enrich the experimental paradigm by recruiting two military volunteers to perform operational scenarios as a commander-driver team where the scenario is less constrained experimentally by incorporating sandbox theory from computer science research.

Current Goals: We will continue analyzing existing datasets, and we have submitted abstracts to present a subset of the research results at the annual Ground Vehicle conference in August 2010. Furthermore, we are actively designing new experimental paradigms that capitalize on our unique Army testing facilities to increase operational fidelity while maintaining sufficient experimental precision, in order to advance our understanding of how complex, operational settings modulate neural processing and performance.

4.2.1.1 Recent Publications:

Kerick, S. E.; McDowell, K. Understanding Brain, Cognition, and Behavior in Complex Dynamic Environments. In D. D. Schmorrow et al., *Foundations of Augmented Cognition. Neuroergonomics and Operational Neuroscience*, Heidelberg, Springer Berlin, 2009, pp 35-41.

Schleifer, L. M.; Spalding, T. W.; Kerick, S. E.; Cram, J. R.; Ley, R.; Hatfield, B. D. Mental Stress and Trapezius Muscle Activation Under Psychomotor Challenge: A Focus on EMG Gaps During Computer Work. Psychophysiology **2008**, 45, 356–365.

Kerick, S. E.; Hatfield, B. D.; Allender, L. E. Event-related cortical dynamics of Soldiers during shooting as a function of varied task demand. Aviation, Space, and Environmental Medicine, 78 (Suppl. 1), 2007, B153-B164.

4.2.2 Research Area 1.2: Multisensory Integration

- Research: 6.1%–100%
- Funding: Internal - 50%; Collaborative - 50%
- Research Projects: 3
- Special Designators: SMART
- Collaborations: Brown U., Carnegie Mellon U., U. Colorado at Boulder

- Keywords: Neuroscience, Vision, Audition

Aim: The goal of this line of research is to understand how information from different senses interacts with one another at different levels of the nervous system, and how these interactions affect perception within variable task demands such as might be encountered in operational environments. Here, we are investigating the neural underpinning of inter-sensory integration, potential interactions between senses, and the development of physiological markers to monitor and utilize this information

Methods: Initial studies focused on assessing the physiological level at which inter-sensory interactions can be observed and predicted, and the perceptual consequences of those interactions. Conjoint use of auditory brainstem techniques (ABR) with high-density EEG investigates higher-cortical influence on low-level processing during varying task loads, as well as behavioral correlates of these interactions. Separate studies using fMRI and EEG explore the role of temporal synchrony and semantic congruence for the integration of environmental events (such as tapping a pencil), focusing on specialized networks that process the congruency of these cues for integration.

Progress: In accordance with long-term goals of assessing multisensory interactions at different levels of processing, we currently have two primary lines of research ongoing. An initial phase of studies using ABR to assess top-down low-level interactions is nearing completion. Studies targeting semantic and temporal congruence have been analyzed and published as a dissertation in Brown University's library, with current efforts on converting the dissertation chapters to journal publications. In addition, additional analyses on low-level sensory effects are planned for summer 2010. Results for both of these foci were presented at the 2010 meeting of the Cognitive Neuroscience Society.

Current Goals: Our primary goal is to examine the physiological basis for low- and high-level multisensory interaction in cognitive awareness, and how this influences performance in operational environments. We strive to identify metrics and manners of capitalizing on these effects in order to maximize performance.

4.2.2.1 Recent Publications:

Vettel, J. M.; Green, J.; Heller, L.; Tarr, M. J. Temporal and Semantic Effects on Multimodal Integration. *J. of Neuroscience,* in revision.

Jeka, J. J.; Oie, K. S.; Kiemel, T. Asymmetric Adaptation With Functional Advantage In Human Postural Control. *Exp. Brain Res.* **2008**, *186* (2), 293–303.

4.2.3 Research Area 1.3: Structure-Function Modeling

- Research: 6.1%–80%; Customer–20%
- Funding: Collaborative - 100%

- Research Projects: 4
- Special Designators: DSI (P), SMART, SCEP
- Collaborations: U. California – SB, ARL –WMRD, ARL – CISD, ARO
- Keywords: Neuroscience, TBI

Aim: This new research area aims to develop a multidisciplinary, multi-scale understanding of the relationship between the brain's physical structure and its dynamic electrochemical functioning. The specific long-term research goals are three-fold: first, to develop predictive models of the dynamic changes in brain structure focusing on short-time period events such as trauma. Second, to develop integrative, global level approaches to understand structural and functional brain states based on recent breakthroughs in both neuroscience and network science. Third, to develop time-evolving predictive models of how brain structure constrains global measures of brain function and cognitive performance.

Methods: Meeting the long-term research goals requires the development of a multi-scale computational platform that relates the evolving structural changes of the individual warfighter to functional brain states. This development will require the integration of several methodologies, including multi-scale computational modeling of high-rate tissue damage mechanics, high-fidelity brain imaging of anatomical and functional connectivity and associated analysis for brain network construction, graph theory approaches to analyzing both functional and structural networks, and connectome-like approaches that bridge independent structural and functional networks and enable simulations of global effects on multiple timescales.

Progress: Previous ARL work has focus solely on functional brain activity; i.e., a recent publication describes a model of neurophysiological data using the ACT-R computational framework to replicate latency effects for particular ERP components, N1 and P300 (Cassenti et al, in press). Based on the predictions from the model, a follow-up EEG study is currently underway to investigate whether the ERP latency can be modulated based on task difficulty.

Current Goals: The brain structure-function coupling project will initially focus on the research goals of modeling the dynamic changes in brain structure (with WMRD) and on integrative, global level approaches to understanding structural and functional brain states (with CISD). Data will be collected to support the development and validation of time-evolving predictive models of brain structure-function coupling in the initial years (with the ICB); however, the actual development of such models is expected towards the end of the proposed effort.

4.3 Thrust Area 2: Advanced Computational Approaches

The dynamics of the brain are highly-multidimensional, and the observable signals that we can access that reflect these dynamics are both highly-integrated and easily contaminated by external noise sources. This is particularly true as we strive to transition from the more controlled confines of the laboratory into the kinds of dynamic, complex task environments that typically comprise Army operations. In order to extract behaviorally-relevant signal components that can usefully characterize cognitive performance under such conditions, novel data analytic methods are required that can overcome the challenges inherent to biosignals analysis. In the advanced computational approaches thrust area, which we are planning on presenting to the TAB in 2010, we are currently focusing on electroencephalography (EEG) as a viable tool for measuring neural activity in both dynamic and mobile settings. While traditional EEG paradigms minimize both the complexity of the task environment and the mobility of the participants, computational advances over the past two decades have revolutionized the potential information that can be extracted through the analysis of EEG. To leverage these advancements, our on-going research projects focus on multi-aspect measurements of both neural and behavioral measures collected during task performance in complex, operational settings, and these datasets are analyzed using both traditional and novel analysis methods to determine metrics that can robustly and uniquely characterize neural processing and/or behavioral performance. The five current research projects in the first research area on data extraction, fusion, and interpretation projects emphasize three elements: examining extracting linear and nonlinear components of the underlying brain dynamics, fusing data from multiple neural, behavioral, and contextual sources, and interpreting complex data sets. For the second research area, only half of the projects are internal, and most of these began this year. These current efforts focus on statistical modeling and the classification of neural and behavioral states. The two research areas aim to advance our capability to measure and interpret brain-environment-task interactions with a goal of providing tools supporting the advancement of neurotechnologies and Soldier-system interactions.

4.3.1 Research Area 2.1: Data Extraction, Fusion, and Interpretation

- Research: 6.1%–40%; 6.2%–60%
- Funding: Internal - 50%; Collaborative - 30%; External - 20%
- Research Projects: 5 + 2 External
- Special Designators: DSI, ATO, TPA, TO, TT
- Collaborations: ARO, U. Wisconsin, U. Southern California, U. Iowa, Raytheon
- Keywords: Neuroscience, Methods

Aim: The aim of this research area is to implement novel methods for the extraction, fusion, and interpretation of biological data with an emphasis on non-linear approaches and joint bio-behavioral-contextual signal analysis to provide robust metrics for the characterization of cognitive state and performance within operationally-relevant task environments.

Methods: We are exploring and evaluating the use of linear and nonlinear methods (e.g., Independent Component Analysis, Phase Lag Index, Machine Learning, etc.) to effectively decompose signals into relevant components and to characterize the spatiotemporal dynamics of brain activity underlying cognitive performance on real-world tasks in real-world environments.

Paradigms are being used which embed classic neuroscience tasks within complex, real-world tasks. Novel methods for data extraction and data fusion utilizing joint biopotential (e.g., EEG, ECG), behavioral (e.g., eye and head movements), and contextual (e.g., task, environment) signals to increase the accuracy and fidelity of operationally-relevant metrics are being explored. Finally, advanced MRI methodologies are being explored to support future model development efforts.

Progress: Recently, we published one of the first systematic investigations examining the ability to extract brain-relevant EEG signal components under dynamic task conditions (Kerick et al.,, 2009), demonstrating that standard ERP signals could be reliably detected despite moderate levels of bodily or environmental motion. With this knowledge in hand, we have proceeded to obtain a number of data sets that reflect the complexity of the operational world, accomplishing a step that is critical to the application and development of the novel data analytical methods. We have accomplished this by performing a number of experiments that utilize both high-fidelity virtual environments implemented into Army crew stations and experimental vehicle testbed platforms (publications in preparation). These data sets are providing a foundational database for the application and development of novel data analysis methods, including new methods for signal decomposition and artifact removal (e.g., Luu et al.,, 2009). We are also improving and integrating EEG and other physiological sensor and data acquisition capabilities, including short-, medium-, and long-term planning to enhance these capabilities as our neuroscience program grows. Software implementations of several novel nonlinear EEG data analysis algorithms are currently being developed, extended, and applied to our extant real-world data sets to establish both the generalizability of these approaches to real-world scenarios and to increase in-house expertise in the application and interpretation of analytic results.

Current Goals: We are advancing in-house capabilities through both our computational infrastructure, including advanced computing resources and software algorithm implementations, and our in-house experience and expertise in data analysis. Further, we are exploring nonlinear analyses of functional connectivity that we foresee as providing an avenue for future analysis of functional networks. Other work focuses on reproducibility of diffusion spectrum imaging, which may provide an avenue to enhancing structural brain models.

4.3.1.1 Recent Publications:

Shackman, A. J.; McMenamin, B. W.; Maxwell, J. S.; Greischar, L. L.; Davidson, R. J. Identifying Robust and Sensitive Frequency Bands for Interrogating Neural Oscillations. NeuroImage, in press.

Casanova, R.; Yang, L. L.; Hairston, W. D.; Laurienti, P. J.; Maldjian, J. Examing the Impact of Spatio-Temporal Smoothness Constraints on the BOLD Hemodynamic Response Function Estimation: an Analysis Based on Tikhonov Regularization. *Physiological Measurement* **2009**, *30* (5), N37–N51.

Hairston, W. D.; Maldjian, J. A. An Adaptive Staircase Procedure for the E-Prime Programming Environment. *Computer Methods and Programs in Biomedicine* **2009**, *93* (1), 104–8.

Kerick, S. E.; Oie, K. S.; McDowell, K. *Assessment of EEG Signal Quality in Motion Environments*; ARL-TR-4866; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2009.

Luu, P.; Frank, R.; Kerick, S.; Tucker, D. M. Directed Components Analysis: An Analytic Method for the Removal of Biophysical Artifacts From EEG Data. Paper presented at the *13th International Conference on Human Computer Interaction (HCI)*, San Diego, CA, 2009.

McMenamin, B.W.; Shackman, A. J.; Maxwell, J. S.; Greischar, L. L.; Davidson, R. J. Validation of Regression-Based Myogenic Correlation Techniques for Scalp and Source-Localized EEG. *Psychophysiology* **2009**, *46*, 578–592.

McMenamin, B.W.; Shackman, A. J.; Maxwell, J. S.; Bachhuber, D. R.; Koppenhaver, A. M.; Greischar, L. L.; Davidson, R. J. Validation of ICA-Based Myogenic Artifact Correction for Scalp and Source-Localized EEG. *NeuroImage* **2009**, *49*, 2416–2432.

Shackman, A. J.; McMenamin, B. W.; Slagter; Maxwell, J. S.; Greischar, L. L.; Davidson, R. J. Electromyogenic Artifacts and Electroencephalographic Inferences. *Brain Topography* **2009**, *22* (1), 7–12.

4.3.2 Research Area 2.2: Statistical Modeling and State Classification

- Research: DSI - 25%; Customer - 75%
- Funding: Internal - 50%; Collaborative - 75%
- Research Projects: 3
- Special Designators: DSI
- Collaborations: ARO, Sandia National Laboratories
- Keywords: Neuroscience, Methods

Aim: This new research area aims to utilize advanced pattern classification techniques for online determination of Soldier mental state based on EEG data and associated physiological and system measurements.

Methods: We are currently exploring the viability of multiple classification algorithms in order to assess their performance across different tasks and different environments.

Progress: In a current study, we are analyzing a dataset collected in collaboration with the Tank and Automotive RDEC that manipulated the congruency of sensory cues, and the analysis explores whether the neural processing state is distinct when perceptual cues are congruent compared to when they are incongruent. Preliminary results will be presented at TAB 2010. Finally, another proposed project would explore classification of driver mental state to distinguish cognitive overload and underload situations during a driving task using EEG data and vehicle sensor state data. The IRB for this project is currently in progress.

Current Goals: We are exploring and defining requirements for the design of data analytic techniques for signal analysis to provide operationally-relevant characterizations and understandings of human cognitive performance and functional state. In addition to its importance for basic research, this understanding of the Soldier's mental state forms the cornerstone for several of the neurotechnologies that we are developing, such as Brain-Computer Interfaces, Task Allocation Systems, and Adaptive Displays.

4.4 Thrust Area 3: Neurotechnologies

Recent rapid advancements in neurotechnologies have resulted from the explosion of neuroscience research over the past several decades. These advancements range from sensor technologies for the real-time measurement of nervous system activity in real-world environments to brain-computer interfaces (BCI) and adaptive systems. We are currently developing a research thrust focused on investigating the applications of neurotechnologies to the military. Most of the research for the first research area on sensors and data acquisition is external projects. ARL is primarily supporting the external development of next-generation sensors and data acquisition systems designed for application within militarily-relevant settings. Research in this domain aims to enable true mobile brain imaging through "wear-and-forget" application technology and improved sensor robustness for use in a wide range of environments. The second research area began about a year ago by two post-docs who have been investigating the state-of-the-art of BCI technologies, and this effort specifically attempts to build our in-house capability to support the research, development, and transition of BCI-related technologies. One of the post-docs was just hired on as a full-time employee and is collecting preliminary data over the next 10 months in order to submit a Director's Research Initiative proposal to fund research on this area next year. Finally, a third research area focuses on the implementation of adaptive information displays and Artificial Intelligence-based systems for crew task management in multiple ground vehicle-based operational scenarios. The majority of research projects for this area are external., Our neurotechnology thrust aims to leverage the understanding and tools developed under the other two thrust areas, neurocognitive performance and the advanced computational approaches, so we can develop technologies that enhance Soldier-system interactions.

4.4.1 Research Area 3.1: Sensors and Data Acquisition

- Research: 6.2%–25%; DSI - 75%
- Funding: Internal - 25%; External - 75%
- Research Projects: 1 + 2 External

- Special Designators: ATO, DSI
- Collaborations: ARL-SEDD, ARO, U. California SD
- Keywords: Neuroscience, Methods

Aim: The Sensors and Data Acquisition sub-area seeks to identify, adapt, develop, and evaluate novel sensors and data acquisition systems to enable multi-aspect measurement of joint biopotential, behavioral, and contextual signals that can robustly characterize Soldier cognitive performance and overcome the technical challenges inherent to measurement in complex, dynamic, operational environments.

Methods: Current experimental efforts have utilized existing ARL sensor measurement systems integrated in a largely *ad hoc* fashion, to provide multi-aspect data sets for use in the development and application of novel data analysis algorithms under other research thrust areas. Surveys and evaluations of existing technologies; consultations with vendors of cutting-edge measurement systems and systematic and opportunistic acquisition of systems; and investments in the development of novel sensor solutions (e.g., dry, wireless, MEMS-based sensors) are being pursued to provide new measurement capabilities in the short-, medium- and long-term timeframes.

Progress: Several completed ARL-led research studies have entailed the simultaneous collection of EEG, physiological measures (e.g., ECG, respiration), and behavioral measures (e.g., eye and head tracking, Soldier-machine interactions) within dynamic, operationally-relevant environments. These efforts have provided a foundation for the development of a framework for systems design that considers the integration of novel sensor and data acquisition solutions as a critical component to a development approach that is situated within the Soldier-System-Environment cycle. A manuscript providing a detailed discussion of this framework is under development. As well, a large-scale survey of existing, state-of-the-art sensor and data acquisition systems has been conducted, and design guidelines for sensor and data acquisition system solutions to enable multi-aspect measurement in operational environments have been developed based on this survey. An ARL Technical Report detailing the results of the survey and specific guidelines is currently under submission. Finally, two state-of-the-art low-density EEG measurement systems have been acquired for evaluation and use in future research projects.

Current Goals: A project to compare an industry-standard, wired, 64-channel EEG system with two low-density, wireless systems that are more suited to use in operational environments is ongoing. This protocol (Vettel et al.,, 2010) will develop quantitative measure of both EEG signal quality and algorithm classification performance to compare and assess system performance and relevance for specific operationally-relevant tasks and environments. Further, a plan for sensor and data acquisition infrastructure development will be completed and implemented. This plan will guide decision making on future capabilities acquisition of an integrated data acquisition infrastructure that can quickly assimilate emerging sensor and measurement technologies and can overcome the technical challenges inherent to multi-aspect measurement in operational environments.

4.4.2 Research Area 3.2: Brain Computer Interface

- Research: 6.1%–67%; Customer - 33%
- Funding: Internal - 33%; Collaborative - 67%
- Research Projects: 2
- Special Designators: ICB
- Collaborations: U. California SB, SAIC, U. Southern California
- Keywords: Neuroscience

Aim: The aim of this new research area is investigate potential avenues for brain-computer interface (BCI) development. A current specific aim is to utilize neural signatures of an individual's viewing targets in order to enhance automated target detection capabilities. We have also proposed using a passive BCI system to improve the responsiveness of adaptive displays by detecting when the user is threatened or under extreme stress, and reducing or eliminating the presentation of non-critical information during these times.

Methods: Focused research into BCI has been initiated with an in-depth literature review on current BCI technologies and invocation techniques. Our initial BCI systems apply classification algorithms to domain-specific features extracted from EEG and other physiological data and utilize tasking related to mobility and security scenarios. Initial real-time computer modifications are envisioned to manipulate the quality of a virtual environment and the augmentation of threat detection.

Progress: Current progress consists of the draft of a literature and technology review on the current state-of-the-art in BCI, psychophysiological measurement, EEG feature extraction methods, and brain state classification algorithms. We have identified affective BCI as a promising avenue for future in-house research over alternatives such as using neural signals for direct moment-to-moment control. An initial BCI application for rapid image analysis has been developed and experimentation into feature extraction from EEG and other physiological signals and potential task-specific classification methods for determining neural functioning has been initiated.

Current Goals: Our next step will be to understand and implement basic offline feature extraction and classification techniques with operationally-relevant EEG equipment and experimental stimuli in order to determine the feasibility of transitioning this research. Based on this preliminary feasibility exploration, we expect to optimize the feature extraction and domain-specific classification techniques and transition the methodology to online algorithms and a full BCI.

4.4.3 Research Area 3.3: Task Allocation Systems and Adaptive Displays

- Research: 6.1%–10%; 6.2%–90%
- Funding: Internal - 10%; External - 90%
- Research Projects: 0 + 2 External
- Special Designators: ATO
- Collaborations: U. Texas, ORSA Corp.
- Keywords: Neuroscience

Aim: The overall aim of this new research area is to develop targeted technical approaches to enhance systems designs that will provide both improved capabilities for the Soldier and an integration and transition pathway for neuroscience-based knowledge and technologies. Specific aims are the development of techniques to enhance information-intensive operations and include: (1) Conceptual development of state representations and algorithms and initial software implementation of an intelligent task management system the adaptive allocation of task load among the members of a manned ground vehicle; and (2) the translation of machine-learning algorithms that model and predict operators' context-specific information preferences into adaptive information displays relevant to current Warfighter-machine interface concepts.

Methods: In the first specific aim, conceptualization of the Task Allocation System (TAS) is based upon advanced computational methods drawn from the field of Artificial Intelligence for the representation of the Mission-Soldier-Task state space (e.g., Dynamic Bayesian Networks), inference-making for estimation of system state (e.g., Rao-Blackwellised Particle Filtering), and policy optimization for intelligent task allocation (e.g., Forward Search Value Iteration). In the second specific aim of this research area, the Responsive Adaptive Display Anticipates Requests (RADAR) system, employs a two-stage stochastic decision process at every time step to: (1) estimate the probability that a user will update their information display based on the current context or situation, and if the probability estimate results in a display update, (2) estimate the probability distribution for the next (i.e., desired) display channel, which can be sampled to select the next display to present. Probability distributions in both stages are estimated through simple buffer networks, which allow both ongoing events and events from the recent past to influence the probability distribution estimates. An adaptive, error-correction learning algorithm changes the buffer weights, increasing weights from activated features and decreasing weights to other features, such that, over time, the system approximates an individual user's context-dependent information display preferences.

Progress: Current TAS efforts are aimed at refining the assumptions and conceptual and algorithmic approaches to provide adequate state representations, in the face of trade-offs between accuracy and computational complexity and efficiency, in modeling mission, tasks, and operators. Given the difficulty in predicting the impact of the complexity of the network (i.e., representation) on the efficiency of the proposed algorithms, an interim software implementation is ongoing that can be tested given various instantiations of mission, task, and operator models. Efforts under the adaptive information displays aim are refining the simulation environment and examining current Warfighter-machine interface concepts to transition algorithms for application to real-world systems.

Current Goals: In-house efforts under these projects have been focused on consultation with collaborative partners to ensure mission and operational relevance, as well as guiding research and capabilities development efforts to facilitate integration into larger ARL neuroscience goals and objectives. Recent ARL personnel additions will help to accelerate this process, bringing needed in-house expertise and leading to increased ARL-led research and experimentation.

4.4.3.1 Recent Publications:

Oie, K. S.; McDowell, K. Neurocognitive Engineering For Systems Development. *Defense Intelligence Journal,* in press, invited article.

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5. Soldier Performance

Develop and conduct a Soldier-oriented R&D program to advance and improve human factors design principles and guidance for enhancing Soldier and small team sensory, perceptual (auditory and visual) and physical performance, while providing the materiel development community with the information necessary for effectively designing systems that are best suited to the operator, maintainer and trainer. Quantify trade-offs between the benefits of providing new technology and the cost to the dismounted Soldier of having and using that technology.

5.1 Thrust Area 1: Sensory Performance—Vision

Work within the Sensory–Vision research thrust consists of two research areas: Visual Target Acquisition; and Perception and Night Vision Sensor Design. The visual target acquisition program applies psychophysical techniques to a set of dismounted Soldier tasks to improve the performance of the Infantry Warrior Simulation (IWARS) computational model. (IWARS is used to assess materiel being considered for acquisition.) This research, executed in collaboration with Natick Soldier Research, Development and Engineering Center (NSRDEC) and the Army Materiel Systems Analysis Activity (AMSAA), seeks to characterize the perceptibility of low-contrast peripheral visual events corresponding to dismounted enemy

Soldiers and use these data to modify the model such that it responds by reorienting its modeled field of view when appropriate. The perception and night vision sensor design research focuses on assessing electro-optical devices and algorithms that compress the dynamic range of scenes in order for Soldiers to extract maximal information from the scene. High Dynamic Range Imaging uses techniques that enable a greater range of luminance between light and dark areas within the image to be displayed. These techniques preserve the integrity of the image while displaying a scene that more closely corresponds to what the human eye "sees" in the real world. ARL HRED is collaborating with Johns Hopkins University in conducting vision experiments to support the Communication and Electronics Research Development and Engineering Center (CERDEC) Night Vision & Electronic Sensors Directorate (NVESD) in optimizing night-vision sensors for urban-lighting conditions, in which Soldiers are often required to simultaneously search bright areas directly adjacent to shadowy, dark areas.

5.1.1 Research Area 1.1: Visual Target Acquisition

- Research: 6.2%–100%
- Funding: Internal - 100%
- Research Projects: 1
- Special Designators: Technology Program Annex (TPA): NSRDEC: Vision Modeling of Real-World Target Acquisition (FY08 - FY10)
- Collaborations: Salus University
- Keywords: Vision, Peripheral, Motion, Flash, Detection

Aim: NSRDEC and AMSAA have collaborated to develop the Infantry Warrior Simulation (IWARS)—a high resolution combat simulation to assess the operational effectiveness of Warfighter equipment, particularly in individual and small-unit dismounted situations. Currently, IWARS characterizes central vision as unrealistically large (2°) and models eye movements with a fixed path, independent of visual events or viewer intent. Our hypothesis is that by improving the ecological validity of the IWARS, its performance (predictive accuracy as well as running time) will be improved. To this end we aim to empirically characterize both a realistic size for central vision in dismounted tasks and the probability of visual detection of low-contrast, moving, or flickering stimuli presented in the far visual periphery.

Methods: Develop custom software and utilize an existing immersive virtual environment (a Cave Automatic Virtual Environment (CAVE) in the HRED Tactical Environment Simulation Facility) to generate stimuli to be presented in the far periphery of participants in order to determine thresholds for contrast, visual eccentricity and speed and duration of motion required to reliably summon attention. Results will be provided to NSRDEC in the form of an ARL technical report for the next version of IWARS. NSRDEC and AMSAA are responsible for evaluation of new vs. old IWARS models.

Progress: In FY09, central vision was characterized by means of a psychophysical study. Parameters of the peripheral vision task and stimuli have been defined through multiple meetings with IWARS developers. Institutional Review Board (IRB) protocol and software development is currently in progress. Results showed a marked increase in contrast threshold for targets of a y of spatial frequencies ranging from 0.5–18.2 cycles/degree appearing greater than +3° to +4° horizontal eccentricity.

Current Goals: Develop and test prototype CAVE software to control stimuli and begin pilot testing to find appropriate levels of stimulus parameters for threshold study.

5.1.1.1 Recent Publications:

Monaco, W. A.; Higgins, K. E.; Kalb, J. T. Central and Off-Axis Spatial Contrast Sensitivity Measures With Gabor Patches; U.S. Army Research Laboratory; Aberdeen Proving Ground, MD, in press.

Monaco, W. A.; Heimerl, J. M.; Kalb, J. T. *A Clinically Useful Tool to Determine an Effective Snellen Fraction*; ARL-TR-4756; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2009.

Vaughan, B. M. *Soldier-in-the-Loop Target Acquisition Performance Prediction Through 2001: Integration of Perceptual and Cognitive Models*; ARL-TR-3833; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2006.

Monaco, W. A.; Kalb, J. T.; Johnson, C. A. *Motion Detection in the Far Peripheral Visual Field*; ARL-MR-0684; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2007.

5.1.2 Research Area 1.2: Perception and Night Vision Sensor Design

- Research: 6.2%–100%
- Funding: Internal - 85%; Collaborative: (Equipment provided by NVESD) - 15%
- Research Projects: 3
- Special Designators: R.IS.2008.04/Soldier Sensor Component & Image Processing TPA #CE-HR-2008-01 “Human Factors Issues for Night Vision Devices”
- Collaborations: CECOM-NVESD; ARL-Computational and Information Sciences Directorate (CISD), ARL-Sensors and Electron Devices Directorate (SEDD), Johns Hopkins University (JHU)
- Keywords: Dynamic Range, Stereopsis, Depth-of-Field

Aim: Conduct perception studies to (1) provide an empirical foundation and a computational foundation for choices among various engineering and optical solutions for enhancing the dynamic range of night vision devices (NVDs); (2) optimize hyperstereo displays to enhance the perception of depth at far ranges; and (3) conduct human factors studies to optimize the tradeoff between sensor properties, such as field-of-view vs. resolution and depth-of-field vs. image quality. One hypothesis being addressed is that standard hyperstereo displays are problematic because the interocular separation between the left-eye and right-eye sensors is constant, rather than adaptive to differences in the range of targets from the observer. Other research is motivated by the validation of a mathematical "Ideal Observer" metric under development in collaboration with the Neuromorphic Engineering Laboratory at JHU.

Methods: The investigations are laboratory experiments that employ apparatus specifically designed to emulate luminance levels and the fields of view of NVDs, and to employ conditions dictated by the "Ideal Observer" metric.

Progress: Two experiments are ongoing: (1) Protocol: "Intra-scene Dynamic Range of the Unaided Eye" is designed to provide data establishing the parameters for a predictive model of intra-scene dynamic range; (2) Protocol: "Dynamic range: Evaluation and development of tone-mapping algorithms to enhance target identification" is designed to measure how perceptual performance corresponds to the "Ideal Observer" metric developed at JHU.

Current Goals: Both experiments address the dynamic-range issues in situations where a Warfighter wears standard-issue NVDs and attempts to thoroughly search an area with targets hidden in bright areas directly adjacent to targets hidden in shadowy, dark areas. Future research will also address hands-free focus designs to solve problems of excessive physical workload associated with the need to repeatedly refocus NVDs for sufficient spatial resolution at near, middle, and far ranges.

5.1.2.1 Recent Publications:

CuQlock-Knopp, V. G.; Wallace, S.; Karsh, R.; Merritt, J.; Kregel, M. Video-Based Criterion Measure. In Identifying Experts in the Detection of Improvised Explosive Devices (IED2) U.S. Army Research Institute for the Behavioral and Social Sciences: Alexandria,VA, in press.

Merritt, J.; CuQlock-Knopp, V. G.; Kregel, M.; Wallace, S.; Vaughan, B. Binocular Depth Acuity. In Identifying Experts in the Detection of Improvised Explosive Devices (IED2). U.S. Army Research Institute for the Behavioral and Social Sciences: Alexandria,VA, in press.

Vaughan, B.; Murphy, J.; Standard, T.; CuQlock-Knopp, V. G.; Anderson, B. Improving IED Detection Through Training and Personnel Selection; U.S. Air Force: Wright Patterson AFB, Ohio, in press, 2010.

Harrison, A.; Etienne-Cummings, R. High Dynamic Range Image Display Quality Assessment: An Ideal Observer. *The IEEE International Conference on Digital Image Processing*, 2010.

Mullins, L. *Effects of Viewpoint Offset for Use in the Development of Advances Indirect View Sensor Systems*; ARL-TR-4775; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2009.

CuQlock-Knopp, G.; Davison, A.; Karsh, R.; Raglin, A.; Schweitzer, K.; Vaughan, B.; Wallace, S. Improving Your Visual IED Detection. *JIEEDO Tactical Pocket Reference Card*, 2009.

CuQlock-Knopp, G.; Bender, E.; Merritt, J.; Smoot, J. The Recognition of Scene Features in Fused Imagery Versus Unfused Visible/Near-Infrared or Long-Wave Infrared Imagery. In *Proceedings of the Military Sensing Symposia Specialty Group on Passive Sensors*, 2008.

Schweitzer, K. M.; CuQlock-Knopp, V. G.; Klinger, D. K.; Martinsen, G. L.; Rodgers, R. S.; Murphy, J. S.; Stanard, T. W.; Warren R. *Preliminary Research to Develop Methodologies For Identifying Experts in the Detection of Improvised Explosive Devices (IEDs): Phase I*; ARL-TR-4375; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2008.

Solberg, J.; Stanard, T.; CuQlock-Knopp, G.; Ashworth, A.; Raglin, A. Evaluating Visual Detection of IEDs. *76th Military Operations Research Symposium*, New London, CT, 10–12 June 2008.

Mohananchettiar, A.; Cevher, V.; CuQlock-Knopp, G.; Chellappa, R.; Merritt, J. Hyperstereo Algorithms for the Perception of Terrain Drop-offs, Head-and Helmet-Mounted Displays XII: Design and Applications. *Proceeding of the SPIE*, 2007, *6557*, 655701.

Merritt, J.; CuQlock-Knopp, G.; Paicopolis, P.; Smoot, J.; Kregel, M.; Corona, B. Binocular Depth Acuity Research to Support the Modular Multi-Spectral Stereoscopic Night Vision Goggle. In *Proceedings of the SPIE Defense and Security Symposium 11th Annual Conference on Helmet-and Head-Mounted Displays X: Technologies and Applications*, 2006, *6224*, 622403.

5.2 Thrust Area 2: Sensory Performance—Audition

Research is conducted in three interconnected areas: Speech Communication under Adverse Conditions; Unconventional Communications; and Auditory Situation Awareness. The Soldier's auditory environment is problematic because it contains adverse noise levels that require use of hearing protection; however, sound is often the first warning of danger and a primary means of communication. Communications devices such as headsets are required for radio communication but interfere with local auditory situation awareness. The goal to maintain maximum auditory situation awareness drives research on hearing protection technologies that restore ambient sounds and unconventional communication technologies, such as bone conduction, that leave the ears uncovered.

The Soldier's environment contains acoustical features atypical of traditional research environments; they have a larger scale and exhibit greater unpredictability than a controlled environment. Auditory situation awareness is defined as the ability to detect, recognize and localize sounds in one's operational environment. It is not possible to consider Soldier auditory situation awareness independently of the need for hearing protection and communications (both face-to-face and over radios). Thus, current research topics include those that quantify the effects of headgear, movement, noise, and reverberation on the ability to localize sound sources in azimuth, elevation, and distance. Other topics identify the features used to identify weapon sounds for use in auditory training.

Critical to this research is the new laboratory facility, the Environment for Auditory Research (EAR), which enables the simulation of the unusual acoustical conditions encountered by Soldiers while allowing the control needed for the experimental isolation of acoustic features needed in order to make inferences about of cause and effect. An element of the research effort is the development and validation of the calibration techniques and measurement tools necessary for the auditory research that is conducted here.

5.2.1 Research Area 2.1: Speech Communications Under Adverse Conditions

- Research: 6.1%–50%; 6.2%–50%
- Funding: Internal - 100%
- Research Projects: 3
- Special Designators: None
- Collaborations: ARL-HRED Dismounted Warrior Branch
- Keywords: Speech, Hearing Loss, Attention, Intelligibility, Communications

Aim: Understand how Soldier comprehension of speech communications and subsequent task performance is affected by adverse conditions. To achieve this, we are measuring the speech intelligibility of various communications and hearing protection systems (C&HPS), and the executive attention requirements associated with various levels of simulated hearing loss. As hearing loss increases, it is predicted that task performance will decrease due to the increase in attention required for speech understanding. Soldiers using C&HPS report experiencing decreases in speech intelligibility, auditory awareness, and sound localization ability. These decreases negatively impact mission performance and Soldier survivability. Normal-hearing Soldiers resist using hearing protection devices (HPDs) because their perception is that they degrade these same abilities; Soldiers with impaired hearing are even more resistant to HPD wear. However, without hearing protection Soldiers are vulnerable to new or additional temporary and permanent hearing loss, which further degrade operational performance, result in degraded quality-of-life, and cost billions in disability payments.

Methods: Measure the speech intelligibility of listeners wearing two C&HPS using a military-specific speech intelligibility measure, the Callsign Acquisition Test (CAT). Simulate various levels of hearing loss by filtering the CAT items. A dual-task methodology with a significant auditory attention requirement is being used to measure the effects of simulated hearing loss on the performance of a navigation task. This task involves participants walking on an Omni-Directional Treadmill through a virtual urban terrain while performing the CAT under various levels of simulated hearing loss.

Progress: Speech intelligibility was measured for two C&HPS. A protocol was approved for the auditory/navigation dual-task experiment. Pilot testing has begun.

Current Goals: Complete dual-task testing directly tying mission performance to hearing ability. Develop subsequent research protocols for measuring the influence of C&HPS on auditory localization.

5.2.1.1 Recent Publications:

Weatherless, R.; Grantham, M.; Kehring, K.; Fedele, P. Interaction Between Simulated Hearing Loss and Navigation Task Performance. Poster presented at the *3rd International Conference on Applied Human Factors and Ergonomics (AHFE 2010)*, Miami, FL, July 2010.

Henry, P.; Weatherless, R. *Evaluation of Auditory Characteristics of Communications and Hearing Protection Systems (C&HPSs) Part I – Sound Attenuation to Low Intensity Sounds*; ARL-TR-5050; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, January 2010.

Henry, P.; Weatherless, R. *Evaluation of Auditory Characteristics of Communications and Hearing Protection Systems (C&HPSs) Part II – Speech Intelligibility*; ARL-TR-5075; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, January 2010.

Blue, M. A.; Ntuen, C.; Letowski, T. Speech Intelligibility Measured With Shortened Versions of CALLSIGN ACQUISITION TEST (CAT). *Applied Ergonomics*, available online 13 September 2009, in press.

Rao, M.; Letowski, T. Callsign Acquisition Test (CAT): Speech Intelligibility in Noise. *Ear and Hearing* **2006**, *27*, 120–128.

Hicks, D.; Rao, M.; Letowski, T. A Comparison of Speech Intelligibility Between the Callsign Acquisition Test and the Modified Rhyme Test (Paper 6285). Paper presented at the *117th Audio Engineering Society Convention (AES Convention)*, San Francisco, CA, October 2004.

5.2.2 Research Area 2.2: Auditory Situation Awareness

- Research: 6.1%–75%; 6.2%–25%
- Funding: Internal - 100%
- Research Projects: 6

- Special Designators: ATOs: NSRDEC Helmet Electronics and Display System-Upgradeable Protection ATO; NSRDEC "Auditory Data Development in Support of IWARS" TPA; CRREL "Localization and Identification of Sounds in Tactical Environments (LISTEN)" TPA; NSRDEC "Efficacy of Head-Mounted Tactile Display for Soldier Performance" (FY10-FY12) TPA
- Collaborations: NSRDEC, SEDD, CRREL
- Keywords: Sound Localization, Sound Identification and Training, Sound Attenuation and Noise, Auditory Distance Estimation

Aim: Soldiers depend on auditory situation awareness as their first warning of events in their environment. However, their environment is unpredictable, noisy, and acoustically complex due to buildings and personal equipment. The Auditory Research Team (ART) studies how these acoustic features affect the ability to detect, recognize/identify, and localize sounds. Specific research goals include determining: factors affecting accurate detection of sounds moving in a straight trajectory; acuity of auditory depth perception; auditory features used to identify weapon signatures and their usefulness for training; developing a database of localization performance ability for use in computer models; and modeling the effect of hearing protection on noise reduction.

Methods: Traditional psychophysical and perceptual measurement paradigms are used. The EAR facility, which was designed to simulate the Soldier's real-world acoustical conditions such as reverberation, distance, and movement, is the primary research space for the studies. Detection, identification and localization performance (accuracy and response time) are measured as a function of various headgear (helmets, masks, hoods, and hearing protection) and acoustic conditions (reverberation, indirect sound pathways, and source azimuth, elevation, distance, and movement). These data are transitioned to the scientific literature and used to create models of auditory performance.

Progress: Currently work is being conducted under a number of protocols and agreements, including two ATOs, three TPAs and an SBIR. Recent publications include six technical reports, three conference proceedings, two submissions to peer reviewed journals, two journal publications, computer software, and several book chapters.

Current Goals: Research is being conducted in order to develop models, (e.g., IWARS model data, Auditory Hazard Assessment Algorithm for Humans [AHAAH] hearing protection module), training methods (weapons identification), psychophysical bases for new technology (bone conduction and tactors) and to populate the research literature with auditory performance data in complex acoustic environments.

5.2.2.1 Recent Publications:

Sound localization: (Determination of sound source, with headgear, with hearing protection…)

Binseel, M.; Scharine, A.; Mermagen, T.; Letowski, T. Sound Localization Ability of Soldiers Wearing Infantry Helmets. *Military Psychology*, in review.

Scharine, A. A. *Degradation of Auditory Localization Performance Due to Helmet Ear Coverage: The Effects of Normal Acoustic Reverberation*; ARL-TR-4879; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2009.

MacDonald, J. A. A Localization Algorithm Based on Head-Related Transfer Functions. *Journal of the Acoustical Society of America* **2008**, *123*, 4290–4296.

MacDonald, J. A.; Tran, P. K. The Effect of HRTF Measurement Methodology on Localization Performance in Spatial Audio Interfaces. *Human Factors* **2008**, *50*, 256–263.

Henry, P. Perception of Auditory Motion. Seminar, U.S. Army Aeromedical Research Laboratory: Ft. Rucker, AL, May 2009.

Henry, P.; Scharine, A. Perception of Auditory Motion in a Straight Trajectory. Podium presentation at the *American Auditory Society Annual Meeting*, Scottsdale, AZ, March 2009.

Scharine, A. A. *An Evaluation of Localization Ability With Selected Level-Dependent Hearing Protection Systems: A Field Study Conducted for the Future Force Warrior Integrated Headgear Integrated Process Team*; ARL-TR-3579; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2005.

Sound Identification: Weapon Signatures

Scharine, A. A. *Predicting Sound Attention and Identification: Modeling Identification of Category, Subcategory and Specific Source as a Function of Mission Context*; ARL-MR-730; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2009.

Gaston, J. G.; Letowski, T. R.; Fluitt, K. F. Mapping Listener Perception of Weapon Signature for Single-Shot Impulse Sounds. Poster presented at the *9th annual Auditory Perception, Cognition and Action Meeting*, Boston, MA, November 2009.

Scharine, A.; Letowski, T. R.; Mermagen, T.; Henry, P. P. Learning to Detect and Identify Acoustic Environments From Acoustic Sound. *Military Psychology* **2010**, *22*, 24–40.

Sound Attenuation in "Noise" (Other Sounds)

Scharine, A.; Fluitt, K.; Letowski, T. The Effects of Helmet Shape On Directional Attenuation of Sound. In *Proceedings of the 16th International Congress on Sound and Vibration*, Krakow, Poland, 2009.

Scharine, A. A.; Letowski, T. R.; Sampson, J. B. Auditory Situation Awareness in Urban Operations [Electronic Version]. *Journal of Military and Strategic Studies* **2009**, *11* (4), 1–28.

Henry, P.; Scharine, A.; Letowski, T. Auditory Localization in the Presence of Spatialized Background Noise. *The American Speech-Language and Hearing Association (ASHA) 2006 Annual Convention*, Miami, FL, 16–18 November 2006.

Henry, P. Non-Linear Hearing Protection for the Individual Soldier. *The International Symposium—Pharmacologic Strategies for the Treatment of Hearing Loss and Tinnitus*, Niagara Falls, Ontario, 9–12 October 2005.

<u>Sound Distance Estimation</u>

Fluitt, K.; Letowski, T.; Mermagen, T. Auditory and Visual Performance in an Open Field. *The 149th Meeting of the Acoustical Society of America*, Poster; Vancouver, BC, 16–20 May 2005.

5.2.3 Research Area 2.3: Unconventional Communications

- Research: 6.1%–100%
- Funding: Internal - 90%; Collaborative - 10%
- Research Projects: 2
- Special Designators: None
- Collaborations: Cooperative Research and Development Agreement (CRADA) no. 08-06 “Advancement of Mobile Communication Solutions Incorporating Bone Conduction (BC) Devices” with Sensory Devices Inc. (SDI); Embry-Riddle Aeronautical University (ERAU); North Carolina A&T University; U.S. Military Academy at West Point.
- Keywords: Unconventional Communications, Bone Conduction, Tactile, Speech Communication, Situation Awareness

Aim: Explore alternative communication means (bone conduction [BC] and tactile) for the needs of modern combat. The primary objectives are to increase the effectiveness of communication, enhance situation awareness, and reduce information overload on the visual and auditory channels by utilizing multi-modal communications. BC and tactile transducers leave ear canals open for sound detection, localization, and face-to-face communication—all vital for military operations—and for using operationally-specific hearing protection (which might be none at all). BC transducers can be hidden in a cap or under hair with no visible cues. They are relatively insensitive to external vibration or noise. Stealthy BC duplex communication is possible through using teeth clicks for sending out coded messages.

Method: Specific research areas include detection thresholds for bone vibration and tactile stimulation, speech intelligibility, transducer optimization and interfacing, and system performance evaluations under a variety of military operational conditions. Research is performed under in-house studies, collaboration with Universities, and a CRADA with SDI.

Progress: Completed a series of studies on optimal BC transducer placement for both incoming (BC vibrator) and outgoing (BC microphone) signals, the determination of BC signal detection and speech intelligibility limits in quiet and noise for effective speech communication (ARL, ERAU, NCA&T), and the development of a tactile communication regime for on-head operations. The collaboration with SDI resulted in a novel design for BC microphones that provides a 25dB improvement in sensitivity over the prior microphones. Fifteen papers and two book chapters have been published.

Current goals: Explore the effects of using multiple BC microphones on speech communication; examine how individual differences among users affect speech intelligibility over BC communication systems (approved protocol); and continue the CRADA with SDI to improve and ruggedize the BC transducers. Future plans involve determining the limitations of concurrent BC and tactile communication, determining the spatial resolution for both means of communication, and developing comfortable, flexible mounting systems for unconventional transducers.

5.2.3.1 Recent Publications:

Tran, P.; Letowski, T. Speech Intelligibility of Air Conducted and Bone Conducted Speech Over Radio Transmission. In *Proceedings From Noise Conference (NOISE-CON)*, April 2010.

McBride, M.; Tran, P.; Letowski, T. BC Intelligibility Headset Comparison Study. *Industrial Engineering Research Conference*, Greensboro, NC, IERC, June 2010.

Henry, P.; Tran, P.; Letowski, T. *Comparison of Bone Conduction Technologies*; ARL-TR-4705; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2009.

Tran, P.; Letowski, T.; McBride, M. Bone Conduction Microphone: Head Sensitivity Mapping for Speech Intelligibility and Sound Quality. *International Conference on Audio, Language and Image Processing (ICALIP 2008)*, July 2008, pp 107–111.

McBride, M.; Letowski, T.; Tran, P. Bone Conduction Reception: Head Sensitivity Mapping. *Ergonomics* **2008**, *51* (5), 702–18.

Henry, P.; Letowski, T. *Bone Conduction: Anatomy, Physiology, and Communication*; ARL-TR-4138; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2007.

MacDonald, J.; Henry, P. Spatial Audio through a Bone Conduction Interface. *International Journal of Audiology* **2006**, *45*, 595–599.

McBride M.; Letowski, T.; Tran, P. Comparison of Bone Conduction Hearing Thresholds in Quiet and Noise Environments. Presentation at the *4th Annual Meeting of the Society of Human Performance in Extreme Environments*, San Francisco, CA, October 2006.

McBride, M.; Letowski, T.; Tran, P. *Bone Conduction Head Sensitivity Mapping: Bone Vibrators*; ARL-TR-3556; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2005.

Scharine, A.; Henry, P.; Binseel, M. *An Evaluation of Selected Communications Assemblies and Hearing Protection Systems: A field Study Conducted for the Future Force Warrior Integrated Headgear Integrated Process Team*; ARL-TR-3475; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2005.

Henry, P.; Mermagen, T. Bone Conduction Communication in a Military Vehicle. *NATO Research and Technology Organization, Applied Vehicle Technology Panel Symposium*, Prague, Czech Republic, 13-1:13-12, October 2004.

Letowski, T.; Mermagen, T.; Vause, N.; Henry, P. Bone Conduction Communication in Noise: A Preliminary Study. In *Proceedings of the 11th International Congress on Noise and Vibration*, St. Petersburg, Russia, July 2004.

5.2.4 Research Area 2.4: Environment for Auditory Research (EAR) Facility

- Research: 6.1%–60%; 6.2%–30%; Customer - 10%
- Funding: Internal - 95%; Collaborative - 5%
- Research Projects: 3
- Special Designators: None
- Collaborations: Missouri Science and Technology University, AuSim, AVI-SPL, Walter Reed Army Medical Center, Michael and Associates, Aberdeen Test Center
- Keywords: Auditory, Spatial, Ambient, Virtual, Simulation, Sound

Aim: The Environment for Auditory Research was developed to simulate realistic military sounds and measure listener task performance. Recordings of actual Army weapons, vehicles, radios, and Soldier related acoustic emissions are used as sources. Outdoor recordings or real-time audio from the OpenEAR simulate natural listening environments. Vector based amplitude panning and AuSIM Vectsonic panning techniques can simulate moving sounds over loudspeaker arrays. Anthropomorphic acoustic manikins and head-related-transfer-function based virtual audio synthesis are used to create virtual audio over headphones. Using these sound tools, a Soldier can hear and respond to relevant military sounds in a controlled laboratory environment. Four specific aims are being pursued as follows: (1) the acoustic characteristics of the facility will be quantified; (2) judgments of spatial sound sources generated from synthetic techniques will be compared with real sound presentations from loudspeakers; (3) a uniquely constructed subject response chair for the EAR facility will be used to compare hand, head, and body pointing response time and accuracy with a non-pointing verbal coordinate response method; and (4) the effect of a priori visual and acoustic spatial cues on auditory depth perception will be determined.

Progress: The reverberation times, noise reduction between rooms, ambient noise levels, and spectral capabilities of the sound systems have been measured and published.

Current Goals: The near term goals are to baseline performance of the virtual audio presentation techniques and subject response equipment. After the hardware and software infrastructure is complete, the focus will shift to creating soundscapes over headphones and loudspeaker arrays to simulate military environments. Target and masking sounds will be portrayed by friendly, neutral, and threatening sounds. Background sounds will emulate a range of conditions from quiet deserts to busy urban streets. Accurate portrayals of military soundscapes and listening tasks will help to better assess and model Soldier performance utilizing various body-worn and communication devices.

5.2.4.1 Recent Publications:

Scharine, A.; Mermagen, T. Characterization of the Environment for Auditory Research (EAR) at the U.S. Army Research Laboratory. In *Proceedings of the 15th International Congress on Sound and Vibration*, Daejon, Korea, 6–10 July 2008, pp 1842–1849.

Amrein, B.; Letowski, T. The Environment for Auditory Research. *Canadian Acoustics, 37* **2009**, 152–153.

Henry, P.; Amrein, B.; Ericson, M. A. The Environment for Auditory Research. *Acoustics Today* **July 2009**, *5* (3), 9–15.

Letowski, T.; Amrein, B.; Ericson, M. Environment for Auditory Research: Design Principles and Capabilities. In *Proceedings of the 17th International Congress on Sound and Vibration*, Cairo, Egypt, 18–22 July 2010, in press.

5.3 Thrust Area 3: Sensory Performance—Tactile

As technology advances, Soldiers are being inundated with battlefield information, and most of this information is being presented through the visual and auditory sensory modalities. The use of the skin as an alternative sensory modality to convey information could be beneficial in enhancing Soldier performance by decreasing errors and increasing situation awareness and overall performance. The major goal of the tactile research area is to investigate how to transfer visual and auditory information to the tactile modality or augment these channels for improved understanding. Past efforts have revealed that the head and torso are suitable locations for tactile communication. Basic research studies have aided in the construction of a head sensitivity map that was used to design a portable, head-mounted tactile display (HMTD). Applied research studies involving the torso have included the measurement of Soldier performance in the use of various torso tactile devices in simulated, battlefield environments. Current tactile work entails a field study to show the efficacy of the HMTD for enhancing Soldier performance in the battlefield environment and a field study to enhance the perception and urgency of the vibratory signal., Future goals in tactile research include determining the feasibility of manipulating the parameters of tactile patterns to add complexity to tactile messages, the development of an intuitive tactile language and the coupling of the HMTD with existing bone conduction systems.

5.3.1 Research Area 3.1: Tactile

- Research: 6.1%–30%; 6.2%–70%
- Funding: Internal - 100%
- Special Designators: Head Research: Hostile Fire Defeat ATO(R); TPA no. NA-HR-2009-02 "Efficacy of Head-Mounted Tactile Display for Soldier Performance" Dismounted Research: TPA no. NA-HR-2009-03 "Exploring the Use of Tactile Displays in Military Environments"
- Collaboration: Morgan State University; Head Research: NSRDEC, ARL-SEDD; Dismounted Research: NSRDEC
- Keywords: Head Research: Tactile Sensitivity, Head Tactile Display, Vibrotactile Thresholds Dismounted Research: Tactile Sensitivity, Vibrotactile, Dismounted

Alternative modes of presenting information to the Soldier are needed due to the anticipated, catastrophic consequences of exclusive use of the visual and auditory sensory modalities as a mode of communication for enhancing Soldier situation awareness (SA) and performance. Thus, HRED researchers are exploring the use of both the head and torso as a means for tactilely conveying information to the Soldier.

<u>Head-Mounted Tactors Research</u>

Aim: The aim of tactile research for the head is to design: (1) a stand-alone, head-mounted tactile display (HMTD) based on optimal tactile sensitivity measures for the head; and (2) a dual-use, tactile-bone conduction communication system.

Methods: Basic research laboratory studies that quantify perceptual parameters associated with vibration applied to the head and applied research studies to determine the efficacy of the HMTD in enhancing Soldier performance in simulated battlefield environments.

Progress: Research progress includes the identification of the optimal head locations and signal frequencies for head tactile communication and the ability to determine the location of an active tactor.

Current Goals: Current goals of tactile research for the head include determining the: (1) effects of navigational movement on the ability to detect vibratory signals on the head and (2) optimal signal frequency for navigational movement.

<u>Dismounted Research</u>

Aim: The aim of tactile research for dismounted Soldiers is to: (1) determine how the tactile modality can be used as a communication medium (2) identify the types of information that can be relayed using the tactile modality and what body location is best suited for relaying that information.

Methods: Methods to accomplish these aims include laboratory and field studies.

Progress: Research progress includes a technical report that identifies the torso as the most suitable location to provide tactile stimuli and the completion of a laboratory study to examine the effects of stimulus intensity and inter-stimulus duration on perceived urgency and the ability to detect and identify tactile patterns.

Current Goals: Current goals of this project are to conduct a field study to determine the effects of stimulus intensity and inter-stimulus duration on perceived urgency and the ability to detect and identify tactile patterns.

5.3.1.1 Recent Publications:

<u>Head Tactile Research</u>

Myles, K.; Kalb, J. T. *Guidelines for Head Tactile Communication*; ARL-TR-5116; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2010.

Myles, K.; Kalb, J. T. *Vibrotactile Sensitivity of the Head*; ARL-TR-4696; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2009.

Kalb, J. T.; Amrein, B. E.; Myles, K. *Instrumentation and Tactor Considerations for a Head-Mounted Display*; ARL-MR-705; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2008.

Myles, K.; Binseel, M. S. *The Tactile Modality: A Review of Tactile Sensitivity and Human Tactile Interfaces*; ARL-TR-4115; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2007.

<u>Dismounted Tactile Research</u>

Glumm, M. M.; Kehring, K. L.; Glumm, M. M. *Effects of Multimodal Displays About Threat Location on Target Acquisition and Attention to Visual and Auditory Communications*; ARL-TR-4074; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2007.

Glumm, M. M.; Kehring, K. L.; Glumm, M. M. *Effects Of Tactile, Visual, And Auditory Cues About Threat Location On Target Acquisition And Attention To Visual And Auditory Communications*; ARL-TR-3863; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2006.

Krausman, A. S.; White, T. L. Effects of Vehicle Vibration on Perception of Tactile Cues in Combat Vehicles. In *Proceedings of the 14th Annual International Conference on Industrial Engineering* Anaheim, CA, 2009.

Krausman, A. S.; White, T. L. *Detection and Localization of Vibrotactile Signals in Moving Vehicles*; ARL-TR-4463; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2008.

Krausman, A. S.; White, T. L. Using the Tactile Modality as a Communication Medium for Dismounted Soldiers. In *Proceedings of the Human Factors and Ergonomics Society 51st Annual Meeting*, Baltimore, MD, 2007.

Krausman, A. S.; Pettitt, R. A.; Elliott, L. R. Effects of Alerts on Army Infantry Platoon Leader Decision Making and Performance. In *Proceedings of the Command and Control Research and Technology Symposium*, San Diego, CA, 2006.

Krausman, A. S.; White, T. L. A Comparison of Vibrotactile Displays Under Simulated Operational Conditions for Dismounted and Mounted Soldiers. In *Proceedings of the 25th Army Science Conference*, Orlando, FL, 2006.

Krausman, A. S.; White, T. L. *Tactile Displays and Detectability of Vibrotactile Patterns as Combat Assault Maneuvers are Being Performed*; ARL-TR-3998; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2006.

Merlo, J.; Terrence, P. I.; Stafford, S.; Gilson, R.; Hancock, P. A.; Redden, E. S.; Elliot, L. R.; Krausman, A.; White, T. L. The Effects of Dynamic Environments and Physiological Stress on Tactical Communication and Signaling. In *Proceedings of the Human Performance in Extreme Environments Conference*, San Francisco, CA, 2006.

Merlo, J.; Terrence, P. I.; Stafford, S.; Gilson, R.; Hancock, P. A.; Redden, E. S.; Krausman, A.; Carstens, C. B.; Pettitt, R.; White, T. L. Communicating Through the Use of Vibrotactile Displays for Dismounted and Mounted Soldiers. In *Proceedings of the 25th Army Science Conference*, Orlando, FL, 2006.

White, T. L. Suitable Body Locations and Vibrotactile Cueing Types for Dismounted Soldiers; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, in press.

White, T. L.; Kehring, K. L.; Glumm, M. M. Effects of Unimodal and Multimodal Cues About Threat Locations on Target Acquisition and Workload. *Military Psychology* **2009**, *21*, 497–512.

5.4 Thrust Area 4: Computational Representations

A computational representation arises from the perspective of thinking about an object of study as analogous to a computer—a working unit that transforms data through algorithmic steps. As a research thrust, computational representations cover a range of psychological topics including cognition in which mental states are constantly updated through computational thought and hearing in which acoustic information goes through a series of conversions until it is in form that may be processed. These conversions are only possible if the listener can perceive the stimuli.

Computational Cognition

The analogy of the mind to a computer has been the foundation of cognitive psychology since the 1980s and has led to a sophisticated array of research studies to understand the perceptual-active cycle or how a person string perceptions, cognition, and action together to complete tasks. Computational representation is also the inspiration for a host of cognitive models of the mind, which are implemented in computer simulations. Models are typically verified against empirical data to figure out if the models can perform in the same way as humans. Cognitive models and experiments further our understanding of the human mind and for Army research lend important insights to how to increase mission performance through system design or task performance strategies.

Auditory Hazard Assessment Algorithm for Humans (AHAAH)

Modern weapons and a broad spectrum of industrial machinery produce intense acoustic impulses which may limit their use. Recent studies indicate that all current noise exposure standards and design guidelines for impulse generating weapons are seriously in error. To overcome these limitations, ARL HRED developed a computational model of the human auditory system that predicts the hazard from any free-field impulse exposure and provides a visual display of the damage process as it is occurring. The model is a powerful design tool that shows the specific parts of the waveform that need to be addressed in machinery and weapon design. This unique model is the only method of assessing noise hazard for the entire range of impulses that are relevant to the Army. The model has the potential to serve as an international design standard for weapons and to provide damage or risk criteria for intense impulses of industrial origin.

5.4.1 Research Area 4.1: Cognition

- Research: 6.1%–100%
- Funding: Internal - 90%; External - 10%
- Research Projects: 3
- Special Designators: NA
- Collaborations: The Pennsylvania State University, Wright State University

- Keywords: Cognitive, Mental Processes, Mental Representation, Workload

Aim: The goal of this research area is to understand how mental processes operate and how increases or decreases in human performance arise from mental states. With the increase in the complexity of Army technology, Soldiers are under increasing strain on their mental resources. The research area is meant to understand mental processes so that human factors engineers may use the research to development Army equipment more suited to the Soldier's mental states or to devise strategies to increase performance.

Methods: Typically, research in cognition begins with identifying research avenues of potential importance to Soldiers. Human subject experiments are designed around testable hypotheses and research protocols are subjected to Internal Review Board (IRB) approval., Data are analyzed through commonplace inferential statistical procedures and results are interpreted. Computer simulations of the experimental tasks are often constructed to represent the experimental results.

Progress: Investigations in cognition have led to numerous publications (see below), cognitive computer models, and soon recommendations for updating the modeling system IMPRINT (Improved Performance Research Integration Tool) with a new performance prediction tool.

Current Goals: Run six more experiments at Penn State in cognitive workload to finish collecting data on a workload effort that will provide guidance for new workload-performance prediction algorithms to IMPRINT. Complete an ongoing experiment with brain monitoring techniques to test the relationship between electric potentials from the brain with cognitive processes. The results will inform a new ACT-R (Adaptive Control of Thought – Rational) cognitive model. Publish a technical note that is currently under internal review to make recommendations to change the S4 (System-of-Systems Survivability Simulation) military mission modeling system.

5.4.1.1 Recent Publications:

Cassenti, D. N. The Intrinsic Link Between Motor Behavior and Temporal Cognition. *New Ideas in Psychology*, in press.

Cassenti, D. N.; Kerick, S. E.; McDowell, K. Observing and Modeling Cognitive Events Through Event Related Potentials and ACT-R. *Cognitive Systems Research*, in press.

Cassenti, D.; Kerick, S.; May, K.; Patton, D. *Changes in ERP Signal From Decision Difficulty*; ARL-20098-09017; Research Protocol, 2009.

Cassenti, D. N. ACT-R Model of EEG latency. In *Proceedings of the Human Factors and Ergonomics Society 51st Annual Meeting*, Human Factors and Ergonomics Society: Santa Monica, CA, 2007, pp 812–816.

Cassenti, D. N.; Kelley, T. D. Towards the Shape of Mental Workload. In *Proceedings of the Human Factors and Ergonomics Society 50th Annual Meeting*, Human Factors and Ergonomics Society: Santa Monica, CA, 2006, pp 1147–1152.

Cassenti, D. N.; Kelley, T. D.; Ghirardelli, T. G. Awareness Yet Underestimation of Distractors in Feature Searches. In R. Sun (Ed.) In *Proceedings of the 28th Annual Conference of the Cognitive Science Society*, Cognitive Science Society: Austin, TX, 2006, pp 1086–1091.

5.4.2 Research Area 4.2: Hearing Protection

- Research: 6.1%–100%
- Funding: Internal - 100%
- Research Projects: 1
- Special Designators: NA
- Collaborations: Medical Research and Materiel Command (MRMC); US Army Public Health Command (Provisional); Auditory Hazard Analysis; National Institute for Occupational Safety and Health (NIOSH); U.S. Air Force Research Laboratory (AFRL); The French-German Research Institute of Saint-Louis (ISL); U.S. Army Aeromedical Research Laboratory (USAARL)
- Keywords: Impulsive Noise, Hearing Protection, Mathematical Model, AHAAH

Aim: To extend the Auditory Hazard Assessment Algorithm for Humans (AHAAH), which uses a generic effect for HPD use, to a rigorous individualized HPD treatment using modeled earmuffs and earplugs. Currently, measurements under hearing protectors worn on human ears or on acoustic manikins are needed for AHAAH to determine their benefit for a particular stimulus (impulsive noise event). Since insertion loss of hearing protectors varies considerably for user self-fit due to leakage and size differences, this method is not suitable for estimating risk distributions for Soldiers. Fortunately, because of the large database of individual hearing protector performance data from Real Ear Attenuation at Threshold (REAT) tests a separate treatment of the hearing protector is allowed.

Methods: Present models describe energy flow along three pathways into the hearing protector: rigid piston-like motion, seal leakage, and material transmission. These mechanical elements are adjusted to fit an individual's REAT values. When inserted into the AHAAH model, they provide a response that can be compared with weapon results (field data) to check the validity and to find the hazard reduction supplied by the hearing protector. Such fits to existing datasets give cumulative distributions of hazard based on fit variations.

Progress: The hearing protection model has been reviewed for publication as an ARL technical report and was presented at the Joint Acoustical society of America/INCE NoiseCon2010 meeting in April 2010.

Current Goals: Include this hearing protection module into the AHAAH for consideration as a revised MIL-STD-1474D, "Noise Limits" standard. In the future models of non-linear hearing protectors, such as the Combat Arms Earplug, will be added.

5.4.2.1 Recent Publications:

AHAAH on website: www.arl.army.mil/ARL-Directorates/HRED/AHAAH/.

Price, G. R. Critical Analysis of: Murphy, Kahn and Shaw, (2009). An Analysis of the Blast Overpressure Study Data Comparing Three Exposure Criteria; EPHB 309-05h; U. S. Department Health Human Service NIOSH: Cincinnati, OH, 45226-1998, pp. 61, In preparation – ARL Report, 2010.

Price, G. R. Susceptibility to Intense Impulse Noise: Evidence From the Albuquerque datAset. Paper presented at the *159th Acoustical Society of America (ASA/NOISE-CON) Meeting*, Baltimore, MD, April 2010.

Binseel, M.; Kalb, J.; Price, G. R. *Using the Auditory Hazard Analysis Algorithm for Humans (AHAAH) Software, Beta Release W93e*; ARL-TR-498; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2009.

Price, G. R. Development and Validation of the AHAAH Model for Assessment of Hazard to Hearing From Intense Sounds. Invited presentation to US/Israeli meeting at HEAT Center, Aberdeen, MD, 2009.

Price, G. R. Physiological Basis for Time-Domain Direct-Reading Noise Hazard Assessment. Invited paper presented at NIOSH 2008 DREAM Workshop, Crystal City, Washington, DC. NIOSH Publication No. 2009-133:2008 Direct-Reading Exposure Assessment Methods (D.R.E.A.M.) Workshop – at website: http://www.cdc.gov/niosh/docs/2009-133/, 2008.

Price, G. R. Auditory Hazard Assessment – We Can Do Better! Or Moving From Frequency-Domain to Time-Domain Hazard Assessment Based on Physiological Constructs. Plenary address to NOISECON08, Dearborn, MI, 2008.

Price, G. R. MIL-STD-1474E and Onward. Invited presentation to Air Force Research Laboratory Sponsored Symposium: *Effects of High Intensity Continuous and Impulse/Blast Noise on Humans*, Moab, UT, 2008.

Price, G. R. The AHAAH Model: Why Bother? Invited presentation to Air Force Research Laboratory Sponsored Symposium: *Effects of High Intensity Continuous and Impulse/Blast Noise on Humans*, Moab, UT, 2008.

Price, G. R. *Hearing Loss and the Noise of Airbag Exposure: Analysis of the Case of Mrs. Elizabeth L. Etheridge*; AHA Tech Report TR170108A; Proprietary for McKenry, Dancigers, Dawson and Lake, 2008.

Price, G. R. Validation of the Auditory Hazard Assessment Algorithm for the Human With Impulse Noise Data. *Journal of the Acoustical Society of America 122* **2007**, 2786–2802.

Price, G. R. Intense Impulse Noise: Hearing Conservation's Poison Gas. Keynote address to the National Hearing Conservation Association (NHCA), Savannah, GA, February 2007.

Price, G. R. Insights Into Hazard From Airbag Noise Gained Through the AHAAH Model; Paper 2005-01-2397; SAE 2005 Transactions Journal of Passenger Cars: Mechanical Systems, Book V114-6, ISBN 0-7680-1692-4, Febuary 2006.

Price, G. R. Predicting Mechanical Damage to the Organ of Corti. *Hearing Research,* Doi: http://dx.doi.org/10.1016/j.heares.2006.08.005 *Pharmacological Strategies for Prevention and Treatment of Hearing Loss and Tinnitus*, Hearing Research, *226*, Issues 1–2, April 2007, pp 5–13.

Price, G. R. Predicting Intracochlear Mechanical Stress With the AHAAH Model. Presentation at the *International Symposium: Pharmacologic Strategies for Prevention and Treatment of Hearing Loss and Tinnitus*, Niagara Falls, Canada, October 2005.

Price, G. R. Current Status of Rating Hazard from Intense Sounds and The Need for an Update to MIL-STD-1474(D), Auditory Hazard Analysis White Paper AHAWP 300805; www.arl.army.mil/ARL-Directorates/HRED/AHAAH/ 2005.

Price, G. R. Critical Analysis and Comment on Patterson and Ahroon (2004) Evaluation of an Auditory Hazard Model Using Data From Human Volunteer Studies USAARL Report No. 2005-01, AHAnalysis TR 190805; www.arl.army.mil/ARL-Directorates/HRED /AHAAH/ 2005.

Price, G. R. Evaluation of Positions Critical to the AHAAH Model. Presentation at IPR at USACHPPM, July 2005.

Price, G. R. The AHAAH Model – the Science and the Issues. Presentation at IPR at USACHPPM, July 2005.

Price, G. R. A New Method for Rating Hazard From Intense Sounds: Implications for Hearing Protection, Speech Intelligibility and Situation Awareness. Keynote 2 in NATO RTO-MP-HFM-123 symposium, New Directions for Improving Audio Effectiveness, ISBN 92-837-1147-5, 2005.

Price, G. R. New Possibilities for Hearing Conservation: Implications of the AHAAH Model. Presentation at the *2005 Military Audiology Short Course*, Andrews AFB, Washington, DC, April 2005.

Price, G. R. Incorporating AHAAH into MIL-STD 1474. Presentation at HRED, December 2004.

Price, G. R. Problems With AHAAH? Presentation at HRED, December 2004.

Price, G. R. Current Status of Rating Hazard from Intense Sounds and the Need for an Update to MIL-STD-1474(D). White Paper written for ARL, 2004.

Price, G. R. Hazard Analysis of Acoustic Output of HIDA. AHAnalysis Letter Report 150904, pp 10, 2004.

Price, G. R. Auditory Hazard From Underground Explosions; AHAnalysis Tech Report 120804; pp 60, 2004.

Price, G. R. Development of AHAAH and Its Application to Risk From Shoulder-Fired Rockets. Presentation to *General Dynamics ATP Program Review*, May 2004.

Price, G. R. *The AHAAH Model and Its Application to Airbag Waveforms*; AH Analysis Tech Report 280104; pp 121, 2004.

Price, G. R. Using AHAAH to Calculate Risk From Intense Sounds. Invited talk presented to *Acoustic, Optical, and Multi-Sensory Device Workshop*, San Antonio, TX, January 2004.

Price, G. R. Predicting Human Performance as a Function of Changes in Hearing. Invited talk presented to *Acoustic, Optical, and Multi-Sensory Device Workshop*, San Antonio, TX, January 2004.

Price, G. R. Using the AHAAH Model to Predict Hazard From Rocket Impulses in Enclosed Spaces. Invited presentation to *SAAB-Bofors Dynamics*, Degefors, Sweden, 2003.

Price, G. R. Weapon Noise Exposure of the Human Ear Analyzed With the AHAAH Model. http://www.arl.army.mil/ARL-Directorates/HRED/AHAAH 2003.

Price, G. R. Impulse Noise and the cat cochlea, http://www.arl.army.mil/ARL-Directorates /HRED/AHAAH 2003.

Price, G. R. Auditory Hazard Assessment Algorithm for the Human Ear. Chapter 2 in *Reconsideration of the Effects of Impulse Noise, RTO*; Technical Report TR-017/HFM-022; ISBN 92-837-1105-X; pp 4, 2003.

Price, G. R. Auditory Hazard Units an Index of Risk From Intense Sounds. Presented at NIOSH/NHCA Impulsive Noise: A NORA Hearing Loss Team Best Practice Workshop, Cincinnati, OH (invited presentation); also http://www.arl.army.mil/ARL-Directorates /HRED/AHAAH 2003.

Price, G. R. The Uniqueness of the Albuquerque Dataset and Evaluation of Impulse Noise Criteria Using Human Volunteer Data by Chan, et al., *Journal of the Acoustical Society of America* **2003**, *110*, 1967–1975; also http://www.arl.army.mil/ARL-Directorates/HRED /AHAAH.

Price, G. R. Response to Chan's: Issues Concerning the AHAAH Model Validation against Army BOP Data. Presentation at meeting of *Impulse Noise Task Force*, SAE Inflatable Restraints Standards Committee: Troy, MI, 2003.

Price, G. R. An Examination of and Response to Auditory Standard Issues by Dr. James Stuhmiller. http://www.arl.army.mil/ARL-Directorates/HRED/AHAAH 2003.

Price, G. R. Validation of the AHAAH Model: Old and New Data. Presentation to the *Sae Working Group on Impulse Noise*, Inflatable Restraints Committee: Troy, MI, 2002.

Price, G. R. Analysis of Airbag Noise With the AHAAH Model of the Ear: Scientific Basis. Presentation to UN-ECE GRSP (Working Party on Passive Safety), Geneva, Switzerland, May 2001.

Price, G. R. New Perspectives on Protecting Hearing from Intense Impulse Noise. Paper presented at *International Military Noise Conference*, Baltimore, MD, April 2001.

Kalb, J. T.; Price, G. R. Firing Weapons from Enclosures: Predicting the Hearing Hazard. Paper presented at *International Military Noise Conference*, Baltimore, MD, April 2001.

Price, G. R.; Kalb, J. T. Development and Validation of an Auditory Hazard Assessment Algorithm for the Human Ear as a Predictor of Hearing Hazard and as an Engineering Tool. In: Report from NATO Research Study Group RSG.29 (Panel 8 – AC/243) Reconsideration of effects of impulse noise, TNO-Report TM-00-I008, pp 6–10 (second meeting), 2000.

Price, G. R.; Kalb, J. T. Progress in the Development and Validation of the Human Hazard Model. In: Report from NATO Research Study Group RSG.29 (Panel 8 – AC/243) Reconsideration of effects of impulse noise, TNO-Report TM-00-I008, p 25 (first meeting). 2000.

Price, G. R. Impulse Noise Hazard: From Basic Research to Application. Invited presentation to *Psychology Department Seminar*, University of Delaware: Newark, DE, September 2000.

Price, G. R. ARL Auditory Model Applied to MACS. Invited presentation to *Macs Project Manager*, Picatinny Arsenal: Dover, NJ, August 2000.

Price, G. R. Auditory Hazard From Airbags – a Clinical Concern. Invited paper presented at the *3rd Annual Force Health Protection Conference*, Baltimore, MD, 2000.

5.5 Thrust Area 5: Physical Performance

Military equipment places physical demands on Soldiers. Whether the equipment is carried by the Soldier, (such as ballistic armor, helmets, ammunition, communication devices, etc.), occupied by the Soldier (such as a vehicle), or the Soldier simply interactions with the equipment, the equipment's physical parameters (size, shape, weight) will affect overall Soldier-System performance. This thrust area focuses primarily on equipment carried by Soldiers, all of which add weight and volume to the Soldier. The effects of adding weight, the effects of the distribution of the weight, and the size of the equipment that needs to be carried or used will affect the Soldier's physical performance. When providing a dismounted Soldier (a Soldier that is not riding in a vehicle) a new technology that is designed to increase performance (for instance, night vision goggles), that new technology comes at a cost to the Soldier (the need to carry added weight in a backpack during the day, and extra weight and an offset Center of Mass of the Helmet at night). Merely investigating the benefits of the new equipment (better target identification in low light conditions) without understanding the detrimental effects of it (more time required to traverse terrain, greater potential for neck strain) and their secondary effects (more headaches, decreased performance due to neck soreness) only provides part of the information necessary to fully understanding the impact of new equipment. The goal of this research thrust is to understand the underlying factors that affect Soldier physical performance, and to provide equipment designers with information to optimize Soldier-System physical performance. Tools used for this research thrust include biomechanics, electromyography, metabolic cost measurements, and other physical performance metrics. This research thrust combines highly controlled laboratory studies with less controlled, but more operationally relevant field studies.

5.5.1 Research Area 5.1: Load Carriage

- Research: 6.2%–100%
- Funding: Internal - 100%
- Research Projects: Anterior load carriage mechanics and energetics
- Special Designators: NA
- Collaborations: NA
- Keywords: Load Distribution, Energy Expenditure, Mobility Performance

Aim: The primary aim of this research area is to develop a better understanding of how various aspects of load carriage impact Soldier mobility performance. This work will provide information that can be used in the design of future Soldier equipment and development of more effective mission plans. Individual investigations will seek to assess the general effects of load distribution on gait kinematics, kinetics and energetic; determine the relationships between changes in dynamics and metabolic cost; quantify the impact of load carriage on the performance of operationally relevant tasks; and develop a model for predicting Soldier mobility performance as a function of the load being carried and its distribution.

Methods: A series of studies incorporating motion capture, gait analysis, cardiopulmonary and electromyographic measurement techniques will be used to quantify the effects of total load carried and the way in which it is distributed on gait kinematics and kinetics, muscle activity, and energy expenditure. Field studies will also be conducted to quantify the time required to complete operationally relevant mobility tasks under various load distributions. The results of these studies will be incorporated into an existing prediction equation for the metabolic cost of load carriage, and subsequently developed into a model of Soldier mobility performance under various load carriage conditions.

Progress: A protocol to investigate the effects of anterior load carriage on gait mechanics and energetics is being developed.

Current Goals: Our present goal is to determine the effects of load distribution on gait dynamics and energetics, and incorporate the impact of those effects into a prediction equation for metabolic cost.

5.5.1.1 Recent Publications:

Boynton, A. C.; Rice, V. J.; DeVilbiss, C. A.; Faughn, J. A. *An Evaluation of the Issue and Wearing of the Personnel Armor System for Ground Troops (PASGT) and Advanced Combat Helmets (ACH)*; ARL-TR-4225; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2007.

Boynton, A. C.; Faughn, J. A. *Quantification of Correct Wear of Properly Fitted Advanced Combat Helmets (ACH) and Personnel Armor System for Ground Troops (PASGT) Helmets*; ARL-TR-4020; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2007.

LaFiandra, M.; Harman, E.; Cornelius, N.; Frykman, P.; Gutenkunst, D.; Nelson, G. *The Effects of the Personal Armor System for Ground Troops (PASGT) and the Advanced Combat Helmet (ACH) With and Without PVS-14 Night Vision Goggles (NVG) on Neck Biomechanics During Dismounted Soldier Movements*; USARIEM Technical Report T07-09; 2007.

Ortega, S.V.; Garrett, L.; Burcham, P. M. *Mobility, Portability, and Human Factors Investigation of an Improved 81-mm Lightweight Mortar System Prototype: Phase II*; ARL-TR-4111; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2006.

Boynton, A. C.; Crowell, H. P. *A Human Factors Evaluation of Exoskeleton Boot Interface Sole Thickness*; ARL-TR-3812; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2006.

Garrett, L.; Harper, W. H.; Ortega, S. V.; White, T. L. *Joint Service General Purpose Mask (JSGPM) Human Systems Integration (HIS) Evaluation: Comfort and Vision Correction Insert Stability Evaluation*; ARL-TR-3900; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2006.

Garrett, L.; Jarboe, N.; Patton, D. J.; Mullins, L. L. *The Effects of Encapsulation on Dismounted Warrior Performance*; ARL-TR-3789; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2006.

5.5.2 Research Area 5.2: Fatigue Exertion

- Research: 6.2%–100%
- Funding: Internal - 100%
- Research Projects: Omni-directional treadmill validation
- Special Designators: NA
- Collaborations: NA
- Keywords: Biomechanics, Energy Expenditure

Aim: The primary aim of this research is to determine the extent to which the biomechanical and physiological effects of overground walking are replicated by the Omni-directional treadmill (ODT) during navigation through a virtual environment, and develop an understanding of the mechanisms behind any observed differences.

Methods: An initial investigation used motion capture, gait analysis and cardiopulmonary measurement techniques to quantify the mechanics and metabolic cost associated with walking overground and on the ODT. A subsequent data collection additionally included EMG measurements and manipulation of cadence to further identify potential sources for the observed difference in physiological demand associated with the ODT.

Progress: A comparison of gait mechanics and oxygen consumption during walking overground and on the ODT has been completed and a draft manuscript is currently in revision for publication as an ARL Technical Report. The results of this study have also been submitted for presentation at the 2010 Meeting of the American Society of Biomechanics. As a follow-on to the initial effort, pilot data have been collected and are currently being analyzed to assess differences in muscle activity and the effects of cadence manipulation. The combined results will be submitted for publication in a peer-reviewed journal.,

Current Goals: Our primary goal is to quantify the biomechanical and physiological differences between walking through a virtual environment on the ODT and performing the same task in the real-world, and identify potential sources for any observed differences so that they can be mitigated and/or accounted for in future studies and training scenarios.

5.5.2.1 Recent Publications:

Boynton, A. C.; Kehring, K. L.; White, T. L. Biomechanical and Physiological Validation of the Omni-direction Treadmill Upgrade as a Mobility Platform for Virtual Environments; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, draft.

LaFiandra, M. The Working Back: A Systems View [Review of the book The working back: a Systems View]. *Ergonomics in Design* **2009**, *17* (3), 30.

LaFiandra, M. Methods, Models & Technology for Lifting Biomechanics. In *Handbook For Digital Human Modeling*: *Research for Applied Ergonomics and Human Factors Engineering*; Duffy, V., Ed.; ISBN 97808058564602008.

5.5.3 Research Area 5.3: Locomotion and Manipulation

- Research: 6.2%–100%
- Funding: Internal - 100%;
- Research Projects: 1 current (Boynton Dissertation)
- Special Designators: NA
- Collaborations: NA
- Keywords: Biomechanics, Motor Control, Load Carriage, Metabolic Cost, Energy Expenditure

Aim: Biological systems have evolved and developed in a way to locomote and manipulate objects and tools in highly efficient ways. Our aim is to establish an understanding of human locomotion and manipulation of objects that can be applied to autonomous systems. This collaboration with the Vehicle Technology Directorate as part of ARL's Robotics Enterprise is a new research area for HRED. The result of this research will be design guidelines that will allow autonomous systems to move and manipulate objects in their environment more efficiently. The aim is to have autonomous systems that can be integrated into teams with Soldiers, adapt to their environment similarly as Soldiers do, and have the autonomous systems be used to perform particularly dangerous tasks.

Methods: The tools and techniques of biomechanics and motor control will be used to gain an understanding of human locomotion and manipulation. Kinematic, kinetic, physiological and electromyographic (EMG) will be collected and used to determine the underlying principles that affect human motion.

Progress: A new building to house our 2800 square foot biomechanics laboratory is currently being constructed as part of the Soldier Performance and Equipment Advanced Research (SPEAR) Facility. We are currently formulating ideas for a research protocol that will focus on examining how humans adjust to landing on surfaces of different stiffnesses when the stiffness of the surface is unknown; it is our belief that this will provide insight needed by the designers of autonomous systems to design systems that can better adapt to their environment.

Current Goals: This is a new research area for HRED, our goal is to grow this area in a way that allows a greater understanding of how humans adapt to their environment and to allow this understanding to be applied to the design of autonomous systems.

5.5.3.1 Recent Publications:

Crowell, H. P.; Milner, C. E.; Hamill, J.; Davis, I. S. Reducing Impact Loading During Running With the Use of Real-Time Visual Feedback. *Journal of Orthopaedic & Sports Physical Therapy* **2010**, *40* (4), 206–213.

Cruz-Neira, C.; Springer, J. P.; Reiners, D. Let Them Move: Incorporating Physical Walking into a Virtual Environment. In *Proceedings of The Engineering of Virtual Reality*, SPIE.: San Jose, CA, January 2010.

Pohl, M. B.; Crowell, H. P.; Davis, I. S. What Strategies Do Runners Utilize to Reduce Tibial Acceleration Following A Gait Retraining Protocol? *Medicine & Science in Sports and Exercise* **2008**, *40*, S19.

Jarboe, N.; Faughn, J. A. *A Human Factors Assessment of Female Soldier's Ability to Pull Hand Grenade Fuze Safety pins and to Throw Inert M67 Hang Grenades*; ARL-TR-4311; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2007.

Wilson, R.; Faughn, J. A.; Harper, W. Evaluation of Crew's Ability to Ingress and Egress Selected U.S. Army Wheeled and Tracked Vehicles While Carrying a Personal Defense Weapon. *Customer report, prepared for PM Individual Weapons*, 2007.

Crowell, H. P.; Davis, I. S. Between Day Reliability of Accelerometry. *Medicine & Science in Sports and Exercise* **2006**, *38* (5), supplement: S256.

Crowell, H. P.; Faughn, J. A.; Tran, P. K.; Wiley, P. W. *Improvements in the Omni-Directional Treadmill: Summary Report and Recommendations for Future Development*; ARL-TR-3958; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2006.

Crowell, H. P.; Davis, I. S. Reducing Lower Extremity Loads Through Gait Retraining Using Real-Time Feedback Methods. In *Proceedings of the 30th Annual Meeting of the American Society of Biomechanics*, Virginia Tech: Wake Forest, 2006.

5.5.4 Research Area 5.4: Weapons

- Research: 6.2%–100%
- Funding: Internal - 100%
- Research Projects: 4
- Special Designators: ATO
- Collaborations: NSRDEC
- Keywords: Small Arms, Shooting Performance

Aim: The aim of this line of research is to optimize shooting performance and to aid in the development of future weapon and Soldier systems. This research area will focus on aspects of weapon and individual Soldier equipment design that may have an impact on the ability of Soldiers to quickly and accurately fire small arms weapons.

Methods: This research is conducted both on a live-fire range and using a shooting simulator. The live-fire range has an acoustic target scoring system that can determine the location of a hit on the target and even missed distance location around the target. The range also uses a shot detector to accurately determine the target engagement time. The shooting simulator allows us to collect the weapon aim point throughout the engagement process and provides a wide variety of target scenarios in a tightly controlled environment. This research line has examined the effect of weapon weight and center of mass on shooting performance.

Progress: A study planned for July 2010, will examine the effects of eye position on shooting performance with follow-on work to examine the effects of prototype helmet/facial protection systems on shooting performance and possible remedies to reduce any performance degradation. Other research efforts will examine the effects of using a vertical grip on shooting performance, determining the effects of firing a commonly zeroed weapon compared to a weapon that they personally zeroed and research focused on multi-target and moving target acquisition and tracking where shooting performance within scenarios of increasing complexity will be examined.

5.5.4.1 Recent Publications:

Harper, W. H.; Ortega, S. V.; Wiley, P. W. Shooting Performance Characterization of 5.56 mm Subcompact Weapons; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, in review.

Statkus, M. J.; Salvi, L.; Peloquin, A. *Dismounted Warrior Performance Data: Moving Targets in Close Combat Data Collection Effort*; NATICK/TR-09/016L; U.S. Army Natick Soldier Research, Development and Engineering Center, 2009.

Harper, W.; Wiley, P. Determining Thumb Control Location for Vertical Foregrips of Assault Rifles. *Proceedings of the 14th Annual International Conference on Industrial Engineering*, Anaheim, CA, 2009.

Faughn, J. A. U.S. Patent 7,415,929, 2008.

Garrett, A. W.; Zaky, A.; Salvi, L. *Documentation of the Close Combat Reflexive Firing Experiment in Support of the Soldier Focused Area Collaborative Team, Critical Research Area*; AMSAA TR-2008-34; Army Materiel Systems Analysis Agency, 2008.

Harper, W.; LaFiandra, M.; Wiley, P. The Effect of Weapon Mass and Center of Mass on Shooting Performance With an Assault Rifle. In *Proceedings of the 13th Annual International Conference on Industrial Engineering*, Las Vegas, NV, 2008.

LaFiandra, M.; Harper, W.; Wiley, P. The Effect of Weapon Mass and Center of Mass on Aiming Movement. In *Proceedings of the 13th Annual International Conference on Industrial Engineering,* Las Vegas, NV, 2008.

LaFiandra, M. E. *A Tool for Calculating the Center of Mass and Moment of Inertia of Small Arms Weapons*; ARL-TR-4517; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2008.

Ortega, S. V.; Garrett, L.; Burcham, P. *Soldier Performance With the M240 Lightweight Machine Gun - Phase II*; ARL-TR-4561; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2008.

Ortega, S. V.; Garrett, L.; Burcham, P. M. *Mobility, Portability, and Human Factors Investigation of an Improved 81-mm Lightweight Mortar System Prototype: Phase II*; ARL-TR-4111; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2007.

Ortega, S. V.; Garrett, L.; Harper, W. H. *Soldier Performance With the M240E6 Lightweight Machine Gun*; ARL-TR-4144; U.S Army Research Laboratory: Aberdeen Proving Ground, MD, 2007.

Ortega, S. V.; Harper, W. H.; Panozzo, P. R. *Training and Qualification Assessment of Soldiers with the MK19 Grenade Machine Gun While the Soldiers Were Using a Standard and Mixed Belt of 40-mm Ammunition*; ARL-TR-4076; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2007.

Wilson, R.; Faughn, J.; Harper, B. Evaluation of Crew's Ability to Ingress and Egress Selected U.S. Army Wheeled and Tracked Vehicles While Carrying a Personal Defense Weapon; customer report prepared for PM Individual Weapons, 2007.

Woods, R. J.; Statkus, M. J.; Salvi, L. *Human Science/Modeling and Analysis Data Project: Urban Canyon Street Flight and Blufor in Defense Data Collection Effort*; Natick/TR-00/009L; U.S. Army Natick Soldier Research, Development and Engineering Center, 2006.

5.6 Thrust Area 6: Medical Human Factors

The application of Medical Human Factors supports both the Army Research Laboratory mission objects, as well as those of the Amy Medical Department. The objective is to identify and apply information on human capabilities and limitations to the design of processes, procedures, products, and places to support the Warrior. Support includes developing and maintaining the skills of and programs for the health care practitioner, as well as focusing on the Warrior across the wellness spectrum including building resilience, sustainment, injury prevention, and ensuring quality treatment, rehabilitation, and return-to-duty. The tools and techniques associated with multidisciplinary network science are employed, with a channeling of effort from evaluating at a macroeronomic level and moving incrementally to a more specific microergonomic perspective. The key thrust area is human performance in terms of medically-related academics, resilience, and technology operation (usability: ease-of-use, feasibility, and effectiveness - both medical and non-medical). Current projects include three studies on reduction of Academic Attrition, one study on assisting with identification of mild/moderate Traumatic Brain Injury (TBI), and one study on resilience, with each having a technology evaluation component.

5.6.1 Research Area 6.1: Education/Training Attrition

- Research: 6.2%–100%
- Funding: Internal - 50%, Customer - 50%
- Research Projects: 4
- Special Designators: NA
- Collaborations: Army Medical Department Center and School, Medical Research and Materiel Command, University of Texas-Austin
- Keywords: Human Factors, Learning, Attrition, Effectiveness, Outcomes

Aim: To identify and create efficient, effective and safe methodologies, products, and environments to inform Healthcare Education/Training and reduce attrition, thus multiplying and protecting the force.

Methods: Applied research, MANPRINT, IMPRINT.

Progress: Goals are set with the Dean of the Army Medical Department Center and School (AMEDDC&S) for attrition-related research line-of-research annually. Implications of research are discussed and shared via customer reports, technical reports, open literature publications, and presentations. Personnel at the AMEDDC&S integrate findings into their curriculum, as suitable. Six protocols for this research area are active.

Current Goals: Continue research focus to decrease attrition and graduate competent health care technicians and professionals, complete current studies, continue to offer human factors research assistance to the AMEDD, Human Dimension (TRADOC), and other commands to ensure Warrior success.

5.6.1.1 Recent Publications:

<u>Refereed Journal Articles:</u>

DeVilbiss, C.; Rice, V. J.; Laws, L.; Alfred, P. If You Want to Know Why Students Fail, Just Ask Them: Self and Peer Assessments of Factors Affecting Academic Performance. *The United States Army Medical Department Journal,* in press.

Rice, V. J.; Vu, T.; Butler, J.; Marra, D.; Merullo, D.; Banderet, L. Fear of Failure Among Students Attending Military Health Care Specialist Training. *Work: A Journal of Prevention, Assessment, and Rehabilitation* **2009**, *34* (4).

Rice, V. J.; Mays, M. Z.; Gable, C. Self-Reported Health Status of Students in-Processing Into Military Medical Advanced Individual Training. *Work: A Journal of Prevention, Assessment, and Rehabilitation* **2009**, *34* (4).

Rice, V. J.; Connolly, V. L.; Pritchard, A.; Bergeron, A.; Mays, M. Z. Effectiveness of a Screening Tool to Detect Injuries Among Army Combat Medic Soldiers. *Work: A Journal of Prevention, Assessment, and Rehabilitation* **2008**, *29* (3), 177–188.

<u>Refereed Conference Presentations/Proceedings</u>

Alfred, P.; Boykin, G.; Caldwell, L.; Rice, V.; Miller, N.; Matsangas, P.; Lieberman, H.; Wesensten, N. Discussion Panel: Sleep Across Military Environments. In *Proceedings of the 2010 Human Factors and Ergonomics Society Annual Meeting*, San Francisco, CA.

Rice, V. J.; Butler, J.; Marra, D. Self-Reported Sleep and Soldier Performance. In *Proceedings of the Applied Human Factors and Ergonomics Conference*, Miami, FL, in press.

Alfred, P.; Rice, V.; Boykin, G.; Laws, L. Auditory Discrimination and Academic Performance. In *Proceedings of the Applied Human Factors and Ergonomics Conference*, Miami, FL, in press.

Boykin, G.; Rice, V. J.; Alfred, P. Past Videogame Experience and Neurocognitive Timing Performance. In *Proceedings of the Applied Human Factors and Ergonomics Conference*, Miami, FL, in press.

Rice, V. J. You've Seen Macroergo and Neuroergo, Now There is "EduErgo": *Collaborating to Use Ergonomics in Education Investigation, Evaluation and Design*, Human Factors and Ergonomics Society Annual Meeting: San Antonio, TX, 2009.

Alfred, P.; Miller, N.; Rice, V. J.; DeVilbiss, C.; Bazley, C.; Jacobs, K.; Vause, N. Discussion Panel: Human Factors Applications in Academic Settings. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, San Antonio, TX, 2009.

Alfred, P.; Rice, V. J. Cognitive Characteristics of Academically 'At Risk' Students Attending Operating Room Specialist Training. *Presented at the Human Systems Integration Symposium*, 2008.

Rice, V. J.; Butler, J. Revisiting an Old Question with a New Technology: Gender Differences on a Neuro-Cognitive Temporal Tracking Task. *Human Factors and Ergonomics Society Annual Meeting*, Baltimore, MD, pp 581–586, 2007.

Banderet, L. E.; Merullo, D. J.; Rice, V. J.; Butler, J.; Marra, D. Personal Thoughts and Success/Failure in a Military, Medical Training Program. *International Military Testing Association Annual Meeting*, Kingston, Canada, October 2006.

Rice, V.J., Butler, J. and Marra, D. (2006). Predicting performance: Self-Esteem among soldiers attending health care specialist training. In *Proceedings of the Human Factors& Ergonomics Society 50th Annual Meeting*. Santa Monica, CA: Human Factors Society.

Sharp, M. A., Pietila, D., and Rice, V. J. (2006). Manual materials handling in multiple person teams. In Karwowski (Ed.) *International Encyclopedia of Ergonomics and Human Factors 2nd Ed*, Taylor & Francis, London.

<u>Technical Reports</u>

DeVilbiss, C.; Rice, V. J. B. *Survey Results for the Development of the Academic Class Composite Tool for the Academic Instructors and Supervisors*; ARL-MR-0677; U.S. Army Research Laboratory: Field Element, Ft. Sam Houston, TX, 78234-6125, 2007.

Rice, V. J. B.; Butler, J.; Marra, D. *Neuro-Cognitive Assessment, Symptoms of Attention Deficit and Hyperactivity Disorder, and Soldier Performance during 68W Advanced Individual Training*; ARL-TR-4292; U.S. Army Research Laboratory: Field Element, Ft. Sam Houston, TX, 78234-6125, 2007.

DeVilbiss, C.; Rice, V. J. B.; Laws, L. Personal Factors Related to Student Performance and Retention Among 68W Healthcare Specialists: Self and Peer Assessments of Factors Affecting Academic Performance; U.S. Army Research Laboratory: Field Element, Ft. Sam Houston, TX, 78234-6125, in press.

<u>Books</u>

Marek, T., Karwowski, W., Rice, V., Eds. Advances in Neuroergonomics and Human Factors of Special Populations.

<u>Book Chapters</u>

Sharp, M. A.; Pietila, D.; Rice, V. J. Manual Materials Handling in Multiple-Person Teams. *International Encyclopedia of Ergonomics and Human Factors*, 2nd ed.; Karwowski, Ed., Taylor and Francis, Ltd: Boca Raton, FL; Chapter 160; pp 786–789; 2006.

5.6.2 Research Area 6.2: Intervention

- Research: 6.2%–100%
- Funding: Internal - 40%, Customer - 60%
- Research Projects: 2
- Special Designators: NA
- Collaborations: MRMC, UT-Austin, ICT
- Keywords: Human Factors, mTBI, Resiliency, Technology

Aim: To assist with evaluating products, programs, and processes for their utility in assisting health care practitioners and others in improving Warrior health, wellness, and resiliency.

Methods: Applied research, MANPRINT, IMPRINT.

Progress: This is a relatively new Research Area with one project nearing completion (Emerging Technologies for Use in Screening for Traumatic Brain Injury [TBI]), one project recently turned over to the TBI Clinic at Brooks Army Medical Center (Describing Clinical Characteristics), and a third project in initial phases of protocol development (Building Soldier Resiliency Through a 'Second Life'). Four protocols are active.

Current Goals: Complete data entry, analysis and written reports for the Traumatic Brain Injury study. Draft research proposal for Second Life study. Continue to offer human factors research assistance to the AMEDD, Human Dimension (TRADOC), and other commands to ensure Warrior success.

5.6.2.1 Recent Publications:

<u>Refereed Journal Articles</u>

Cooper, D. B.; Mercado-Couch, J. M.; Critchfield, M. S.; Kennedy, J.; DeVilbiss, C. A.; Bowles, A. O.; Cullen, M.; Gaylord, K. M. Factors Predicting Cognitive Dysfunction Following Explosion Injuries in OIF/OEF Service Members: Traumatic Severity, Mild Traumatic Brain Injury (mTBI), Medication Effects, and Psychiatric Co-Morbidity. *Neurorehabilitation*, in press.

Bowles, A. O.; Cooper, D. B.; DeVillbis, C.; Rice, V. Clinical Characteristics of OIF/OEF Service Members With Mild and Moderate Traumatic Brain Injuries. *Journal of Neurotrauma* **2009**, *26* (8), A-24.

<u>Refereed Conference Presentations/Proceedings</u>

Boykin, G.; Rice, V. J.; Alfred, P.; Laws, L. Past Videogame Experience and Neurocognitive Timing Performance. In *Proceedings of the Applied Human Factors and Ergonomics Conference*, Miami, FL, in press.

Cooper, D. B.; Mercado-Couch, J. M.; Critchfield, M. S.; Kennedy, J.; DeVilbiss, C. A.; Bowles, A. O.; Cullen, M.; Gaylord, K. M. Factors Predicting Cognitive Dysfunction Following Explosion Injuries in OIF/OEF Service Members: Traumatic Severity, Mild Traumatic Brain Injury (mTBI), Medication Effects, and Psychiatric Co-Morbidity. *11th Annual George E. Omer, Jr. Research and Alumni Lectureship*, 2009.

Bowles, A. O.; Cooper, D. B.; DeVillbis, C.; Rice, V. Clinical Characteristics of OIF/OEF Service Members With Mild and Moderate Traumatic Brain Injury. Poster presentation at *the National Neurotrauma Society Symposium*, September 2009.

Rice, V. J. Ergonomics and Rehabilitation: Similarities, Differences, and the Interface. Presented in a *Panel Discussion at the Human Factors and Ergonomics Society Annual Meeting*, NY, 2008.

Technical Reports

Boynton, A. C.; Rice, V. J.; DeVilbiss, C. A.; Faughn, J. A. *An Evaluation of the Issue and Wearing of the Personnel Armor System for Ground Troops (PASGT) and Advanced Combat Helmet (ACH)*; ARL-TR-4225; U.S. Army Research Laboratory, Human Research and Engineering Directorate: Aberdeen Proving Ground, MD, 2007.

Rice, V. J.; Lindsay, G.; Overby, C.; Jeter, A.; Boykin, G. L.; DeVilbiss, C.; Alfred, P. E.; Bateman, R. Brain Acoustic Monitor: Human Factors Feedback; U.S. Army Research Laboratory, Human Research and Engineering Directorate: Aberdeen Proving Ground, MD, in press.

Other Publications

Alfred, P. E. Applied Human Systems Integration: Developing a Methodology for the DOTMLPF Assessment of the Army's Land Warrior System. Unpublished Master's Thesis. Naval Postgraduate School, Monterey, CA, 2007.

Savage-Knepshield, P.; Rice, V. J.; Butler, J.; DeVilbiss, C. Saving Soldiers: Combat Challenges in Iraq Spur Medical Innovations. *Human Factors and Ergonomics Society Bulletin* **2006**, *49* (8), 1–3.

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Appendix A. Abstracts of U.S. Army Research Laboratory (ARL) Protocols and Published Works

This appendix appears in its original form without editorial change.

Human Robot Interaction

Thrust Area 1: Soldier-Robot Teaming

Research Protocols:

Safe Operation of Autonomous Robot Teams: Impact of Autonomy, Teaming, and Workload on Operator Trust and Performance (PIs: Florian Jentsch, Thomas Fincannon, Bill Evans)

This experiment will examine the safe performance of robotic assets and their operators, performing in a supervisory role while a team of UVs conducts persistent surveillance operations, i.e., while the team completes preplanned mission routes intended to provide both accurate reconnaissance information and to distract enemy forces. To perform this task, UVs will operate in one of three modes, (a) Independent Autonomous Operation, (b) Team Collaborative Autonomous Operation, or (c) Independent Manual Operation. In addition to these three operating conditions, UVs will conduct their mission tasks in environments designed to vary operator workload based on the number of potential targets. Key issues to be investigated include supervisory as opposed to direct control of multiple UVs. An additional parameter will encompass robot-to-robot supervision as opposed to supervision of multiple semi-autonomous UVs. Safety issues to be examined will include pedestrians in unsafe locations as well as deliberate or natural obstacles.

Journal Articles and Book Chapters:

Chen, J. Y. C. (under review). Effects of operators' spatial ability on their performance of target detection and robotics tasks. Chapter in P. Knepshield-Savage (Ed.), *Designing Soldier Systems: Current Issues in Human Factors* (series of Human Factors in Defence). Ashgate.

This chapter summarizes five human-in-the-loop simulation experiments that investigated the effects of operators' spatial ability (SpA) on their performance of target detection and robotics tasks. In the first experiment, the operator's task was to conduct route reconnaissance missions using one or three heterogeneous robots to detect enemy targets along a designated route. In the second, third, and fourth experiments, the operators performed three tasks concurrently (i.e., gunnery targeting, robotics, and communication tasks) and the types of robotics tasks were manipulated (i.e., monitoring the streaming video from an autonomous unmanned ground vehicle [UGV], managing a semi-autonomous UGV, and teleoperating a UGV). In the third experiment, an aided-target-recognition (AiTR) capability (delivered via visual and/or tactile cueing) was implemented to assist the operators with their primary (gunnery) task. In the fourth experiment, the reliability levels of the AiTR system were manipulated (i.e., false-alarm prone vs. miss prone). Finally, in the fifth experiment, a military reconnaissance environment was simulated to examine the performance of UGV operators who were instructed to utilize streaming video from an unmanned aerial vehicle (UAV) to navigate his/her ground robot to the locations of the targets. Details of the experiments can be found in Chen et al., (2008), Chen & Joyner (2009), Chen & Terrence (2008), Chen & Terrence (2009), and Chen & Clark (2008).

Chen, J. Y. C., Durlach, P. J., Sloan, J. A., & Bowens, L. D. (2008). Human robot interaction in the context of simulated route reconnaissance missions. *Military Psychology, 20*(3), 135-149.

The goal of this research was to examine the ways in which human operators interact with simulated semiautonomous unmanned ground vehicles (UGVs), semiautonomous unmanned aerial vehicles (UAVs), and teleoperated UGVs (Teleop). Robotic operators performed parallel route reconnaissance missions with each platform alone and with all three platforms. When given all three platforms, participants failed to detect more targets than when given only the UAV or UGV; they were also less likely to complete their mission in the allotted time. Target detection during missions was the poorest with the Teleop alone, likely because of the demands of remote driving. Spatial ability was found to be a good predictor of target-detection performance. However, slowing sensor feed video frame rate or the imposition of a short response latency (250 ms) between Teleop control and Teleop reaction failed to affect target- detection performance significantly. Nevertheless, these video image manipulations did influence assessment of system usability.

Chen, J. Y. C. & Terrence, P. I. (2009). Effects of imperfect automation on concurrent performance of military and robotics tasks in a simulated multi-tasking environment. *Ergonomics, 52*(8), 907-920.

This study investigated the performance and workload of the combined position of gunner and robotics operator in a simulated military multitasking environment. Specifically, the study investigated how aided target recognition (AiTR) capabilities for the gunnery task with imperfect reliability (false-alarm-prone vs. miss-prone) might affect the concurrent robotics and communication tasks. Additionally, the study examined whether performance was affected by individual differences in spatial ability and attentional control. Results showed that when the robotics task was simply monitoring the video, participants had the best performance in their gunnery and communication tasks and the lowest perceived workload, compared with the other robotics tasking conditions. There was a strong interaction between the type of AiTR unreliability and participants’ perceived attentional control. Overall, for participants with higher perceived attentional control, false-alarm-prone alerts were more detrimental; for low attentional control participants, conversely, miss-prone automation was more harmful. Low spatial ability participants preferred visual cueing and high spatial ability participants favoured tactile cueing. Potential applications of the findings include personnel selection for robotics operation, robotics user interface designs and training development. The present results will provide further understanding of the interplays among automation reliability, multitasking performance and individual differences in military tasking environments. These results will also facilitate the implementation of robots in military settings and will provide useful data to military system designs.

Technical Reports:

Chen, J. Y. C., & Clark, B. R. (2008). UAV-UGV Teaming: UAV-Guided Navigation (ARL Tech Rep. ARL-TR-4462). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

We simulated a military reconnaissance environment and examined the performance of ground robotics operators who needed to use sensor images from an unmanned aerial vehicle (UAV) to navigate their ground robot to the locations of the targets. We aFlso evaluated participants' spatial ability and examined if it affected their performance or perceived workload. Results showed that participants' overall performance (speed and accuracy) was better when they had access to images from larger UAVs with fixed orientations, compared to other UAV conditions (baseline- no UAV, micro-air vehicle, and UAV with orbiting views). Participants experienced the highest workload when the UAV was orbiting.

Proceedings Papers:

Alban, J., **Cosenzo, K**., Johnson, T., Hutchins, S., Metcalfe, J. &Capstick, E. (2009). Robotics Collaboration Army Technology Objective Capstone Soldier Experiment: Unmanned System Mobility. *Proceedings of the AUVSI Conference*, Washington, DC, CD-ROM.

The RC ATO (2004-2008), a joint program between the U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC) and the Army Research Laboratory (ARL), has the mission of developing the appropriate tools, techniques and autonomy to maximize mounted and dismounted control of ground unmanned systems and optimize Soldier-robot and robot-robot teams. This was accomplished through the development and testing of assisted autonomy and situational awareness solutions, optimizing Soldier-machine interface usability across varying display sizes, control devices and dissimilar robotic systems and the deployment of unique multi-modal control techniques. The ATO concluded its Capstone Experiment and demonstration in September 2008. This paper will detail the technology developed and utilized under the program as well as highlight Capstone Experiment results.

Barnes, M.J., **Cosenzo, K**., Jentsch, F., **Chen, J**. & McDermott, P. (2006) Understanding Human robot teaming using virtual media. In Proceeding of the *NATO Conference on the Use of Virtual Media for Military Application* . West Point, NY, Jun 2006

The Human Research and Engineering Directorate (HRED), U.S. Army Research Laboratory (ARL) 5-year Army Technology Objective (ATO) research program is addressing human robot interaction (HRI) and teaming for both aerial and ground robotic assets in conjunction with the U.S. Army Tank and Automotive Research and Development Engineering Center (TARDEC).

The ATO has recently been enlarged to encompass intelligent collaboration among unmanned aerial systems (UAS) and renamed the Collaborative Robotics ATO. The purpose of the program is to understand HRI issues in order to develop and evaluate technologies to improve HRI battlefield performance for Future Combat Systems (FCS) and the Future Force Warrior (FFW). Soldier robot teams will be an important component of future battlespaces: creating a complex but potentially more survivable and effective combat force. The complexity of the battlefield of the future presents its own problems. The variety of robotic systems and the almost infinite number of possible Army missions create a dilemma for researchers who wish to predict HRI performance in future environments. Most of the FCS proposed systems are still in the conceptual stage and the nature of the environments that they are being designed for can only be approximated.

Barnes, M., Jentsch, F., **Chen, Y**., **Haas, E**., & **Cosenzo, K**. (2008). Five Things You Should Know About Soldier –Robot Teaming. *Proceedings of the 26th Army Science Conference*, Orlando, FL, CD-ROM.

The Human Research and Engineering Directorate(HRED), U.S. Army Research Laboratory (ARL) and partner Tank and Automotive Research Development Command (TARDEC) embarked on a 5-year Army Technology Objective (ATO) research program that addressed human robot interaction (HRI) and teaming for both unmanned aerial vehicles (UAV) and unmanned ground vehicles (UGV). The program's objective was to understand HRI issues in order to develop technologies and mitigations that enhance HRI performance in future combat environments. In order to put the five year program in manageable perspective, we summarized five important HRI principles and supporting results that emerged from the research effort. The principles cover the benefits of teaming relations for robotic missions as well as crew multitasking problems associated with future robotic missions and possible solutions. We alsodiscussed the importance of individual differences for HRI design and training implications and the advantages of multimodal interfaces and adaptive automation.

Chen, J.Y.C. (2009). Effects of individual differences on operators' interaction with imperfect automation in a simulated multitasking environment. *Proceedings of NATO HFM-181/RSY Symposium*. Sofia, Bulgaria, 5-7 Oct. 2009.

We simulated a military tank environment and examined the performance of the combined position of gunner and robotics operator and how aided target recognition (AiTR) capabilities with imperfect reliability (i.e., miss-prone or false-alarm-prone) for the gunnery task might affect the concurrent robotics and communication tasks. Specifically, we investigated whether performance was affected by individual differences in attentional control and spatial ability. Results showed that when the robotics task was simply monitoring the video, participants had the best performance in their gunnery and communication tasks and the lowest perceived workload, compared with the other robotics tasking conditions. There was a strong interaction between the type of AiTR unreliability and participants' perceived attentional control. Overall, for participants with higher perceived attentional control, false-alarm-prone alerts were more detrimental; for low attentional control participants, conversely, miss-prone automation was more harmful. Consistent with previous findings, low spatial ability participants preferred visual cueing, and high spatial ability participants favored tactile cueing.

Chen, J. Y. C., & Joyner, C. (2006). Individual Differences in Concurrent Performance of Gunner's and Robotic Operator's Tasks. In Proceedings of *the Human Factors and Ergonomics Society 50th Annual Conference, San Francisco*, CA, October 16-20, 2006.

In this study, we simulated a military mounted environment and conducted an experiment to examine the workload and performance of the combined position of gunner and robotic operator and how individual difference factors such as perceived attentional control and spatial ability were related to the task performance. Results showed that gunner's target detection performance degraded significantly when he or she had to concurrently monitor, manage, or teleoperate an unmanned ground vehicle compared to the gunnery-single task condition. Those with higher spatial ability performed significantly better than those with lower spatial ability. Participants with higher perceived attentional control performed better on a concurrent communication task in the more challenging robotic task conditions. Participants' perceived attentional control was negatively correlated with the severity of their simulator sickness but not with their perceived workload.

Chen, J. Y. C., & Terrence, P. I. (2008). Individual differences in performance of robotics tasks in military multi-tasking environments. *Proceedings of Human Factors and Ergonomics Society 52nd Annual Meeting* (pp. 1407-1411), NYC, Sep. 2008.

We simulated a military tank environment and examined the performance of the combined position of gunner and robotics operator and how aided target recognition (AiTR) capabilities (delivered either through tactile or tactile + visual cueing) for the gunnery task might benefit the concurrent robotics and communication tasks. Specifically, we investigated whether performance was affected by individual differences factors such as spatial ability and perceived attentional control. Results showed that participants' robotics and communication tasks both improved significantly when the AiTR was available to assist them with their gunnery task. The participants' spatial ability was found to be a good indicator of their gunnery and robotics task performance. However, when AiTR was available to assist their gunnery task, those participants of lower spatial ability were able to perform their robotics tasks as well as those of higher spatial ability. There was also evidence that operators' preference of cueing modality was related to their spatial ability and attentional control.

Thrust Area 2: Supervisory Control

Research Protocols:

Effects of Imperfect Automation on Operator's Supervisory Control of Multiple Robots (PIs: **Jessie Chen**, **Mike Barnes**, and **Caitlin Kenny**).

We developed an intelligent agent RoboLeader, a robotic surrogate that could help the human operator coordinate a team of ground robots by suggesting route changes for the robots based on developments in the environment (Chen, Barnes, & Qu, 2010). In the current study, we are going to manipulate the reliability (i.e., false alarm and miss rates) of the RoboLeader's recommendations and examine its effect on the operator's performance (i.e., robotics and concurrent tasks including a gauge monitoring task and an auditory communication task) and workload. The effects of individual differences factors such as operator spatial ability and attentional control will also be investigated.

The Impact of Adaptive Automation on Unmanned Vehicle Operators’ Performance in a Multi-tasking Environment (PIs: **Keryl Cosenzo**, **Jessie Chen**, **Mike Barnes**, Lauren Reinerman, Denise Nicholson)

A challenge that arises is the multitasking requirements that robots impose on the Soldier; operators may be given multiple tasks to manage, such as navigating an unmanned ground vehicle (UGV) while firing at targets and communicating with a team via radio or a computer-based chat program. Although some level of automation will likely be required to support human-robot performance, when automation aides should be invoked may vary based on individual differences of the robot operator as well as changes in the task load imposed upon them throughout a mission. In the current study, we will examine the impact of automation on a robot operator’s performance, workload, and situation awareness in a simulated military multi-tasking environment. Automation will be applied to the method of robot navigation (i.e., teleoperation or semi-autonomous navigation) during simulated military reconnaissance operations. Each participant will receive the following four automation conditions: 1) No automation; 2) Task-based adaptive automation (Manual → Auto); 3) Task-based adaptive automation (Auto → Manual); and 4) Static automation.

Research Area 2.1 - Supervisory Control of Multiple Robots and Robotic Swarms

Journal Articles and Book Chapters:

Chen, J. Y. C. (2010). Robotics control in multi-tasking environment. In M. J. Barnes & F. Jentsch (Eds), *Human-Robot Interactions in Future Military Operations.* Ashgate.

A series of four experiments was conducted in a simulated military mounted crewstation environment to examine the workload and performance of the robotics operator in either a single-tasking or a multi-tasking environment. In the multi-tasking environment, the operator also had to concurrently perform gunnery and communication tasks. In both tasking environments, the robotics tasks involved managing a semi-autonomous ground robot or teleoperating a ground robot to conduct reconnaissance tasks. Results showed that, in the single-tasking environment, operator’s performance was significantly worse when the robot had to be teleoperated than when it was semi-autonomous. In the multi-tasking environment, in contrary, operator’s robotics task was significantly worse when the robot was semi-autonomous, implying the operator's increasing reliance on automation when under heavy workload of multiple tasks. The operator's robotics task performance improved when the concurrent gunnery task was automated. However, when the automation was not reliable (i.e., miss-prone or false alarm-prone), the operator's robotics task performance degraded, and the severity of the degradation was affected by both the type of automation unreliability and the operator's attentional control. More specifically, for high attentional control operators, false alarm-prone alerts were more detrimental than miss-prone alerts. For low attentional control operators, conversely, miss-prone automation was more harmful than false alarm-prone automation. Finally, our data indicated that the operators' preference of cueing display was related to their spatial ability. Low spatial ability operators preferred visual cueing over tactile cueing, and high spatial ability operators favored tactile cueing over visual cueing.

Chen, J. Y. C., **Barnes, M.** J., Harper-Sciarini, M. (under review). Supervisory control of multiple robots: Human performance issues and user interface design. *IEEE Transactions on Systems, Man, and Cybernetics--Part C: Applications and Reviews.*

The purpose of this paper is to review research pertaining to the limitations and advantages of supervisory control for unmanned systems. We identify and discuss results showing technologies that mitigate the observed problems such as specialized interfaces, and adaptive systems. In the report, we first present an overview of definitions and important terms of supervisory control and human-agent teaming. We then discuss human performance issues in supervisory control of multiple robots with regard to operator multitasking performance, trust in automation, situation awareness, and operator workload. In the following sections, we review research findings for specific areas of supervisory control of multiple ground robots, aerial robots, and heterogeneous robots (using different types of robots in the same mission). In the last section, we review innovative techniques and technologies designed to enhance operator performance and reduce potential performance degradations identified in the literature.

Technical Reports:

Chen, J. Y. C., **Barnes, M. J**., & Qu, Z. (Feb 2010). *RoboLeader: A Surrogate for Enhancing the Human Control of a Team of Robots* (ARL Memorandum Report ARL-MR-0735). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

We developed an intelligent agent, RoboLeader, that could assist human operators in controlling a team of robots. More specifically, RoboLeader could help the operators with their route planning tasks. Although there were no significance differences between the RoboLeader and Baseline conditions for target detection, the Roboleader group reduced their mission completion times by approximately 13% compared to Baseline. We compared the operators' target detection performance in the 4-robot and 8-robot conditions. The results showed that the participants detected significantly less targets when there were 8 robots compared to the 4-robot condition. Those participants with higher spatial ability detected more targets than did those with lower spatial ability. Participants experienced significantly higher workload when there were 8 robots compared to the 4-robot condition, and those with better attentional control reported lower workload than did those with poorer attentional control. Females also reported significantly higher workload than did males.

Haas, E.C., Fields, M.A., **Stachowiak, C.C**., **Hill, S**., and **Pillalamarri, K**. (2010). Designing interfaces and algorithms for soldier-robotic swarm interaction (multimodal controls). (ARL Tech Report ARL-TR-####), U.S. Army Technical Report, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD.

In theory, autonomous robotic swarm can be used for critical Army tasks (i.e., accompanying convoys); however, the Soldier controlling the swarm must be able to monitor swarm status and correct actions, especially in disrupted or degraded conditions. For the concluding year of this two-tear Director's Research Initiative (DRI), we designed multimodal (speech and touch) Soldier-swarm control concepts to allow Soldiers to efficiently control a robotic swarm participating in a representative convoy mission. We used a potential field approach for swarm control because it scales easily to large heterogeneous swarms and allows users to dynamically alter swarm behavior by adjusting field parameters. We tested the effectiveness of the swarm controls in a laboratory study using 12 male Marines (volunteers) with a mean age of 19 years. The metacognition results showed that the swarm (which consisted of members fulfilling sentry and explorer functions) could maintain adequate coverage most of the time. Interface results showed that 66% of participants used speech commands first, while the remaining used touch commands first. The onset of a first command was significantly (approximately one second) greater, if the first command was presented as touch, rather than as speech. Results can be applied to future swarm, and command and control systems

Haas, E., Fields, M., **Hill, S**., & **Stachowiak, C**. (2009). Extreme Scalability: Designing Interfaces and Algorithms for Soldier-Robotic Swarm Interaction (ARL Tech Report ARL-TR-4800). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

In theory, autonomous robotic swarms can be used for critical Army tasks (i.e., accompanying convoys); however, the Soldier controlling the swarm must be able to monitor swarm status and correct actions, especially in disrupted or degraded conditions. For this two-year Director's Research Initiative (DRI), we designed metacognition algorithms and Soldier-swarm display concepts to allow Soldiers to efficiently interact with a robotic swarm participating in a representative convoy mission. We used a potential field approach for swarm control because it scales easily to large heterogeneous swarms and allows users to dynamically alter swarm behavior by adjusting field parameters. The Soldier-swarm interface displayed swarm and convoy geospatial position; swarm health and communication; and convoy status information, using visual, auditory, and tactile combinations. We measured swarm metacognition by determining the proportion of time the simulated swarm could maintain a specific orbital ring around the convoy over six terrains in 13-min scenarios. We tested interface effectiveness in a laboratory study using 16 male Marines (volunteers) with a mean age of 19 years. The metacognition results showed that the swarm could maintain the pre-defined dispersion more than 85% of the time in each terrain. Using multimodal displays, Soldier workload decreased and performance increased (i.e., response time reduced).

Proceedings Papers:

Chen, J. Y. C., **Barnes, M. J**. (2010). Supervisory control of robots using RoboLeader. *Proceedings of Human Factors and Ergonomics Society 54th Annual Meeting,* San Francisco, Sep. 27- Oct. 1, 2010.

We investigated the effectiveness of RoboLeader, an intelligent agent that could help the human operator control a team of robots, for enhancing the overall human-robot teaming performance. We compared the operators' target detection performance in the 4-robot and 8-robot conditions. The results showed that the participants detected significantly fewer targets with 8 robots vs. 4 robots. Although there were no significance differences between the RoboLeader and Baseline (no RoboLeader) conditions for target detection, the Roboleader group reduced their mission completion times by approximately 13% compared to Baseline. Those participants with higher spatial ability detected more targets than did those with lower spatial ability. Participants experienced significantly higher workload with 8 robots compared to the 4-robot condition, and those with better attentional control reported lower workload than did those with poorer attentional control.

Chen, J. Y. C. & **Barnes, M. J.** (2008). Robotic Operator Performance in a Military Multi-Tasking Environment. In Proceeding of *3rd ACM/IEEE International Conference on Human-Robot Interaction,* 11-15 March 2008, Amsterdam, the Netherlands.

We simulated a military mounted environment and examined the performance of the combined position of gunner and robotics operator and how aided target recognition (AiTR) capabilities (delivered either through tactile or tactile + visual cueing) for the gunnery task might benefit the concurrent robotics and communication tasks. Results showed that participants' teleoperation task improved significantly when the AiTR was available to assist them with their gunnery task. However, the same improvement was not found for semi-autonomous robotics task performance. Additionally, when teleoperating, those participants with higher spatial ability outperformed those with lower spatial ability. However, performance gap between those with higher and lower spatial ability appeared to be narrower when the AiTR was available to assist the gunnery task. Participants' communication task performance also improved significantly when the gunnery task was aided by AiTR. Finally, participant's perceived workload was significantly higher when they teleoperated a robotic asset and when their gunnery task was unassisted.

Fields, MA, **Haas, E., Hill, S., Stachowiak, C.** and Barnes, L. (2009). Effective robot team control methodologies for battlefield applications. *Proceedings of the 2009 IEEE/RSJ International Conference on Intelligent Robots and Systems* (IROS 2009), pp. 5842-5867.

In this paper, we present algorithms and display concepts that allow Soldiers to efficiently interact with a robotic swarm that is participating in a representative convoy mission. A critical aspect of swarm control, especially in disrupted or degraded conditions, is Soldier-swarm interaction-the Soldier must be kept cognizant of swarm operations through an interface that allows him or her to monitor status and/or institute corrective actions. We provide a control method for the swarm that adapts easily to changing battlefield conditions, metrics and supervisory algorithms that enable swarm members to economically monitor changes in swarm status as they execute the mission, and display concepts that can efficiently and effectively communicate swarm status to Soldiers in challenging battlefield environments.

Haas, E.C. , **Stachowiak, C**., White, T., **Pillalamarri, K**., and **Feng, T**. (2009). Tactile and Auditory Cues to Communicate Multiple Levels of Information. Proceedings of the 2009 International Forum for Multisensory Information, New York, N.Y.

There has been a significant increase of empirical work on multisensory integration over the past years in applications such as navigation, guidance, and warnings. Many researchers (Sarter, 2006; Van Erp, 2002) explored the design of tactile cues to communicate one level of warning information (e.g., type or direction of event). However, little research has been conducted to explore the design of tactile cues to communicate multiple levels of information (type and direction of event), and how to integrate tactile cues with auditory signals in a multisensory display. This talk will describe two laboratory studies conducted to examine 1) the effectiveness of different tactor configurations and temporal signal parameters in communicating multiple dimensions of information (signal type and direction); and 2) the integration of tactile with auditory cues to provide redundant and non-redundant multisensory warning information. Response time and accuracy were measured. Data from the first experiment indicated that participants experienced confusion when those activations were in the same physical region due to different body/limb orientations. Implications of user body orientation while using tactile cues will be discussed. Results from the second experiment suggest that redundant presentation of auditory and tactile information is most efficient. The implications of this work for displays used in robotics, teleoperation and avionics applications will be described.

Hill, S.G. and Bodt, B. (2007). A field experiment of autonomous mobility: Operator workload for one and two robots. *Proceedings of the 2007 ACM/IEEE Conference on Human-Robot Interaction*, March 8-11, 2007, Arlington, VA. (pp. 169-176). **Best paper runner-up, HRI 2007**

An experiment was conducted on aspects of human-robot interaction in a field environment using the U.S. Army's Experimental Unmanned Vehicle (XUV). Goals of this experiment were to examine the use of scalable interfaces and to examine operator span of control when controlling one versus two autonomous unmanned ground vehicles. We collected workload ratings from two Soldiers after they had performed missions that included monitoring, downloading and reporting on simulated reconnaissance, surveillance, and target acquisition

(RSTA) images, and responding to unplanned operator intervention requests from the XUV. Several observations are made based on workload data, experimenter notes, and informal interviews with operators.

Research Area 2.2 - Mitigation Strategies for Managing Task Load

Journal Articles and Book Chapters:

Chen, J. Y. C., **Barnes, M. J**., Harper-Sciarini, M. (under review). Supervisory control of multiple robots: Human performance issues and user interface design. *IEEE Transactions on Systems, Man, and Cybernetics--Part C: Applications and Reviews.*

The purpose of this paper is to review research pertaining to the limitations and advantages of supervisory control for unmanned systems. We identify and discuss results showing technologies that mitigate the observed problems such as specialized interfaces, and adaptive systems. In the report, we first present an overview of definitions and important terms of supervisory control and human-agent teaming. We then discuss human performance issues in supervisory control of multiple robots with regard to operator multitasking performance, trust in automation, situation awareness, and operator workload. In the following sections, we review research findings for specific areas of supervisory control of multiple ground robots, aerial robots, and heterogeneous robots (using different types of robots in the same mission). In the last section, we review innovative techniques and technologies designed to enhance operator performance and reduce potential performance degradations identified in the literature.

Chen, J. Y. C., & Joyner, C. T. (2009). Concurrent performance of gunner's and robotic operator's tasks in a multi-tasking environment. *Military Psychology*, *21*(1), 98 - 113.

In this study, we simulated a generic mounted crew station environment and conducted an experiment to examine the workload and performance of the combined position of gunner and robotics operator. Results showed that participants' gunnery task performances degraded significantly when he had to concurrently monitor, manage, or teleoperate an unmanned ground vehicle compared to the gunnery single task condition. For the robotics tasks, participants had the lowest performance when using the semi-autonomous robot, indicating overreliance on the aided target recognition capabilities available when task load was heavy (i.e., concurrent performance of the gunnery task). Participants' perceived workload increased consistently as the concurrent task conditions became more challenging. Individual difference factors such as spatial ability and perceived attentional control were found to correlate significantly with some of the performance measures. Implications for military personnel selection were discussed.

Chen, J. Y. C. & Terrence, P. I. (2009). Effects of imperfect automation on concurrent performance of military and robotics tasks in a simulated multi-tasking environment. *Ergonomics, 52*(8), 907-920.

This study investigated the performance and workload of the combined position of gunner and robotics operator in a simulated military multitasking environment. Specifically, the study investigated how aided target recognition (AiTR) capabilities for the gunnery task with imperfect reliability (false-alarm-prone vs. miss-prone) might affect the concurrent robotics and communication tasks. Additionally, the study examined whether performance was affected by individual differences in spatial ability and attentional control. Results showed that when the robotics task was simply monitoring the video, participants had the best performance in their gunnery and communication tasks and the lowest perceived workload, compared with the other robotics tasking conditions. There was a strong interaction between the type of AiTR unreliability and participants' perceived attentional control. Overall, for participants with higher perceived attentional control, false-alarm-prone alerts were more detrimental; for low attentional control participants, conversely, miss-prone automation was more harmful. Low spatial ability participants preferred visual cueing and high spatial ability participants favored tactile cueing. Potential applications of the findings include personnel selection for robotics operation, robotics user interface designs and training development. The present results will provide further understanding of the interplays among automation reliability, multitasking performance and individual differences in military tasking environments. These results will also facilitate the implementation of robots in military settings and will provide useful data to military system designs.

Chen, J. Y. C. & Terrence, P. I. (2008). Effects of tactile cueing on concurrent performance of military and robotics tasks in a simulated multi-tasking environment. *Ergonomics, 51*(8), 1137-1152.

This study examined the concurrent performance of military gunnery, robotics control and communication tasks in a simulated environment. More specifically, the study investigated how aided target recognition (AiTR) capabilities (delivered either through tactile or tactile þ visual cueing) for the gunnery task might benefit overall performance. Results showed that AiTR benefited not only the gunnery task, but also the concurrent robotics and communication tasks. The participants' spatial ability was found to be a good indicator of their gunnery and robotics task performance. However, when AiTR was available to assist their gunnery task, those participants of lower spatial ability were able to perform their robotics tasks as well as those of higher spatial ability. Finally, participants' workload assessment was significantly higher when they teleoperated (i.e. remotely operated) a robot and when their gunnery task was unassisted. These results will further understanding of multitasking performance in military tasking environments. These results will also facilitate the implementation of robots in military settings and will provide useful data to military system designs.

Cosenzo, K. & Parasuraman, R. (2010). Automation Strategies for Facilitating Human Robot Interaction. In M. J. Barnes & F. Jentsch (Eds), *Human-Robot Interactions in Future Military Operations.*

This book chapter describes results of five experiments using the Robotic NCO Simulation and SIL Environments. Results revealed generally consistent evidence for the efficacy of adaptive automation in supporting human operator supervision of multiple UMS. Thus adaptive automation may be a useful mitigation strategy to help offset the potential deleterious effects of high cognitive load on Army robotic operators in a multi-tasking environment. The adaptive automation was successful not only in supporting the human operator in an appropriate context—when their change detection performance was low, pointing to low perceptual awareness of the evolving mission elements—but also freed up sufficient attentional resources to benefit performance on the sub-tasks.

Parasuraman, R., **Barnes, M**., & **Cosenzo, K**. (2007). Adaptive automation for human-robot teaming in future command and control systems. *International Journal of Command and Control,* 1(2), 43-68.

Advanced command and control (C2) systems such as the U. S. Army's Future Combat Systems (FCS) will increasingly use more flexible, reconfigurable components including numerous robotic (uninhabited) air and ground vehicles. Human operators will be involved in supervisory control of uninhabited vehicles (UVs) with the need for occasional manual intervention. This paper discusses the design of automation support in C2 systems with multiple UVs. Following a model of effective human-automation interaction design (Parasuraman et al., 2000), we propose that operators can best be supported by high-level automation of information acquisition and analysis functions. Automation of decision making functions, on the other hand, should be set at a moderate level, unless 100 percent reliability can be assured. The use of adaptive automation support technologies is also discussed. We present a framework for adaptive and adaptable processes as methods that can enhance human-system performance while avoiding some of the common pitfalls of "static" automation such as over-reliance, skill degradation, and reduced situation awareness. Adaptive automation invocation processes are based on critical mission events, operator modeling, and real-time operator performance and physiological assessment, or hybrid combinations of these methods. We describe the results of human-in-the-loop experiments involving human operator supervision of multiple UVs under multi-task conditions in simulations of reconnaissance missions. The results support the use of adaptive automation to enhance human-system performance in supervision of multiple UVs, balance operator workload, and enhance situation awareness. Implications for the design and fielding of adaptive automation architectures for C2 systems involving UVs are discussed.

Parasuraman, R, **Cosenzo, K**., & DeVisser, E. (2009). Adaptive Automation for Human Supervision of Multiple Unmanned Vehicles: Change Detection, Situation Awareness, & Workload. *Military Psychology,* 21, 270-297.

Human operators supervising multiple uninhabited air and ground vehicles (UAVs and UGVs) under high task load must be supported appropriately in context by automation. Two experiments examined the efficacy of such adaptive automation in a simulated high-workload reconnaissance mission involving four sub-tasks: (1) UAV target identification; (2) UGV route planning; (3) communications, with embedded verbal situation awareness probes; and (4) change detection. The results of the first "baseline" experiment established the sensitivity of a change detection procedure to transient and non-transient events in a complex, multi-window, dynamic display. Experiment 1 also set appropriate levels of low and high task load for use in Experiment 2, in which three automation conditions were compared: manual; static automation, in which an automated target recognition (ATR) system was provided for the UAV task; and adaptive automation, in which individual operator change detection performance was assessed in real time and used to invoke the ATR if and only if change detection accuracy was below a threshold. Change detection accuracy and situation awareness were higher and workload was lower for both automation conditions compared to manual performance. In addition these beneficial effects on change detection and workload were significantly greater for adaptive compared to static automation. The results point to the efficacy of adaptive automation for supporting the human operator tasked with supervision of multiple uninhabited vehicles under high workload conditions.

Technical Reports:

Barnes, M., Parasuraman, R & **Cosenzo, K**. (2006) Adaptive automation for military robotic systems (chap.7.4) in NATO Technical Report *RTO-TR-HFM-078 Uninhabited Military Vehicles: Human Factors Issues in Augmenting the Force*, (pp. 420-440).

Robotic systems with diverse roles, tasks and operating requirements are being designed to exploit future battle spaces. The role of the human operator is not well understood; however most of the contemplated systems will require either active human control or supervision with the possibility of intervention. In the most extreme case, soldiers will operate multiple systems while on the move and while under enemy fire. In all cases, the workload and stress will be variable and unpredictable- changing rapidly as a function of the military environment. The purpose of this chapter is to investigate technologies that unload the warfighter interacting with unmanned systems during multi-tasking missions. First, we will investigate automation technologies, specifically their positive and negative effects on human performance and situation awareness. Next, we will discuss adaptive and adaptable processes as methods that potentially overcome the disadvantages of preset automation. The last section will survey diverse physiological measures that can be used to trigger adaptive processes emphasizing the rapid development of these methods and their current limitations.

Chen, J. Y. C., & Joyner, C. (June 2006). Concurrent Performance of Gunner's and Robotic Operator's Tasks in a Simulated MCS Environment (ARL Tech. Rep. ARL-TR-3815). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

We simulated a Mounted Combat System (MCS) environment and conducted an experiment to examine the workload and performance of the combined position of gunner and robotic operator. Results showed that gunner's target detection performance degraded significantly when s/he had to concurrently monitor, manage, or teleoperate an unmanned ground vehicle compared to the baseline condition (gunnery task only). For the robotic tasks, participants detected significantly fewer targets when their robotic asset was semi-autonomous instead of teleoperated. The effects of individual difference factors such as spatial ability and perceived attentional control on the performance measures were also examined.

Chen, J. Y. C., & Terrence, P. I. (2008). Effects of Automation Reliability on Concurrent Performance of Gunnery and Robotics Tasks (ARL Tech Rep. ARL-TR-4455). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

In this study, we simulated a generic mounted environment and conducted an experiment to examine the performance and workload of the combined position of gunner and robotics operator. Aided target recognition (AiTR) (via tactile and visual cueing) with imperfect reliability (false alarm-prone versus miss-prone) was provided to the participants to aid their gunnery task. Besides the gunnery task, participants performed robotics and communication tasks concurrently. Results show that when the robotics task was simply monitoring the video feed, participants had the best performance in the other two concurrent tasks and the lowest perceived workload, compared with the other robotics tasking conditions. Our data also show that there is a strong interaction between the type of AiTR unreliability and participants' perceived attentional control. Overall, it appears that for high attentional control participants, false alarm-prone alerts were more detrimental than miss-prone alerts. For low attentional control participants, conversely, miss-prone automation was more harmful than false alarm-prone automation. Additionally, low spatial ability participants preferred visual cueing over tactile cueing, and high spatial ability participants favored tactile cueing over visual cueing.

Chen, J. Y. C. & Terrence, P. I. (August 2007). Effects of Tactile Alerts on Concurrent Performance of Gunner's and Robotics Operator's Tasks in a Simulated Mounted Environment (ARL Tech Rep. ARL-TR-4227). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

In this study, we simulated a generic mounted environment and conducted an experiment to examine the performance and workload of the combined position of gunner and robotics operator. More specifically, we compared the performance and workload of the operator when his/her gunnery tasks were assisted by the aided target recognition (ATR) capabilities (delivered through tactile cueing or a combination of tactile and visual cueing) versus when the gunnery task was unassisted. While performing gunnery tasks, participants also had to control a semi-autonomous unmanned ground vehicle (UGV) or tele-operate a UGV. Participants also performed a tertiary communication task concurrently. Results showed that participants' gunnery task performance improved significantly when it was assisted by ATR. The performance of those participants with higher spatial ability exceeded that of participants with lower spatial ability. It was also found that significantly fewer neutral targets (which were not cued) in the gunnery environment were detected (which implies less visual attention being devoted to the gunnery station) when participants concurrently tele-operated a robotic asset or when the gunnery task was assisted by ATR. Participants' robotics (tele-operation) task improved significantly when the ATR was available to assist them with their gunnery task. It was also found that the performance gap between those participants with higher and lower spatial ability appeared to be narrower when the ATR was available. A similar pattern was also observed for the perceived attentional control factor. Participants' communication task performance also improved significantly when the gunnery task was assisted by ATR. Finally, participants' perceived workload was significantly influenced by the type of robotics tasks and whether the gunnery task was assisted by ATR. Participants' perceived workload was significantly higher when they tele-operated a robotic asset and when their gunnery task was unassisted. In a post-experimental survey, 65% of the participants indicated that they relied predominantly on the tactile cues when tactile and visual displays were available; only 15% said they relied primarily on the visual cues. Those who preferred visual cuing tended to have lower spatial ability, and their gunnery and robotics task performance tended to be inferior.

Cosenzo, K.A., **Barnes, M**., & Parasuraman, R. P. (May, 2006). Implementation of Adaptive Automation for Control of Robotic Systems. (ARL-TR-3808). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

Future Force Warrior (FFW) and Future Combat Systems (FCS) represent an integrated materiel approach to transform the future U.S. Army into a more lethal, deployable, and survivable force. Technology alone will not ensure efficacy. Soldiers and specifically their performance in this environment will determine the success or failure of the fielded systems. In particular, robotic technology will be a vital component of future combat, by extending manned capabilities, acting as force multipliers, and most importantly, by saving lives. The role of the human operator in the human-robot environment is not well understood; however most contemplated systems will require either active human control or supervision with the possibility of intervention. In the most extreme case, Soldiers will operate multiple systems while on the move and under enemy fire. In all cases, workload and stress will be variable and unpredictable, changing rapidly as a function of the military environment. Automation technologies have been successfully applied to aid human operators in various environments, including aviation and military command and control. This paper addresses strategies to minimize the demands on Soldiers in the robotic environment through the use of adaptive and adaptable automation. Adaptable interfaces allow the Soldier to define conditions for automation decisions during mission planning while adaptive interfaces automate tasks as a function of some environmental or behavioral indicator (Parasuraman, Sheridan & Wickens, 2000). Although multiple robot control and the application of adaptive and adaptable automation have been investigated in some contexts, they have not been investigated as an aid to multiple robot control. We are examining the use of adaptive or adaptable automation to assist an operator who will control multiple robotic aerial and ground systems from a single interface in a vehicular environment. In this report we provide an overview of the current state of the research. We also discuss the joint research being conducted by the

Army Research Laboratory and George Mason University on adaptive and adaptable interfaces that unload the Soldier during overload or emergency situations for the robotic multitasking environment. The results of the 1st experiment are reported as a baseline assessment of task performance in a simulated robotic environment without automation. We discuss the implications of these results for designing adaptive systems and the future directions for this research.

Cosenzo, K. Parasuraman, R., & **Pillalamarri, K**. (2009). Appropriate & Inappropriately Applied Automation for the Control of Unmanned Systems on Operator Performance. (ARL-TR-4933). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

Robotic technology will be a vital component of future combat. However, the combination of robotic operational tasks with other traditional military tasks will create high workload peaks during military operations. The objective of this research is to develop and evaluate flexible automation strategies to aid the operator in this complex military environment. In this experiment we evaluated the effect of an automation that was invoked based on task load. Participants conducted a military reconnaissance mission using a simulation that required them to use an unmanned air vehicle sensor for target detection, monitor an unmanned ground vehicle, and respond to multilevel communications. Participants completed sixteen missions in the environment, during which task load and automation were manipulated. The results of this experiment showed that operator performance did improve when the automation, an aided target recognition system for the unmanned air vehicle, was invoked, relative to when it was not invoked. Further, when automation was appropriately applied (high task load conditions) workload decreased significantly. This data along with the results of other experiments discussed in this paper indicate that adaptive automation may be a useful mitigation strategy to help offset the potential deleterious effects of high cognitive load on Army robotic operators in a multitasking environment.

Mitchell, D. K. (2008). Predicted Impact of an Autonomous Navigation System (ANS) and Crew-Aided Behaviors (CABs) on Soldier Workload and Performance, ARL-TR-4342. Army Research Laboratory, Aberdeen Proving Ground, MD.

To predict the impacts of an autonomous navigation system (ANS) and crew-aided behaviors (CABs) on Soldier workload and performance, an analyst from the U.S. Army Research Laboratory (ARL) used the Improved Performance Research Integration Tool (IMPRINT) to model Soldiers with these technologies. The ARL IMPRINT analysis had three objectives: (a) to use IMPRINT to predict the impact of a mission planning and a automated route planning CAB and ANS on Soldier mental workload and performance; (b) to compare the IMPRINT predictions to the data from field experiments that evaluated the impacts of these same technologies on Soldier workload and performance; (c) to extend the experimental data and predict the impact of moving targets on Soldier performance with and without ANS and the CABs. This was because the field experiments used in the comparison had only stationary targets. For the first objective, IMPRINT predicted that one Soldier would not experience overload during mission planning with or without the mission-planning CAB. In addition, the IMPRINT analysis predicted that both the CAB and ANS would reduce workload and improve Soldier performance. Furthermore, IMPRINT predicted that both the CAB and ANS would reduce overall mission time and improve target detection performance. Therefore, both these technologies have the potential to increase Soldier survivability by reducing workload, reducing mission time, and increasing the number of targets detected. Despite the reduction in workload attributable to CAB and ANS, however, the IMPRINT analysis predicted that one Soldier who was trying to complete all the mission-related tasks would be overloaded, especially visually and cognitively, throughout the mission. Because of the predicted high workload, the ARL analyst recommends that additional experiments with CABs and ANS consider reallocation of monitoring tasks to a second crew member as a possible mitigation strategy for overload. Techniques other than visual displays for monitoring battlefield awareness and the status of the remote follower might help mitigate overload as well. For the second objective, a comparison of the IMPRINT data with the Soldier experimental data showed that IMPRINT correctly predicted the number of targets detected for the manual and ANS experimental conditions. It also correctly predicted the reduction in route planning time because of CAB availability. IMPRINT underestimated overall mission time, however. Therefore, the IMPRINT analyst recommends incorporation of vehicle speed and actual route distance into future IMPRINT analyses to ensure more accurate overall mission time. A comparison of the experimental workload data with the IMPRINT workload predictions matched across conditions. Both IMPRINT and the experiment showed the highest workload numbers when the Soldiers planned a route for the remote follower (RF) in the manual driving condition versus the ANS condition. The IMPRINT analyst could not compare the IMPRINT workload predictions to the Soldier's self-report ratings within each mission because the experimenters did not collect workload ratings during the experiment–only at the end. However, the performance decrements attributable to high workload predicted by IMPRINT were consistent with Soldier performance throughout the experiment. For example, the Soldiers had to stop the vehicle in order to complete the plan for the RF. To meet the third objective, the IMPRINT analyst built models representing moving targets and compared these data to the stationary target data from the experiment. The comparison showed no difference in the rate of detection for moving versus stationary targets for any of the conditions.

Perala, C. H., **Sterling, B. S.,** Scheiner, S., & Butler, D. (2007). Effects of crew-aiding behaviors on Soldier performance during target engagement tasks in a virtual battlefield simulation (ARL Tech. Rep. ARL-TR-4026). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

This research examined the impact of crew-aiding behaviors (CABs) on Soldier workload, stress, situation awareness, and performance in a laboratory setting. Specifically, this experiment examined the effectiveness of CABs designed to prioritize targets (based on threat level and proximity) and provide weapons platform and munitions recommendations to service each target.

This condition was compared with a NoCAB or manual condition in which participants performed the same task of prioritizing and engaging targets without the use of the CABs. Results showed that CABs significantly reduced time and workload when participants conducted the task of prioritizing and engaging targets. Participants took significantly less time to complete the prioritization and engagement task when using CABs versus when they performed the same task manually (i.e., the NoCAB condition). Overall task time was reduced by 36% when CABs were used. Overall workload, as well as the subscales of mental, temporal, and effort workload, were significantly reduced when CABs were used. Overall workload was 28% less when CABs were used versus when they were not. Mental and temporal workload were both 46% less when CABs were used versus when they were not, and effort workload was 36% less when were used versus when they were not.

Sterling, B. S., & Jacobson, C. A. (2006). A human factors analysis of aided target recognition technology (ARL Tech. Rep. ARL-TR-3959). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

We conducted a study to address three research objectives: (1) to determine how the use of a specific aided target recognition (AiTR) system affected scout workload, stress, and performance; (2) to examine Soldier-system interface issues; (3) to determine tactics, techniques, and procedures (TTPs) for using AiTR. We found that overall workload, stress, and performance with AiTR were acceptable, although subject matter expert ratings of scout performance may have been lenient because of the scouts lack of experience with AiTR. Workload and stress tended to be higher in an airport surveillance scenario, perhaps because of the complexity of the situation and the amount of territory to survey. Workload and stress are higher at night, perhaps because with differences in day and night thermal imagery, structures and terrain features are represented differently, depending on light conditions, so that cues normally used in daylight imagery may be altered or not available in night imagery. However, with more experience with thermal imagery at night, stress levels may decrease. Workload and stress tended to be higher when AiTR was used intermittently, perhaps because of constant switching between modes and the effects of reestablishing situational awareness, based on the features of each mode (i.e., refamiliarizing oneself with image chips). Concerning performance, target detection was rated slightly better when the AiTR was not used, which perhaps reflected use of the stare mode when an observation post (OP) was initially occupied. Several specific recommendations were made for improving the interface, such as adding grid lines to the map. A few TTPs for using AiTR were identified, including the use of the stationary target indicator mode when an OP was occupied; then we switched to moving target indicator mode. Another TTP was using AiTR to detect targets (perhaps except when an OP was initially occupied) and then stare (manual) mode to identify them.

Proceedings Papers:

Chen, J.Y. C. (2009). Concurrent performance of military tasks and robotics tasks: Effects of automation unreliability and individual differences. *Proceedings of the 3rd ACM/IEEE International Conference on Human-Robot Interaction.* 11-13 Mar 2009, La Jolla, CA.

This study investigated the performance and workload of the combined position of gunner and robotics operator in a simulated military multitasking environment. Specifically, we investigated how aided target recognition (AiTR) capabilities for the gunnery task with imperfect reliability (false-alarm-prone vs. miss-prone) might affect the concurrent robotics and communication tasks. Additionally, we examined whether performance was affected by individual differences in spatial ability and attentional control. Results showed that when the robotics task was simply monitoring the video, participants had the best performance in their gunnery and communication tasks and the lowest perceived workload, compared with the other robotics tasking conditions. There was a strong interaction between the type of AiTR unreliability and participants' perceived attentional control. Overall, for participants with higher perceived attentional control, false-alarm-prone alerts were more detrimental; for low attentional control participants, conversely, miss-prone automation was more harmful. Low spatial ability participants preferred visual cueing, and high spatial ability participants favored tactile cueing. Potential applications of the findings include personnel selection for robotics operation, robotics user interface designs, and training development.

Chen, J. Y. C. (2008). Effectiveness of concurrent performance of military and robotics tasks and effects of cueing in a simulated multi-tasking environment. *Proceedings of Human Factors and Ergonomics Society 52nd Annual Meeting* (HRI II Symposium) (pp. 237-241), NYC, Sep. 2008.

We simulated a military mounted crewstation environment and conducted two experiments to examine the workload and performance of the combined position of gunner and robotics operator. The robotics tasks involved managing a semi-autonomous ground robot or teleoperating a ground robot to conduct reconnaissance tasks. We also evaluated whether aided target recognition (AiTR) capabilities (delivered either through tactile or tactile + visual cueing) for the gunnery task might benefit the concurrent robotics and communication tasks. Results showed that participants' gunnery task performance degraded significantly when s/he had to concurrently monitor, manage, or teleoperate a robot compared to the gunnery-single task condition. When there was AiTR to assist them with their gunnery task, operators' concurrent performance of robotics and communication tasks improved significantly. However, there was a tendency for participants to over-rely on automation when taskload was heavy, and performance degradations were observed in instances where automation failed to be entirely reliable. Participants' spatial ability was found to be a reliable predictor of robotics task performance.

Participants' perceived workload increased consistently as the concurrent task conditions became more challenging and when their gunnery task was unassisted.

Chen, J. Y. C., Drexler, J. M., Sciarini, L. W., **Cosenzo, K. A**., **Barnes, M. J**., & Nicholson, D. (2008). Operator workload and heart-rate variability during a simulated reconnaissance mission with an unmanned ground vehicle. *Proceedings of the 26th Army Science Conference.* Orlando, FL, Dec 1-4, 2008.

In this study, we simulated a generic mounted crewstation environment and conducted an experiment to examine the workload and performance of the operator of a ground robot. Participants were randomly assigned to four tasking conditions: robotics tasks only, robotics plus an auditory task, robotics plus a visual monitoring task, or all three tasks simultaneously. Participants completed four mission scenarios. In two of these scenarios, their robot was semi-autonomous. In the other two scenarios, they had to teleoperate the robot. An Aided Target Recognition (AiTR) system was available to help them with their target detection tasks in only two of the four scenarios. Results showed that operators' situational awareness and perceived workload were significantly worse when they teleoperated the robot. Individual differences factors such as the operator's spatial ability and attentional control were also investigated. Implications for military personnel selection were discussed.

Cosenzo, K., **Chen, J**., Reinerman-Jones, L., **Barnes, M**., & Nicholson, D. (2010). Adaptive Automation Effects on Operator Performance during a Simulated Reconnaissance Mission with an Unmanned Ground Vehicle. Accepted for presentation at the f the Human Factors and Ergonomics Society 54th Annual Meeting. San Francisco, CA: Human Factors and Ergonomics Society.

We simulated a generic military crew station and examined the workload and performance of robotics operators when interacting with a ground robot in the two modes of robotic autonomy, teleoperation or semi-autonomous. We examined the effect of autonomy and invocation strategies on performance. The operator had either full teleoperation (manual) or semiautonomy (static) regardless of task load. In a third condition, the robots autonomy changed based on task load (adaptive). The operator had to identify hostile targets during the mission and maintain situation awareness (SA) of his local environment and the overall mission via a SA map. Results showed that when task load increased from low to high, participants' SA performance was better in the adaptive and static automation conditions than the manual condition; their threat detection performance degradation was less in manual and adaptive than in the static condition. On the other hand, when task load shifted from high to low, threat detection performance was better in the adaptive than the other two conditions.

Cosenzo, K. Parasuraman, R., & **Barnes, M**. (2006). Adaptive Automation for Robotic Systems: Theoretical and Human Performance Issues. In Proceedings of the *NATO Conference on the Human Factors of Uninhabited Military Systems,* France, October 2006.

Modern warfare systems have increased in complexity in response to a progressively more multifaceted, unpredictable, and dangerous world. In particular, ground and aerial automated systems have changed the tenor of the battlefield. Robotic systems are becoming an essential part of the Army's force. They are intended to extend manned capabilities, be force multipliers, and most importantly, save lives; however, the addition of robotic systems will likely increase, or certainly change, the Soldier's cognitive workload. Automation is a possible solution to this cognitive workload issue. We propose the use of adaptive systems that use flexible automation strategies to account for the ever changing combat environment. This paper presents supporting research, results from two multitasking studies in human robot interaction, and our rationale for the implementation of adaptive automation in this environment. Finally, we discuss ongoing research in terms of its theoretical and Soldier performance implications for designing adaptive algorithms as part of the crew interface for remote targeting with robotic systems.

Cosenzo, K., Parasuraman, P., Bhimdi, T, & Novak, A. (2005). Adaptive Automation for Control of Unmanned Vehicles: Simulation Platform for Rapid Prototyping and Experimentation. *Proceedings of the 11th Annual Human-Computer Interaction International Conference, Las Vegas*, NV.

Robotic systems will be an essential part of the Army's Future Force; they extend manned capabilities, are force multipliers and most importantly, they can save lives. The addition of robotic systems may also increase the task load on the soldier. The role of the human operator is not well understood; however most contemplated systems will require either active human control or supervision with the possibility of intervention. In the most extreme case, soldiers will operate multiple systems while on the move and under enemy fire. In all cases, workload and stress will be variable and unpredictable, changing rapidly as a function of the military environment. Automation technologies have been successfully applied to aid human operators in various environments, including aviation and military command and control. Research to date has not examined the feasibility of adaptive or adaptable automation to assist an operator who will control multiple robotic aerial and ground assets from a single interface in a vehicular environment. The robotic environment for future forces will be highly complex and the existing test-beds limit our ability to assess automation concepts in a highly controlled manner. We have created a simulation platform, Robotic NCO, which emulates the essential robotic tasks based on an existing prototype interface. Robotic NCO is a multitask environment that includes unmanned ground vehicle control, unmanned aerial vehicle sensor use, and multilevel communications. The simulation platform allows for rapid prototyping and experimentation. The first experiment will evaluate the impact of completing multiple tasks on performance and workload in the robotic environment. From this we will determine which tasks may be best to automate and possible strategies to minimize the demands on the soldier in the robotic environment, specifically the use of adaptive versus adaptable automation. We will demonstrate the functions of Robotic NCO program and present results from the first experiment.

Cosenzo, K.A., Parasuraman, R., & **Pillalamarri, K.** (2008). The Effect of Task Based Automation for the Control of Unmanned Systems on Operator Performance. *Proceedings of the Human Factors and Ergonomics Society's* 52nd Annual Meeting, New York, NY, CD-ROM.

Robotic technology will be a vital component of future combat. However, the combination of robotic operational tasks with other traditional military tasks will create high workload peaks during military operations. The objective of this research is to develop and evaluate flexible automation strategies to aid the operator in this complex military environment. In this experiment we evaluated the effect of an automation that was invoked based on task load. Participants conducted a military reconnaissance mission using a simulation that required them to: use an unmanned air vehicle sensor for target detection, monitor an unmanned ground vehicle, and respond to multilevel communications. Participants completed sixteen missions in the environment, during which task load and automation were manipulated. The results of this experiment showed that operator performance did improve when the automation, an aided target recognition for the unmanned air vehicle, was invoked relative to when it was not invoked. Further, when automation was appropriately applied (high task load conditions) workload decreased significantly. This data along with the results of other experiments discussed in this paper indicate that adaptive automation may be a useful mitigation strategy to help offset the potential deleterious effects of high cognitive load on Army robotic operators in a multitasking environment.

Fidopiastis, C., Drexler, J., Barber, D., **Cosenzo, K**. et al., (2009). Impact of Automation and Task Load on Unmanned System Operator's Eye Movement Patterns. *Proceedings of the Human Computer Interaction International Conference*, San Diego, CA, CD-ROM.

Eye tracking under naturalistic viewing conditions may provide a means to assess operator workload in an unobtrusive manner. Specifically, we explore the use of a nearest neighbor index of workload calculated using eye fixation patterns obtained from operators navigating an unmanned ground vehicle under different task loads and levels of automation. Results showed that fixation patterns map to the operator's experimental condition suggesting that systematic eye movements may characterize each task. Further, different methods of calculating the workload index are highly correlated, $r(46) = .94$, $p = .01$. While the eye movement workload index matches operator reports of workload based on the NASA TLX, the metric fails on some instances. Interestingly, these departure points may relate to the operator's perceived attentional control score. We discuss these results in relation to automation triggers for unmanned systems.

Mitchell, D. K. & Chen, J. (2006) Impacting system design with human performance modeling and experiment: Another success story. Proceedings of the 50th HFE Conference, San Francisco, CA 2006.

In this study, task-network models using the Improved Performance Research Integration Tool were built to predict the mental workload and performance of the crew of a conceptual mounted combat vehicle. The modeling project analyzed which crewmember, if any, should be allocated the functions of controlling robotic assets in addition to standard mission functions similar to present tank crew missions. In order to further investigate issues derived from the modeling project and to verify its analytical results, a simulation experiment was conducted to examine the mental workload and performance of the combined position of robotics operator and gunner. The results of this experiment were consistent with the predictions generated by the modeling analysis. The modeling and experimental data have successfully contributed to modifications in the design concept for the modeled platform as well as its crewmember function allocations.

Sciarini, L. W., Nicholson, D., **Cosenzo, K., Chen, J**., & **Barnes, M.** (2008). Operator Workload and Heart Rate Variability During a Simulated Reconnaissance Mission with an Unmanned Ground Vehicle. *Proceedings of the 26th Army Science Conference*, Orlando, FL, CD-ROM.

In this study, we simulated a generic mounted crewstation environment and conducted an experiment to examine the workload and performance of the operator of a ground robot. Participants were randomly assigned to four tasking conditions: robotics tasks only, robotics plus an auditory task, robotics plus a visual monitoring task, or all three tasks simultaneously. Participants completed four mission scenarios. In two of these scenarios, their robot was semi-autonomous. In the other two scenarios, they had to teleoperate the robot. An Aided Target Recognition (AiTR) system was available to help them with their target detection tasks in only two of the four scenarios. Results showed that operators' situational awareness and perceived workload were significantly worse when they teleoperated the robot. Individual differences factors such as the operator's spatial ability and attentional control were also investigated. Implications for military personnel selection were discussed.

Taylor, G., Reinerman-Jone, L., **Cosenzo, K**., & Nichoson, D. (2010). Integrating Multiple Physiological Sensors to Classify Operator State in Adaptive Automation Systems. Accepted for presentation at the f the Human Factors and Ergonomics Society 54th Annual Meeting. San Francisco, CA: Human Factors and Ergonomics Society.

Automating tasks alleviates operator resources to be delegated to other demands, but the cost is often situation awareness. In contrast, complete manual control of a system opens the door for greater human error. Therefore, a combination of the two ends of the continuum is create an adaptive system in which automation can be triggered based on performance of a particular task, time spent on the task, or perhaps physiological response. The latter pertains to the goal for this particular study. Electroencephalogram (EEG), electrocardiogram (ECG), and eye tracking measures were recorded during six multi-tasking scenarios to assess if one or all three measures are best suited for future implementation as an automation invocation. EEG showed the greatest potential for that purpose.

Thrust Area 3: Intuitive Soldier Interactions

Research Protocols:

Effectiveness of Stereoscopic Displays for Indirect-vision Driving & Robot Teleoperation (PIs: **Jessie Chen** and Razia Nayeem Oden).

In the current study, we investigated whether a stereoscopic display (SD) could improve the operators' indirect vision driving (IVD) and robot teleoperation performance, and which type of SD supported better performance. We evaluated two types of SD technologies: active shutter glasses (nVIDIAR) and passive polarized glasses (MiracubeR). Thirty-two individuals (19 males and 13 females, mean age = 25.8) from the Orlando, FL area participated in the experiment. They were randomly assigned to the nVIDIA or the Miracube group. The experiment had three parts – Perceptual evaluation, Robot Teleoperation, and Virtual (simulated IVD). For the Perceptual part, participants viewed still images of terrain using one of the SDs in 3-D and responded about object distance from the camera as well as object height on elevation planes. They also viewed videos of hazardous terrain using one of the SDs in 3-D and responded when they detected a terrain drop-off. For the Robot Teleoperation part of the experiment, participants maneuvered a TALONR robot through a course of cones on a grass terrain using one of the SDs in both 2D and 3-D modes. For the Virtual part of the experiment, participants drove through both 3-D stereo and non-stereo scenarios in a simulated driving environment (VBS2R; Figure 2). Different types of terrains (negative terrains and obstacle courses) were simulated in the virtual scenarios.

Impact of 360° Sensor Information on Vehicle Commander Performance (PIs: **Keryl Cosenzo,** Jillyn Alban, **Theo Feng,** Erin Capstick).

The objective of this research is to evaluate the effect of the new 360/90° sensor system on the vehicle commander’s ability to maintain local area awareness and disseminate the information to his crew. Through this experiment we will determine what combination of displays and interface tools constitutes the optimal for 360° degree vision as it relates to local situational awareness. In addition to this primary objective, we investigated the cognitive limitation of operator’s to maintain SA. To this end, we examined how target features and environmental characteristics impacted the operator’s ability to maintain local SA as measure by target detection performance. In addition to the traditional human factors measures of objective performance and subjective workload, we included a non-invasive physiological measure to our paradigm, eye tracking. Screen region usage was assessed with the performance data. Through this experiment we planned to determine what combination of displays and interface tools constitutes the optimal interface design for 360° vision as it relates to local situational awareness. Results can be further used to identify performance bottlenecks that may require additional technology in addition to a 360/90° field of view.

Robotic telepresence for reconnaissance: Operator performance and user experiences (PIs: **Linda R. Elliott, Elizabeth S. Redden,** Rodger A Pettitt, Leo van Breda, and Chris Jansen)

This experiment will examine the effectiveness of telepresence robot controller features during indoor and outdoor beyond-line-of-sight robot reconnaissance missions. Soldier-participants will control a reconnaissance robot with each of two controllers: one with and one without telepresence capabilities developed by TNO Human Factors. Telepresence capabilities include a head-mounted three-dimensional visual and audio display. In addition, the robot camera will be guided by operator head movements to provide a more intuitive and hands-free visual search. Soldiers will perform equivalent observation, localization, search and identification tasks with the telepresence interface and with a baseline controller interface. Measures will include indices of performance (e.g., time, accuracy), NASA TLX, situation awareness, and user experience. Soldiers will also complete tests of color vision and spatial ability.

Research Area 3.1 - Dismounted Operations

Journal Articles and Book Chapters:

Coovert, M. D., Gray, A., **Elliott, L**., & **Redden, E.** (2007) A tool for the accumulation and evaluation of multimodal research. IEEE Transactions on Systems, Man, and Cybernetics.

There has been a surge of interest in multimodal research and interfaces. This is due, at least in part, to an exponential increase in the amount and type of information that can be presented to a user. When a great deal of information is presented via a single sensory modality, it can exceed the operator's capacity to manage the information efficiently, generating cognitive overload. As a consequence, the user's performance becomes susceptible to slower response times, loss of situational awareness, faulty decision-making, and execution errors. Researchers and designers have responded to these issues with the development and application of multimodal information displays. The cross-disciplinary flavor of multimodal applications presents a challenge to the accumulation, evaluation, and dissemination of relevant research. We describe the development of a taxonomy for the evaluation and comparison of multimodal display research studies, and the implementation of the taxonomy into a database: the Multimodal Query System (MQueS).

Duistermaat, M., **Elliott, L**., van Erp, J., **Redden, E.** (2007). Tactile land navigation of dismount soldiers. In D. de Waard, G. Hockey, P. Nickel, K. Brookhuis (Eds.) Human factors issues in complex environment performance. Europe chapter of the Human Factors and Ergonomics Society: Shaker Publishing.

In land navigation by dismounted soldiers, using a visual display obstructs the use of the soldier's eyes and hands for other tasks. This issue can be resolved by presenting navigation information on a tactile waist belt, which proved to be effective in previous studies. In this paper we present an experiment focused on navigation, target detection and situational awareness (SA) in a multitask environment. We compared the performance and subjective ratings for a tactile and two visual navigation systems. 24 Soldiers navigated three densely forested routes at night, with live and silhouette targets along the route. The tactile display proved to be very intuitive, the soldiers found the display easy to use and reached high performance levels. More targets were detected and higher navigation speeds were reached on part of the route. The soldiers rated the tactile system high, and especially appreciated the hands-free and eyes-free aspect of it. However, the soldiers also indicated that the tactile system was less suited to build up global situational awareness.

Elliott, L., van Erp, J., **Redden, E.**, Duistermaat, M. (2009) Field-based validation of tactile display for dismount soldiers. IEEE Transactions on Haptics,

In this paper, we present three field-based evaluations of a tactile land navigation system. In Experiment 1, we transition from a laboratory setting to rugged terrain used to train U.S. Army soldier land navigation. Navigation in this challenging terrain requires careful attention to one's surroundings. Participants navigated 3 waypoints along 600 meters through heavily wooded terrain, using (a) map and compass, (b) standard alpha-numeric handheld GPS device, and (c) the tactile GPS system, while also responding to radio requests for information. Experiment 2 used the same challenging terrain during night operations, where participants must also search for live and silhouette targets, using (a) handheld GPS device,(b) head-mounted map-based GPS, and (c) the tactile GPS system. In addition to navigating, participants searched for silhouette and live (human) targets. Experiment 3 had participants navigate with (a) a commercial GPS arrow display, (b) the tactile GPS system, and (c) both together. We conclude that tactile navigation displays can be used in strenuous outdoor environments and can outperform visual displays under conditions of high cognitive and visual workload.

Grey, A. A., **Redden, E. S**., Coovert, M.D., & **Elliott, L. R**. (2008). Empowering followers in virtual teams: Guiding principles from theory and practice. Computers in Human Behavior.

Effective leadership has several components. Arguably, nothing is more important to a leader than communicating one’s intent to followers, for it is only through effectively transmitting intent that followers come to understand and then carry out the goals of the team and leader. The modern work-world is dominated by computer-mediated communication, and this communication is the bread and butter of virtual teams; however, simple transmission of information from point A to point B is not enough--the virtual environment presents significant challenges to effective communication. In this paper we review issues related to virtual teams and developments in multimodal displays which allow teams to communicate effectively via single or multiple modalities (e.g., visual, auditory, tactile). Guiding principles were identified and culled based on multiple review criteria from an extensive literature review. The resulting searchable database of principles should therefore facilitate the development of communication and information display systems for multiple purposes. We describe the problem of communicating a leader’s presence to virtual followers in the applied example of commander’s intent and then present guiding principles from our database that can be used to facilitate the design of a system of interaction.

Oron-Gilad, T., **Redden, E. S.** Minkov, Y. (in review). Robotic displays for dismounted warfighter situation awareness of remote locations. In *Journal - JCEDM Special Issue on Improving Human-Robot Interaction Journal of cognitive engineering and decision making special issue on improving human-robot interaction*.

This study investigated scalability of unmanned vehicle displays for dismounted warfighters. Task performance, workload and preferences for three display devices were examined in two operational settings: tele-operation of an unmanned ground vehicle and intelligence gathering from a remote unmanned vehicle. **Background**. Previous research has demonstrated variability in operational needs with regard to active tele-operation versus passive intelligence gathering. Thus, it was important to identify whether there was actually a dichotomy between the two in terms of screen space requirements and whether this difference stems from task differences or other factors. **Method**. Thirty-one soldiers participated in a field study at Ft. Benning, GA. They were required to perform tele-operation and intelligence gathering tasks. **Results.** Results reconfirmed our hypothesis that display type influences performance in intelligence-related tasks that require the use of video feed and digital map. No significant differences among display types were found in the UGV tele-operation task. **Conclusions**. Dismounted warfighters can adequately perform both active and passive duties with a HHD where the video window is as small as 4.3 inches in diameter. **Implications**. Monocular HMDs for robotic displays can be problematic and should be carefully assessed before use.

Redden E. & **Elliott L**. (in press). Robotic control for dismounted Soldiers . In M. J. Barnes & F. J. Jentsch (eds), *Human-Robot Interactions in Future Military Operations*. Farnham: Ashgate Publishing.

None.

Redden, E. S., **Elliott, Linda R**., **Pettitt, Rodger A**., **Carstens, Christian B**. (2010) A Tactile option to reduce robot controller size. In *Journal on Multimodal User Interfaces, 2,*205-216. http://www.springer.com/computer/user+interfaces/journal/12193.

In response to operational requirements for smaller robotic controller devices for use by dismounted US Army soldiers, three types of robot controller navigation map display configurations were evaluated for effects on beyond line-of-sight robotic navigation tasks. We predicted better performance with the larger split screen display that presents both a map display and a camera-based driving display on a 6.5 inch screen. Two smaller alternatives were also evaluated. One alternative was a 3.5 inch display that allowed the operator to toggle back and forth between the driving display and the map display. The third option added a torso-mounted tactile display to the toggle-based display in order to provide direction information simultaneously with the camera display and thus reduce the need to toggle as frequently to the map display. Each display option was evaluated based on objective performance data, expert-based observations, and scaled subjective soldier questionnaire items. Findings indicated that operators' navigation performance with the multimodal 3.5 inch toggle display was as effective as their performance with a 6.5 inch split screen display. Operator performance was significantly lower with the 3.5 inch toggle display that did not have the tactile display.

Redden, E., **Elliott, L**., **Pettitt, R**., **Carstens, C**. (in review). Scaling Robotic Systems for Dismounted Warfighters. In Journal - JCEDM Special Issue on Improving Human-Robot Interaction Journal of cognitive engineering and decision making special issue on improving human-robot interaction.

As robot usage becomes more prevalent in military applications, there is a pressing need to develop smaller, lighter robot systems that are still rugged, easy to learn, and easy to use. This paper describes four experiments designed to investigate how best to scale robot controllers for dismounted warfighters. The first experiment evaluates four levels of camera screen size. The second experiment evaluated robot controller features. A third experiment compared a split screen display with a toggle-driven single display and a multisensory display. The fourth experiment examined effectiveness of hand-held displays versus head-mounted displays, given two movement techniques. The employment techniques contrasted stationary bounding operations with robot control while the warfighter was on the move. These experiments address specific design issues for scaling robot controllers to be smaller and lighter.

Technical Reports:

Coovert, M., Prewett, M., Saboe, K., Johnson, R., **Elliott, L**. *Development of principles for multimodal displays in Army Human Robot Operations.* (In review). ARL-TR-xxxx, Aberdeen Proving Ground, MD: Army Research Laboratory.

Work in the area of robots and human-robot interaction is exploding. We review part of the literature and provide recommendations for future research. Three papers review topics of special interest: workload, autonomy, and visual displays. Further information on the papers reviewed for this project can be found in an on-line database.

Cosenzo, K., Capstick, E., **Pomranky, R**., Dungrani, S., & Johnson, T. (2009). Soldier Machine Interface for Vehicle Formations: Interface Design and an Approach Evaluation and Experimentation. (ARL-TR-4678). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

This document presents interface designs developed through a number of technology development and experimentation efforts at the U.S. Army Tank Automotive Research Development and Engineering Center and U.S. Army Research Laboratory, respectively. Through these efforts, a functional Soldier Machine Interface (SMI) was developed using Future Combat System concepts to support the tasks of monitoring and maintaining coordinated movement of platoon size units conducting a tactical road march. This report provides an in depth description of the approach used to develop the SMI and the features of the SMI. In addition, we describe a modeling and simulation environment that is being used to support human-in-the-loop experiments to evaluate the current SMI and examine the impact of the SMI on the supporting operator's roles.

Cosenzo, K. A. & Stafford. S. (2007). Usability Assessment of Displays for Dismounted Soldier Applications (ARL –TR-4326). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

This report presents a usability assessment of scalable displays for dismounted robotic control applications. The assessment covered three components: display size, button features (e.g., size, location), and controllers for tele-operation. Twelve Soldiers participated in the assessment. Before the assessment, the Soldiers were trained on a larger version of the displays. They then used the three scalable display configurations to plan and execute a mission for an unmanned vehicle (UV). During the execution of the task, video was recorded and the experimenters asked scripted questions about the displays. Results showed that the Soldiers were successful in using the various display configurations to complete the UV task; however, all the Soldiers asked clarifying questions about how to plan the mission. These results suggest that the original and largest display design lacked design principles that were fully transferable to smaller displays. With respect to display size and button size, the interviews showed that a small display was preferred to the larger one used in training for dismounted operations. However, the buttons on the small display were difficult to use without a stylus. For mounted operations or during conditions when the Soldier would not have to be mobile, the larger display was preferred. This report discusses these results in detail, related theories, and the implications for designing effective scalable displays.

Elliott, L.R., Coovert, M.D., Prewett, M., Walvord, A. G., Saboe, K. and Johnson, R. (2009) A Review and Meta Analysis of Vibrotactile and Visual Information Displays (ARL-TR-4955). Aberdeen Proving Ground: Army Research Laboratory.

Many studies have investigated the impact of vibrotactile cues on task performance, but the wide range of cue and task types have made findings difficult to interpret without a quantitative synthesis. We provide a systematic review of studies on vibrotactile cue effectiveness with regard to task performance, organized by types of comparisons and cue complexity. Forty five studies met the criteria for meta-analytic comparisons. Three types of comparisons were made: (1) the addition of a new tactile cue to a "baseline" condition, (2) the comparison of tactile cues to visual cues representing the same information, and (3) the comparison of visual cues compared to a multimodal combination of tactile and visual cues representing the same information. The level of cue information complexity was also examined as a moderator. When added to a baseline task or existing visual cues, tactile cues enhanced task performance. When tactile cues replaced visual cues, however, effects are attenuated and moderated by cue information complexity. Tactile alerts are effective when replacing visual alerts, but tactile direction cues do not improve performance when replacing visual direction cues. This meta-analysis of tactile applications underscores the benefits of vibrotactile and multimodal displays, highlights conditions in which tactile cues are particularly effective, and identifies areas in need of further investigation.

Elliott, L.R., Duistermaat, M., **Redden, E**., van Erp, J., (2007). Multimodal Guidance for Land Navigation. (Technical Report No. ARL-TR-4295). Aberdeen Proving Ground: Army Research Laboratory.

This report describes the third in a series of collaborative experiments between the U.S. Army Research Laboratory and TNO Human Factors (Soesterberg, The Netherlands). In each experiment, a personal tactile navigation (PTN) system for land navigation was compared with alternate land navigation systems in wooded terrain at Fort Benning, Georgia, during high workload conditions that included secondary tasks such as radio communications, target detection, and determination of location coordinates. This report briefly summarizes results of the first and second studies and describes in further detail the third experiment which assessed navigation and target detection performance when the PTN and a hand-held commercial global positioning system (GPS) device were used singly and together. Most important are findings relevant to how systems can be used most effectively when Soldiers have both. Results demonstrate the effectiveness and high Soldier appreciation of having both systems. This report also contains Soldier recommendations for how both systems can be improved and how best to use both systems when in operations.

Elliott, L. R., Redden, E. S. Jansen, C. **Pettitt, R. A.** (in review). Robotic Telepresence: Perception, Performance, and User Experience. (ARL-TR-xx), , Aberdeen Proving Ground, MD: Army Research Laboratory.

This experiment examined the effectiveness of telepresence robot controller features during indoor and outdoor beyond-line-of-sight robot reconnaissance missions. Soldier-participants controlled a reconnaissance robot with each of two controllers: one with and one without telepresence capabilities developed by TNO Human Factors. Telepresence capabilities included a head-mounted three-dimensional visual and audio display. In addition, the robot camera was guided by operator head movements to provide a more intuitive and hands-free visual search. Soldiers performed equivalent search and identify tasks with the telepresence interface and with a baseline controller interface. Measures included indices of performance (e.g., time, accuracy), NASA TLX, situation awareness, and user experience. Results indicate performance outcomes were similar in both conditions. Feedback from Soldiers was overall positive. Suggestions for improvement included a more lightweight, portable system, higher visual clarity, and enhanced ease of use. A follow-on experiment is planned to further ascertain the contribution of individual telepresence capabilities to performance of tasks such as observation of human movement and behavior (tracking task), audio-guided search, and additional visual search and robot maneuver tasks.

Pettitt, R.A, **Redden, E.S**. & **Carsten, C.B**. (2009) *Scalablity of Robotic Controllers: Speech-based Robotic Controller Evaluation* (ARL-TR-4858)," Aberdeen Proving Ground, MD: US Army Research Laboratory.

This study focused on the feasibility of reducing robotic controller size by replacing some of the manual controls with speech-based controls and the effect of a speech-based robotic controller on SUGV control. It took place at Fort Benning, GA. Eleven Soldiers from the Officers Candidate School (OCS) served as participants. After training on the operation of the iRobot PackBot SUGV system, each Soldier teleoperated the SUGV using two controller conditions; combination of speech and manual control and manual control only. Soldiers were tasked to drive the robot and to perform operations such as surveillance using the robotic arm. The terrain and hazards were counterbalanced along with the controller type to control for sequence effects. Controller type and usability were evaluated based on objective performance data, data collector observations, and Soldier questionnaire responses. Workload for each controller was measured by having the Soldiers complete the NASA -Task Load Index (TLX) survey after using each controller type. Speech-based control exhibited the potential for benefits beyond controller size reduction. It decreased time and effort when performing multiple tasks simultaneously by allowing speech commands to be given for control of the robotic arm while at the same maneuvering the robot using manual controls. The speech based control system also has the potential to provide other benefits beyond those addressed in this study. Certain tasks, such as menu navigation, can be extremely time consuming and detrimental to the Soldier's situation awareness of his surroundings when a hand controller is used. For example, having to use up-down keys on the hand-controller for menu navigation is much more demanding than speech based control of these tasks.

Pettitt, R. A., **Redden, E. S**., **Carstens, C.B.** (2008). *Scalability of Robotic Controllers: An Evaluation of Controller Options.* ARL-TR-4457, Aberdeen Proving Ground, MD: Army Research Laboratory.

This study, conducted at Fort Benning, GA, was an operational investigation of teleoperation control performance using three different robotic control devices. Twelve Soldiers from the Officers Candidate School (OCS) and three Soldiers from Headquarters Company 1st Battalion 11th Infantry Regiment served as participants. Prior to any training, Soldiers provided an initial evaluation of the intuitiveness of controller features. After training on the operation of the IRobot PackBot Robot system, each Soldier completed a driving course using three different controller types. Controller A was the largest of the three controllers and each control manipulation had a single function. Both controller A and controller B had a similar number of single-function controls; however, controller B's controls were laid out in a different configuration and were smaller than controller A's. Controller C had the fewest controls and the controls were multi-functional., Soldiers were tasked to drive the robot and to perform operations such as surveillance using the robotic arm. Workload for each controller was measured by having the Soldiers complete the NASA -Task Load Index (TLX) survey after using each controller type. Controller type and usability were evaluated based on objective performance data, data collector observations, and Soldier questionnaires. The multifunctional controller was reported to be more difficult to learn and use than the controller with reduced control sizes because switching between functions was time consuming and confusing. This difficulty increased perceived workload. Soldiers also found that several robotic control functions could not be performed simultaneously (i.e., raise the control arm while turning the sensor head) with the multifunction controller. This necessitated sequential operation which was time consuming and difficult. Findings indicate that reducing the size of the individual controls shows promise as a valid approach for reducing overall controller size.

Redden, E. S. **Pettitt, R. A., Carstens, C. B.** & **Elliott, L. R.** (2008). *Scalability of Robotic Displays: Display Size Investigation.* ARL-TR-4456, Aberdeen Proving Ground, MD: Army Research Laboratory.

This study was an investigation of the effect of camera-view display sizes on robotic teleoperation control performance in a realistic context. It took place at Fort Benning, GA and used Soldiers from the Officer Candidate School (OCS). After training on the operation of the TALON Robot system, each Soldier completed exercises using four different display sizes that were chosen to match the size and resolution of displays that might be used by dismounted Soldiers for other purposes in the near future. The terrain, targets, and hazards were counterbalanced along with the display size to control for the effect of learning. Display size and usability for robotic driving were evaluated based on objective performance data, data collector observations, and Soldier questionnaires.

Redden, E., **Carstens, C**., **Pettitt, R.** *Intuitive Speech Based Robotic Control.* (In press). ARL-TR-xxx, Aberdeen Proving Ground, MD: Army Research Laboratory.

We conducted a speech-based robotic control study using 29 Soldiers recruited from Fort Benning, GA. Findings indicated Soldiers were able to perform a secondary task (writing numbers) significantly faster when operating a robot using speech control versus using manual control. This demonstrated that robotic control requires multitasking and also implies that speech control requires less attention than manual control, thus freeing up cognitive resources for additional tasks. Speech control allowed significantly faster performance when the task involved using menu items (enlarge picture, shrink picture). Speech control allowed direct access to the menu items, whereas manual control required navigating through a menu and selecting an item two levels deep into the menu. Speech control was also significantly faster for labeling items where Soldiers had to choose and select from a list to label a picture. Alternatively, speech control took significantly longer when performing continuous tasks, such as turning the robot during the "take a picture" task and driving to the blue waypoint, which involved a significant amount of turning. When interpreting the results, one should consider that the intuition and speech-control portions of the experiment featured tasks that could be found in a robotic reconnaissance mission and the findings are specific to these tasks.

Redden, E. & **Elliott, L.** (2007). Research-Based Display Design Guidelines for Vehicle Crewman and Ground Warrior Interfaces, Which Enhance Situational Understanding and Decision Cycle Performance. (ARL-TR- 4231). Aberdeen Proving Ground, MD: Army Research Laboratory.

Warrior and the Future Combat Systems It provides guidelines pertaining to the design of information displays to increase the efficiencies of warfighters operating in echelons of platoon and below by avoiding information overload and incompatibilities between the display design and warfighter primary tasks. This document includes guidelines based upon ATO-sponsored research experiments and meta-analyses regarding the optimization of different types of displays (e.g., visual displays, auditory displays, tactile displays); designing displays for different types of tasks; and designing for individual differences which can affect performance with different types of displays. For each guideline, a commentary, examples, and sources are provided. The guiding principles that are contained in the appendix of this document were developed from a review of available literature on experiments that were performed outside of the ATO.

Redden, E., Pettitt, R., **Carstens, C**., **Elliott, L**. (In press). *Scaling Robotic Displays: Displays and Techniques for Dismounted Movement with Robots.* ARL-TR-xxxx, Aberdeen Proving Ground, MD: Army Research Laboratory.

The purpose of this research was to examine the effects of display type and robotic employment techniques on robotic control during dynamic dismounted Soldier operations. It took place at Fort Benning, GA and used Soldiers from the Officer Candidate School (OCS) as participants. The employment techniques contrasted stationary bounding operation with operation of the robot while the Soldier was on the move. The two display types were a handheld display (HHD) and a helmet mounted display (HMD). Results indicated that Soldiers performed better with the HHD than they did with the HMD used in this experiment. Their course completion times, driving errors, and the number of times they drove off course were all lower with the HHD. The Soldiers also preferred the HHD to the HMD and rated the workload with the HHD lower. Soldiers preferred the bounding technique to the continuous movement technique. Fewer driving and off course errors were made and more items were detected with the bounding technique than with the continuous movement technique. Until robots become more autonomous in their navigation, robotic control during Soldier movement is beyond the multitasking ability of most Soldiers.

Redden, E.S., **Petitt, R.A** , **Carsten, C.B**., **Elliott ,L.R**. & Rudnick, D.(2009) *Scaling Robot Displays: Visual and Multimodal Options for Navigation by Dismounted Soldiers* (ARL-TR-4708) Aberdeen Proving Ground, MD: US Army Research Laboratory.

This study was an investigation of the impact of three types of navigation map displays on navigation performance. It took place at Fort Benning, GA and used Soldiers from the Officer Candidate School (OCS). After training on the operation of the TALON Robot system, each Soldier completed navigation exercises using three different navigation display configurations.

The first configuration was a split screen display that consisted of a driving display on top and a map display on the bottom of a 6.5 inch screen that allowed simultaneous or near simultaneous viewing. The second was a 3.5 inch display that allowed the Soldier to toggle back and forth between the driving display and the map display. The use of a 3.5 inch display demonstrated the potential to reduce size and weight and bandwidth requirements. The third display configuration was identical to the second configuration except that it added a tactile belt that transmitted directional information to the Soldier. Thus this multimodal option presented the tactile navigational display information concurrently with the driving camera display. Soldiers could also toggle to the map display when they needed to see specifically where the TALON was located. The terrain, targets, and hazards were counterbalanced along with the display configuration to control for the effect of learning. Display configuration and usability for robotic driving were evaluated based on objective performance data, data collector observations, and Soldier questionnaires. Findings indicated that Soldiers' navigation performance with the multimodal 3.5 inch display was as effective as their performance with a 6.5 inch split screen display. Their performance with both the multimodal and split screen displays was better than their performance with a 3.5 inch display that required them to toggle back and forth between the driving camera and map displays.

Proceedings Papers:

Coovert, M**., Elliott, L.** (2009). UAV Pilot specifications from O*NET. *Proceedings of the 2009 Aviation Psychology Conference,* Dayton, OH.

The use of robots in aviation is widespread, for use as targets, decoys, remote sensing, reconnaissance, and increasingly for combat missions. Robots come in all forms and capabilities, from handheld micro air vehicles to hypersonic versions capable of high altitude long distance missions. At the same time, ground-based robots have proven effective for both military and manipulations. Certainly, Talon and Packbot robots have proven their worth in battle conditions. Just as there is great variance in the type of robot being developed and utilized, so too is there tremendous variation operator requirements. Thus, it is essential the individual possess the requisite knowledge, skills, abilities and other characteristics to do so. Our work specifies the requirements for a prototypical robot operator through an examination of the U.S. Department of Labor/Employment and Training Administration's Occupational Information Network (O*NET). The applicable aviation occupations include UAV operations and also many other robots used in the aviation domain. Results yield the following for operator characteristics. Knowledge: The high frequency types are mechanical, production and processing, computers and electronics. Skills: high language component with high active learning, active listening and reading comprehension, critical thinking and mathematics. Abilities: Seven specific types cognitive ability are deemed important: problem sensitivity, information ordering, oral comprehension, deductive reasoning, oral expression, inductive reasoning, and written comprehension. Our paper documents the full operator profile that can be used for a variety of purposes including selection, training, and human factors design and specifications.

Elliott, Coovert, & **Redden**. (2009) A summary review of meta-analysis of tactile and visual displays. Invited paper presented to the 13th International Conference on Human- Computer Interaction, June, San Diego, CA.

The literature is replete with studies that investigated the effectiveness of vibrotactile displays; however, individual studies in this area often yield discrepant findings that are difficult to synthesize. In this paper, we provide an overview of a literature review and meta-analyses that organized studies to enable comparisons of visual and tactile presentations of information, to yield information useful to researchers and designers. Over six hundred studies were initially reviewed and coded along numerous criteria that determined appropriateness for meta-analysis categories. This resulted in 64 studies meeting the inclusion criteria for meta-analyses. Comparisons were made between conditions that compared (a) adding a tactile cue to a baseline condition, (b) a visual cue with a multimodal (visual and tactile) presentation, and (c) a visual cue with a tactile cue. In addition, we further categorized within these comparisons with regard to type of information, that ranged from simple alerts and single direction cues to more complex tactile patterns representing spatial orientation or short communications. Results demonstrated effectiveness of tactile displays, particularly when they provide additional information or are presented as multimodal (tactile and visual) cues.

Elliott, L. R., **Redden, E.R**., **Pettitt, R.A**. (2010). Using a GPS-based tactile belt to assist in robot navigation. *Proceedings of the 3rd Applied Human Factors & Ergonomics Intl Conference,* Orlando, FL.

Researchers from the U.S. Army Research Laboratory have conducted a series of experiments aimed at reducing the size of robotic controllers for use by dismounted warfighters. The goal of the research is to reduce the size and weight of the robotic controllers without adversely affecting the human robotic interface. The specific goal of the current experiment was to investigate two alternative robot controller navigation map display configurations with the potential to replace a larger split screen display that presents both a map display and a camera-based driving display side by side on a 6.5 inch screen. The first alternative was a 3.5 inch display that allowed the operator to toggle back and forth between the driving display and the map display. The second alternative added a torso-mounted tactile display to the toggle-based display in order to provide direction information simultaneously with the camera display. Each display option was evaluated based on objective performance data, expert-based observations, and questionnaire items. Findings indicated that operators' navigation performance with the tactile-supported 3.5 inch toggle display was as effective as their performance with a 6.5 inch split screen display. Operator performance was significantly lower with the 3.5 inch toggle display that did not have the tactile display.

Hutchins, S., **Cosenzo, K**., McDermott, P. **Feng, T**., **Barnes, M**., Gacy, M., (2009) "An Investigation of the Tactile Communications Channel for Robotic Control," Proc Human Factors and Ergonomics Society Annual Meeting Proceedings, Volume 53, 4, pp. 182-186(5).

The impacts on performance of three different forms of communication (radio, chat, and tactile belt) were explored in the context of a small unmanned ground vehicle (SUGV) target identification task. The target identification task required a Commander with knowledge of target locations and access to a digital map displaying the current SUGV position and orientation to direct a Soldier remotely operating the SUGV to the targets using a finite set of eleven commands. The study revealed no evidence for a loss of soldier performance with the tactile belt communications channel. The finding suggests that the tactile use of haptic signals may be feasible, a potentially important finding for situations requiring covert communications.

Luck, J., McDermott, P.L., & **Allender, L**. (2006). An Investigation of Situational Awareness in Real World Control of Robotic Assets with Communication Latency. In Proceeding of the *Third Annual Cognitive Engineering Research Institute (CERI) Human Factors of UAVs Workshop*, May 2006.

Unmanned vehicles (UVs) are already being used in a variety of applications, including the military battlefield. The applications will only increase as robotic technology, such as autonomy, continues to advance. As the technology advances, the number of applications will increase, as will the demands on the associated network. Limited bandwidth, extended transmission ranges, and high network traffic can all result in communication latency. A previous publication summarized the effects on operator performance from two experiments investigating the effects of communication latency when controlling a robot (Luck, 2006). This paper will detail the effects on operator Situational Awareness (SA) from the same two experiments.

Luck, J., McDermott, P.L., **Allender, L**., & Fisher, A. (2006). Advantages of Co-Location for Effective Human to Human Communication of Information Provided by an Unmanned Vehicle. In Proceeding of the *Human Factors and Ergonomics Society 50th Annual Conference*, San Francisco, Oct 2006.

Much of the research on unmanned-vehicles (UVs) focuses on technology or interface design. This study investigated how to best support effective communication between the UV operator and the Soldier in the field using UV-provided information to complete a mission. In a previous study investigating the impact of different team configurations and the utility of supporting communication technologies, our team found co-location of team members to be beneficial (McDermott et al.,, 2005). In this experiment we investigate what aspects of co-location are key to successful team performance: Is face-to-face communication vital compared to voice-only when team members are distributed? Is the ability of the UV operator to see what the Soldier performing the mission can see critical? We also seek additional insight to inconclusive results from the first study regarding the utility of image transmission and access to an electronic map displaying both the UV and Soldier locations.

Luck, J., McDermott, P.L., **Allender, L**., & Russell, D.C. (2006). An Investigation of Real World Control of Robotic Assets under Communication Latency. In Proceeding of the *2006 Association for Computing Machinery Conference on Human-Robot Interaction*, Salt Lake City.

Robots are already being used in a variety of applications, including the military battlefield. As robotic technology continues to advance, those applications will increase, as will the demands on the associated network communication links. Two experiments investigated the effects of communication latency on the control of a robot across four Levels Of Automation (LOAs), (1) full teleoperation, (2) guarded teleoperation, (3) autonomous obstacle avoidance, and (4) full autonomy. Latency parameters studied included latency duration, latency variability, and the "direction" in which the latency occurs, that is from user-to-robot or from robot-to-user. The results indicate that the higher the LOA, the better the performance in terms of both time and number of errors made, and also the more resistant to the degrading effects of latency. Subjective reports confirmed these findings. Implications of constant vs. variable-latency, user-to-robot vs. robot-to-user latency, and latency duration are also discussed.

Research Area 3.2 – Specialized Interfaces

Journal Articles and Book Chapters:

Coovert, M. D., Gray, A., **Elliott, L**., & **Redden, E.** (2008) A tool for the accumulation and evaluation of multimodal research. IEEE Transactions on Systems, Man, and Cybernetics.

A surge of interest exists in multimodal research and interfaces. This is due, at least in part, to an exponential increase in the amount and type of information that can be presented to a user. When a great deal of information is presented via a single sensory modality, it can exceed the operator's capacity to manage the information efficiently, generating cognitive overload. As a consequence, the user's performance becomes susceptible to slower response times, loss of situational awareness, faulty decision making, and execution errors. Researchers and designers have responded to these issues with the development and application of multimodal information displays. The cross-disciplinary flavor of multimodal applications presents a challenge to the accumulation, evaluation, and dissemination of relevant research. We describe the development of a taxonomy for the evaluation and comparison of multimodal display research studies, and the implementation of the taxonomy into a database: the Multimodal Query System (MQueS).

Cosenzo, K. A., Capstick, E., & **Pomranky** (2010). Impact of Advanced Display Features on Situation Awareness, Workload and Performance of Complex Military Tasks. *Journal of Cognitive Engineering and Decision Making*. In Review.

The objective of this research was to evaluate the effect of advanced interface features on an operator's ability to perform the duties and responsibilities associated with the role of Platoon Leader (PL); maintain and monitor vehicles in a formation, respond to communications, and maintain security around his vehicle. Participants conducted a military convoy mission using a basic interface (representative of the current force technology) and an interface with advanced cues and alerts. Participants completed two missions with each interface configuration. Results showed that the advanced interface significantly improved the PL's ability to respond correctly and quickly to vehicles deviating from the formation. Further, participants reported better situation awareness and lower workload with the advanced interface than the baseline interface. Appropriately applied advanced formation tools such as status information on the vehicles and alerts do improve military effectiveness and are important for military operations.

Haas, E.C., and van Erp, J. (2010). Tactile displays for human robot interaction. In Barnes, M., Jentsch, F. (Eds), Human Robot Interactions in Future Military Operations, in press.

None.

Haas, E.C. (2007). "The role of emerging multimodal technologies in enhancing combat and civilian system safety." *Journal of the American Society of Safety Engineers*.

This article describes how spatial audio and skin-based control and display technologies can be used to enhance system safety in military and civilian applications. The article describes how automatic speech recognition controls are relevant to military and civilian system safety, and shares practical considerations associated with the efficient use of these technologies, including technology demands and limitations.

Johnson, R., Saboe, K., Prewett, M., Coovert, M., **Elliott, L.** (2009). Autonomy and Automation Reliability in Human-Robot Interaction: A Qualitative Review. In Human Factors and Ergonomics Society Annual Meeting Proceedings, Volume 53, Number 18, 2009 , pp. 1398-1402(5) Publisher: Human Factors and Ergonomics Society

The effectiveness and reliability of automation aids are critical topics in the area of human-robot interaction (HRI). As more tasks are subsumed by robots and autonomous systems, it is important to examine the relationships between these entities and their human operators. Research to date has covered various manipulations of autonomy, but this broad body of research is in need of focus and consistency. The current study presents a qualitative overview of research regarding levels and reliability of autonomy/control and the effects they have on important HRI-relevant outcome variables. Results indicate that autonomy and automation aids operate uniquely for different tasks, and that there are many complex factors that can affect not only performance but also usability, confidence, and safety. Unresolved issues in the field and challenges and opportunities for future research are also presented.

Noyes, J. & **Haas. E.C.** (2007). Military Applications of Speech Recognition. In C. Feng (Ed.), New Trends in Speech Based Interactive Systems, in press.

Speech based systems have been considered in military applications for Command and Control, teleoperation, information entry and retrieval, repair and maintenance, training, and language translation. These applications can appear in stand-alone, embedded, mobile, or hand-held platforms. However, the military domain is a harsh environment for the use of speech recognition and synthesis technology. Many applications are safety-critical, which has implications for recognition performance. Further, physical (noise, vibration, acceleration) and cognitive characteristics (user stress, time pressure, and workload) of the operating environment make many demands on the technology. As a result, many speech applications are still at the experimental rather than the operational phase, and full implementation of speech based systems in many military applications has not yet been realized.

Prewett, M. S., Johnson, R., Saboe, K., Coovert, M., **Elliott, L.** (in press). Managing workload in human–robot interaction: A review of empirical studies. Accepted by Computers in Human Behavior.

Working with robots is challenging, often characterized by high levels of workload with technical systems that stress the information processing capabilities of human operators. We seek to understand these workload demands through examining the literature in major content areas of human-robot interaction. Background: Socio-technical systems perspective provides a useful framework for human-robot interaction (HRI). As research on HRI continues to explore a host of issues with operator workload, there is a need to synthesize the extant literature to determine its current state and to guide future research. Method: Employing the backdrop of socio-technical systems, we review workload in HRI using the framework of multiple resource theory (MRT; Wickens, 2002). Studies are organized as targeting either perceptual or response demands. Results: This review examined the utility of different interventions for reducing demands on the perceptual system (e.g., multimodal displays) and responses (e.g., automation). The review concludes with guiding principles for application and directions for future research as HRI systems continue to be integrated within larger socio-technical systems. Conclusions: Working with robots is a complex and demanding task. Our synthesis of the literature demonstrates that much is known about how to decrease operator workload. Applications: This work furthers our understanding of workload in complex environments such as those found when working with robots. Principles are provided for those interested in decreasing operator workload in applied settings and also for future research.

Prewett, M.S.; Saboe, K.N.; Johnson, R. C.; Coovert, M.D.; **Elliott, L. R.** (2009). Workload in Human-Robot Interaction: A Review of Manipulations and Outcomes. Human Factors and Ergonomics Society Annual Meeting Proceedings, Volume 53, Number 18, 2009 , pp. 1393-1397(5)

The current study reviews the relationship between manipulations of teleoperator workload and task outcomes, using multiple resource theory as the underlying framework. Results indicated that controlling more than two platforms is detrimental to many performance indices (reaction time, error rate), but overall productivity improves. For studies that manipulated workload for a single robot task, visual demands were a limiting factor, and interventions which reduced visual demands improved performance. The review concludes with guiding principles for managing workload and improving teleoperator performance.

Technical Reports:

Bodenhamer, A. (2007). Assessment of Stereoscopic Display Systems for Assisting in Route Clearance Manipulation Planning Tasks (ARL Tech. Rep. ARL-TR-4195). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

This study was conducted to objectively compare how the use of a three-dimensional (3-D) or two-dimensional (2-D) visual display affects manipulation planning performance in a spatial perception task relevant to the operation of the Buffalo vehicle manipulator arm. Portions of the results are also generalizable to any tele-operated precision manipulation task. The task evaluated involves judging the position of the Buffalo arm relative to targets and obstacles as seen in the visual display from the arm camera. Thirty-two Soldiers trained to use the route clearance vehicle participated in this study at Fort Leonard Wood, Missouri, during the summer of 2006. Significant planning performance benefits were found when the 3-D visual display was used as opposed to the 2-D display. A significant correlation between subjective confidence ratings and objective performance was found with 3-D displays but not with 2-D displays. Most participants indicated that they preferred using the 3-D display instead of the 2-D display.

Bodenhamer, A., and **Pettijohn, B.** (2007). Stereo-Vision Integration on the Route Clearance and Interrogation System (RCIS) (ARL Tech. Rep. ARL-TR-4190). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

During a limited objective experiment conducted by the Maneuver Support Battle Lab at Fort Leonard Wood, Missouri, in 2006, researchers from the U.S. Army Research Laboratory's Human Research and Engineering Directorate assembled and integrated a prototype stereoscopic camera and display system onto the Route Clearance and Interrogation System concept vehicle. The intent was to subjectively determine the effectiveness and suitability of stereo-vision capability as applied to tele-operated route clearance tasks. Soldiers participated in several scenarios in which the following were examined: targets in culverts and behind guardrails; targets buried beside roads; rubble in the roads; rubble piles beside the roads, in partially destroyed structures, and buried in asphalt or concrete. The conceptual system showed promise in certain tasks such as manipulating debris and interrogating targets. However, in certain tasks, stereo-vision provided no perceived benefit. Suggestions for improvement of future stereo-vision system hardware were also developed.

Chen, J. Y. C., Oden, R. V. N., **Kenny, C.**, & Merritt, J. O. (in press). Effectiveness of stereoscopic displays for indirect-vision driving & robot teleoperation (ARL Tech Report ARL-TR-). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

A three-part experiment was conducted to investigate the usefulness of two types of 3-D stereoscopic displays (SDs) for simulated indirect-vision driving (with various terrains) and live robot teleoperation. Results showed that overall, participants completed their tasks significantly faster when they used an SD in 3-D mode compared to the baseline 2D/monoscopic condition. They also navigated more accurately with SDs in 3-D mode. When the effectiveness of the SDs was examined separately, the results showed that the system with active 3-D shutter glasses appeared to be more effective in supporting faster responses and task completion times than did the system using passive polarized 3-D glasses. Participants' self-assessed "simulator sickness" and workload after interacting with the two SD systems did not differ significantly between displays or between the 3-D vs 2D modes of operation.

Coovert, M., Prewett, M., Saboe, K., Johnson, R., **Elliott, L**. *Development of principles for multimodal displays in Army Human Robot Operations.* (In review). ARL-TR-xxxx, Aberdeen Proving Ground, MD: Army Research Laboratory.

Work in the area of robots and human-robot interaction is exploding. We review part of the literature and provide recommendations for future research. Three papers review topics of special interest: workload, autonomy, and visual displays. Further information on the papers reviewed for this project can be found in an on-line database.

Elliott, L. R., Coovert, M. D., Prewett, M. S., Walvoord, A. G., Saboe, K. N., Johnson, R. C. (2009). A review and metaanalysis of vibrotactile and visual information displays. Technical Report, Army Research Laboratory/Human Research and Engineering Directorate.

Many studies have investigated the impact of vibrotactile cues on task performance, but the wide range of cue and task types have made findings difficult to interpret without a quantitative synthesis. We provide a systematic review of studies on vibrotactile cue effectiveness with regard to task performance, organized by types of comparisons and cue complexity. Forty five studies met the criteria for meta-analytic comparisons. Three types of comparisons were made: (1) the addition of a new tactile cue to a "baseline" condition, (2) the comparison of tactile cues to visual cues representing the same information, and (3) the comparison of visual cues compared to a multimodal combination of tactile and visual cues representing the same information. The level of cue information complexity was also examined as a moderator. When added to a baseline task or existing visual cues, tactile cues enhanced task performance. When tactile cues replaced visual cues, however, effects are attenuated and moderated by cue information complexity. Tactile alerts are effective when replacing visual alerts, but tactile direction cues do not improve performance when replacing visual direction cues. This meta-analysis of tactile applications underscores the benefits of vibrotactile and multimodal displays, highlights conditions in which tactile cues are particularly effective, and identifies areas in need of further investigation.

Elliott, L.R., Duistermaat, M., **Redden, E**., van Erp, J., (2007). Multimodal Guidance for Land Navigation. (Technical Report No. ARL-TR-4295). Aberdeen Proving Ground: Army Research Laboratory.

This report describes the third in a series of collaborative experiments between the U.S. Army Research Laboratory and TNO Human Factors (Soesterberg, The Netherlands). In each experiment, a personal tactile navigation (PTN) system for land navigation was compared with alternate land navigation systems in wooded terrain at Fort Benning, Georgia, during high workload conditions that included secondary tasks such as radio communications, target detection, and determination of location coordinates. This report briefly summarizes results of the first and second studies and describes in further detail the third experiment which assessed navigation and target detection performance when the PTN and a hand-held commercial global positioning system (GPS) device were used singly and together. Most important are findings relevant to how systems can be used most effectively when Soldiers have both. Results demonstrate the effectiveness and high Soldier appreciation of having both systems. This report also contains Soldier recommendations for how both systems can be improved and how best to use both systems when in operations.

Pettijohn, B., **Bodenhamer, A**., Kingston, D., Newell, S., and Geulen, V. (2009). 3-D Visualization System Demonstration on the TALON Robot (ARL Tech. Rep. ARL-TR-4980). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

During a demonstration conducted at Fort Leonard Wood, MO during 18–22 August 2008, researchers from the U.S. Army Research Laboratory, Polaris Corporation, and Concurrent Technologies Corporation integrated a stereoscopic camera and display system onto the TALON robot. The intent of the demonstration was to determine how well this new three-dimensional (3-D) vision performed as compared to the current two-dimensional (2-D) system. Seven Soldiers participated in several scenarios in which targets were examined behind guard rails, rubble piles, caves, point monitoring, site surveillance, and route reconnaissance. Three of the missions were shown to have a statistically significant savings in mission time when using 3-D as compared to 2-D (22%–43% time savings). Stereovision was also shown to help Soldiers successfully accomplish a mission compared to the 2-D system. Using 3-D provided greater manipulator spatial awareness as was seen in the point monitoring mission. Soldiers overwhelmingly expressed a favorable opinion of the 3-D visualization system in performing their missions. They indicated enhanced depth perception, more confidence in controlling the TALON robot, and greater precision in using the arm. Design improvements were identified including smaller and more ruggedized cameras, signal transmission refinement, screen glare reduction, and integrated controls with the TALON operational control unit.

Pettijohn, B. & **Bodenhamer, A.** (2007) Stereo-Vision on the Mine-Protected Clearance Vehicle (Buffalo) (ARL Tech. Rep. ARL-TR-4189). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

During an experiment conducted by the Maneuver Support Battle Lab at Fort Leonard Wood, Missouri, in November 2006, researchers from the U.S. Army Research Laboratory's Human Research and Engineering Directorate integrated a stereoscopic camera and display system onto the medium mine-protected vehicle (Buffalo). The intent of the experiment was to determine how well this new three-dimensional (3-D) vision system performed as compared to the current two-dimensional (2-D) system. For the first time, the 3-D system had parity with the 2-D system in the ability to pan, tilt, and zoom. Soldiers participated in several scenarios in which targets were examined behind guard rails, buried beside roads, rubble piles beside the roads, berms, and in vehicles. The stereoscopic system showed promise in tasks that were close to the end of the manipulator arm as compared to the investigation of objects by zooming from a great distance. Several manipulative tasks were also performed such as putting the tines through the twist ties of a trash bag and moving the bag, lifting trashbags, lifting tires, lifting flaps on boxes, and flipping a box over. Most of the manipulative tasks took less time when stereo-vision was used versus 2-D. Suggestions for the improvement of future stereo-vision system hardware were also developed.

Pettijohn, B. & **Bodenhamer, A.** (2007) Stereo-Vision on the Mine-Protected Clearance Vehicle (Buffalo) (ARL Tech. Rep. ARL-TR-4189). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

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Pomranky, R., **Cosenzo, K**., **Bodenhamer, A**., & **Pettijohn, B**. (2009). Experimental Evaluation of Computer –Aided Tele-operation (CATO) and Computer-Aided Robotic Manipulation (CARMAN) Technology Technical Report.

None.

Proceedings Papers:

Bodenhamer, A., **Pettijohn, B**., Pezzaniti, J., Edmondson, R., Vaden, J. (2010) 3-D Vision Upgrade Kit for the TALON Robot System. In Proceedings of Society of Photo-Optical Instrumentation Engineers Stereoscopic Displays and Applications Conference, San Jose, January 2010.

In September 2009 the Fort Leonard Wood Field Element of the US Army Research Laboratory - Human Research and Engineering Directorate, in conjunction with Polaris Sensor Technologies and Concurrent Technologies Corporation, evaluated the objective performance benefits of Polaris' 3-D vision upgrade kit for the TALON small unmanned ground vehicle (SUGV). This upgrade kit is a field-upgradable set of two stereo-cameras and a flat panel display, using only standard hardware, data and electrical connections existing on the TALON robot. Using both the 3-D vision system and a standard 2D camera and display, ten active-duty Army Soldiers completed seven scenarios designed to be representative of missions performed by military SUGV operators. Mission time savings (6.5% to 32%) were found for six of the seven scenarios

when using the 3-D vision system. Operators were not only able to complete tasks quicker but, for six of seven scenarios, made fewer mistakes in their task execution. Subjective Soldier feedback was overwhelmingly in support of pursuing 3-D vision systems, such as the one evaluated, for fielding to combat units.

Chen, J. Y. C., Oden, R. V. N., **Kenny, C**., & Merritt, J. O. (2010). Stereoscopic displays for robot teleoperation and simulated driving. *Proceedings of Human Factors and Ergonomics Society 54th Annual Meeting,* San Francisco, Sep. 27- Oct. 1, 2010.

A three-part experiment was conducted to investigate the usefulness of two types of 3-D stereoscopic displays (SDs) for simulated indirect-vision driving (with various terrains) and live robot teleoperation. Results showed that, overall, participants completed their tasks significantly faster when they used an SD in 3-D mode compared to the baseline 2D/monoscopic mode. They also navigated more accurately with SDs in 3-D mode. The results also showed that the system with active 3-D shutter glasses appeared to be more effective in supporting faster responses and task completion times than the system using passive polarized 3-D glasses. Participants' self-assessed "simulator sickness" and workload after interacting with the two SD systems did not differ significantly between displays or between the 3-D vs. 2D modes of operation.

Coovert, M. D., & **Elliott, L. R**. (2008, Nov). Robotic enhancements to visual perception: A qualitative review on human-robot interaction. Poster session at 2nd annual Education and Research Center Research Poster Session, University of South Florida, Tampa, FL.

None.

Edmondson, R, Vaden, J, Morris, J, Hyatt, B, Pezzaniti, Chenault, D, Tchon, J, Barnidge, T, Kaufman, S, Kingston, D, Newell, S, **Pettijohn, B, and Bodenhamer, A.**   3-D vision upgrade kit for TALON robot. (Paper 7692-20). In Proceedings of SPIE Vol. 7692, Unmanned Systems Technology XII, Orlando, FL, April 6-9, 2010.

None.

Edmondson, R, Vaden, J, Morris, J, Hyatt, B, Pezzaniti, Chenault, D, Tchon, J, Barnidge, T, Kaufman, S, Kingston, D, Newell, S, **Pettijohn, B, and Bodenhamer, A.** (2010)   3-D display for enhanced tele-operation and other applications. (Paper 7690B-44). In Proceedings of SPIE Vol. 7690, Display Technologies and Applications for Defense, Security, and Avionics IV, Orlando, FL, April 6-9, 2010.

None.

Haas, E.C. (2006). The role of emerging multimodal technologies in enhancing combat and civilian system safety. In Proceedings of the *American Society of Safety Engineers 2006 Conference*.

Within the last several years, the introduction and use of increasingly complex equipment has made military systems relatively dynamic and cognitively demanding, where soldiers must simultaneously monitor multiple displays, operate multiple controls, and process large amounts of information. U.S. Army, Navy and Air Force researchers have been exploring advanced control and display technologies to make military systems safer and more effective to use under such challenging conditions. These technologies include spatial auditory displays, skin-based haptic and tactile displays, and automatic speech recognition (ASR) controls. When used by themselves or together, displays involving more than one sensory modality (also known as multimodal displays) can enhance Soldier safety in a wide variety of applications. Multimodal controls and displays are also found in civilian applications.

Haas, E.C. (2007). Integrating auditory warnings with tactile cues in multimodal displays for challenging environments. In Proceedings of the *International Conference on Auditory Displays,* 127-131.

In battlefield environments of the future, auditory warnings may be integrated with tactile cues in multimodal displays. The U.S. Army is exploring the use of audio and tactile multimodal displays in applications such as the human robotic interface (HRI) to enhance Soldier performance in controlling battlefield robots. Particularly important issues in the Army HRI, as in many challenging environments, include maintaining user spatial situation awareness and providing warning signals for safety hazards. This paper will describe current research in audio and tactile display design for HRI and other applications. Best practices for integrating audio with tactile signals will be described, as well as design issues that need to be resolved.

Haas, E.C. (2007). Emerging Multimodal Technologies Relevant in Enhancing Combat and Civilian System Safety. In Proceedings of the *Professional Safety, American Society of Safety Engineers.*

None.

Haas, E.C., **Pillalamarri, R.S**., **Stachowiak, C.C**., and **Lattin, M.A**. (2006). Audio Warning cues to assist visual search in narrow field-of-view displays. In Proceedings of the *International Ergonomics Association* 16th World Congress on Ergonomics.

Mission demands have made the robotics collaboration operator control unit (OCU) into a relatively dynamic, demanding, cognitively complex system where Soldiers must perform multiple tasks such as controlling multiple robots and processing large amounts of information in environments that sometimes contain high levels of noise. Research and modeling data indicate that audio display technologies would be very useful in OCU applications such as guiding visual display search. The purpose of this study was to examine the effectiveness of the integration of auditory display technologies in visual search tasks such as those that occur in robotic OCUs. Independent variables were audio signal mapping scheme, type of verbal positional cue, and visual target azimuth. Dependent variables were visual target search time and the National

Aeronautics and Space Administration Task Load Index workload rating of the target search task. Participants were 36 students (15 males and 21 females) from Harford Community College. The results indicated that the use of auditory signal mapping and verbal positional cues significantly reduced visual display search time and workload and that positional cues mixed with specific audio mappings were the most efficient means of reducing search time. Specific design recommendations are made regarding the use of auditory signals in environments with narrow field-of-view visual displays.

Haas, E.C., **Stachowiak, C.C**., (2007). Multimodal displays to enhance human robot interaction on-the-move. In Proceedings of the *Performance Metrics for Intelligent Systems (PerMIS) Conference* (p. 135-140).

The U.S. Army is exploring the use of advanced technologies such as tactile and spatial (3-D) audio displays to enhance Soldier performance in human-robot interaction (HRI) tasks. A field study was conducted at the U.S. Army Research Laboratory (ARL) in 2006 to determine the extent to which the integration of spatial auditory and tactile displays affects soldier situation awareness in a simulated UV HRI target search task performed in a moving HMMWV. Participants were 12 civilian males ranging in age from 18 to 46 years, with a mean age of 32 years. Participants performed a target search task, in which they searched for one target symbol among 50 non-target symbols displayed on an 18-inch diagonal computer monitor (a 30° field of view (FOV) visual display). Participants received audio and tactile cues to indicate on which third of a computer screen the target symbol was located. The independent variables were display modality, signal azimuth, participant age, and HMMWV movement condition. Display modalities were visual displays with supplemental cues in three display modalities; spatial audio, tactile, and combined spatial audio + tactile. The dependent variables were participant response time and accuracy, as well as the participant's subjective workload rating of display modality effectiveness. Accuracy data indicated that participants located over 99% of the targets correctly. Display modality was significant in terms of participant workload ratings, but was not significant for response time. Response time data indicated that no one display modality provided the shortest response time to all age groups, for all terrains. Workload with auditory + tactile displays was rated lowest of the three display modalities, which may have been because the combination audio + tactile display incorporated cues from both the audio and tactile modalities, an advantage in an environment with strong auditory and tactile distractors. The discrepancy between the workload and the performance data indicate that a greater understanding is needed of the role of each modality in on-the-move operations. Future research will deal with multimodal directional cues that can inform Soldiers of important HRI events 360° around of their field of view.

Johnson, R. C., Saboe, K. N., Prewett, M. S., Coovert, M. D., & **Elliott, L. R.** (2008, Nov.). Autonomy and automation reliability in human-robot interaction: A qualitative review. Poster session at 2nd annual Education and Research Center Research Poster Session, University of South Florida, Tampa, FL.

Automation and the reliability of automation aids are both hot topics in the area of human-robot interaction (HRI). As more tasks are subsumed by robots and autonomous systems, it is important to examine the relationships between these entities and their human operators. Research to date has covered many task categories and various manipulations of autonomy, but this broad body of research is in need of focus and consistency. The current study presents a qualitative overview of research in the areas of level of autonomy/control and automated aid reliability and the effects they have on important outcome variables as they directly pertain to HRI. Results indicate that autonomy and automation aids operate very differently for different tasks, and that there are many complex factors that can affect not only performance but also usability, confidence, and safety. Unresolved issues in the field and challenges and opportunities for future research are also presented.

Johnson, R., Prewett, M., Saboe, K., **Elliott, L.** Coovert, M. (2009). Multi-Platform Control and Task Difficulty in Human-Robot Interaction: A Qualitative Review In Proceedings of the Human-Robot Interaction, Santa Monica, CA. Publication.

With the increasing application of robots, there is a need to establish the workload conditions for optimal user performance. A body of research has examined workload in human-robot interactions (HRI) via two methods: by providing more platforms to use for the same tasks, or by increasing the difficulty of the platform tasks. The current study addresses the theoretical impact these two manipulations have on user workload and, subsequently, user performance. It also tests the developed theoretical models by reviewing HRI experimental studies on workload. Results indicate that controlling more than two platforms causes a serious detriment for many performance indices (reaction time, efficiency), but such control can improve overall productivity. Time pressure and task criterion manipulations of task difficulty resulted in sharper decreases in study outcomes. The reviewed studies also suggested that automation and multimodal feedback can mitigate the negative impact of workload. In conclusion, the review suggests a resource model of workload in HRI instead of a single channel model, and provides several guiding principles for workload in HRI.

Saboe, K., Johnson, R., Prewett, M., **Elliott, L.** Coovert, M. (2009). Effectiveness of Visual Modalities in Human-Robot Interaction: A Qualitative Review. In Proceedings of the Human-Robot Interaction Conference,2009, Santa Monica, CA. Publication.

Visual modalities employed in human-robot interaction (HRI) have matured from mere tools to integrated technological extensions of the body. Research must follow suite and strive to create a programmatic framework to address the current lack of common operations. The current quantitative analysis organizes five commonly manipulated visual modalities into three categories. We synthesized existing research to create a needed foundation for future studies. Analytic results suggest that robot enhanced visual systems aid operators' overall task performance insofar the visual modality is congruent with the operators' task. More importantly, results indicate that our current understanding of visual modalities is rudimentary and full of caveats

Saboe, K. N., Johnson, R. C., Prewett, M. S., Coovert, M. D., & **Elliott, L. R.** (2008, Nov). Robotic enhancements to visual perception: A qualitative review on human-robot interaction. Poster session at 2nd annual Education and Research Center Research Poster Session, University of South Florida, Tampa, FL.

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Thrust Area 4: Human Inspired Robotics - Cognitive Robotics

Research Protocols:

Costs and Benefits of Types of Human to Robot Communication (PIs**: Troy Kelley, Daniel Cassenti**)

As use of robots increases in military tasks, there is a corresponding need for Army research to increase the power and flexibility of robotic systems. The proposed experiment was designed to provide data to increase the performance capabilities of robotic operators with particular emphasis on human-robot communication and the recognition that Soldiers often must multi-task while performing a primary duty. The study will shed light on how style of communication affects performance and how a robotic control system would need to be modified to provide greater robotic goal achievement. The study will include three levels of robotic control: manual, verbal commands restricted to direction information, and verbal commands that allow reference to objects in the environment. Another independent variable will include or not include a secondary math task. Results will be analyzed using typical statistical procedures and interpreted to provide guidance for preferred modifications to a robotic control system.

Research Area 4.1 – Perception

Journal Articles and Book Chapters:

Kelley, T. D. (2006). Developing a Psychologically Inspired Cognitive Architecture for Robotic Control: The Symbolic and Subsymbolic Robotic Intelligence Control System (SS-RICS). *International Journal of Advanced Robotic Systems*, Vol. 3, No. 3.

This paper describes the ongoing development of a robotic control architecture that was inspired by computational cognitive architectures from the discipline of cognitive psychology. The robotic control architecture combines symbolic and subsymbolic representations of knowledge into a unified control structure. The architecture is organized as a goal driven, serially executing, production system at the highest symbolic level; and a multiple algorithm, parallel executing, simple collection of algorithms at the lowest subsymbolic level. The goal is to create a system which will progress through the same cognitive developmental milestones as do human infants. Common robotics problems of localization, object recognition, and object permanence are addressed within the specified framework.

Kelley, T.D. & **Cassenti, D.N.** (in press). Theoretical explorations of cognitive robotics using developmental psychology. *New Ideas in Psychology*.

How can cognitive robotics inform developmental psychology researchers and what can developmental psychology tell us about creating robots? More importantly, how can cognitive robotics and developmental psychology nourish each other to become a symbiotic relationship for future research? We address the theoretical underpinnings of developmental change using a cognitive architecture implemented on a robotic system and how our theories of knowledge representation relate to critical periods of infant development. Next, we will show how descriptive theories of cognitive development, specifically Zelazo's Levels of Consciousness (LOC; Zelazo, 2000, 2004; Zelazo & Jacques, 1996), can be mapped onto a computational cognitive architecture (ACTR; Anderson & Lebiere, 1998). Following our discussion of Zelazo's theory, we will apply the ACT-R architecture specifically to the problem of object permanence. Finally, we will address how cognitive robotics can serve as a computational proving ground of developmental psychology for future research.

Kelley, T.D., Long, L.N. (in press). Deep Blue can't play checkers: The need for generalized intelligence for mobile robots. *Journal of Robotics.*

Generalized intelligence is much more difficult than originally anticipated when Artificial Intelligence (AI) was first introduced in the early 1960s. Deep Blue, the chess playing supercomputer, was developed to defeat the top rated human chess player and successfully did so by defeating Gary Kasporov in 1997. However, Deep Blue only played chess; it didn't play checkers, or any other games. Other examples of AI programs which learned and played games were successful at specific tasks, but generalizing the learned behavior to other domains was not attempted. So the question remains: Why is generalized intelligence so difficult? If complex tasks require a significant amount of development time and task generalization is not easily accomplished, then a significant amount of effort is going to be required to develop an intelligent system. This approach will require a system of systems approach that uses many AI techniques: neural networks, fuzzy logic, and cognitive architectures.

Technical Reports:

Kelley, T. D. (2009). Using a Cognitive Architecture to Solve Simultaneous Localization and Mapping (SLAM) Problems (ARL Tech. Rep. ARL-MR-0639). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

The cognitive production system architecture, the Atomic Components of Thought-Rational (ACT-R), was applied to the problem of simultaneous localization and mapping (SLAM). The map space was represented as a topological map of salient features, which was then evaluated using a production system architecture (ACT-R). Results showed that intrinsic error associated with robotic sensor readings was overcome by using the simulated human memory activation equations of ACT-R. Additionally, results showed that recognition of different topological map locations by using evaluations of ACT-R was possible and allowed the robot to recognize five unique map locations.

Proceedings Papers:

Cassenti, D.N. (2007). Recovery from automation error after robot neglect. In Proceedings of the *Human Factors and Ergonomics Society 51st Annual Conference*, (pp. 1096-1100). Santa Monica, CA: Human Factors and Ergonomics Society.

Automation is a robot's ability to control itself without operator intervention. Advances in automation have resulted in a phenomenon called robot neglect (Crandall & Goodrich, 2003) in which a robot operator infrequently attends to an automated robot. Robot neglect becomes a problem when automation fails and the robot operator is not attending to the robot. This work outlines a set of guidelines for aiding an operator faced with robot neglect followed by automation failure. The guidelines focus on how video replay of the incidents leading up to the failure may help the operator overcome inattention and regain situation awareness. Complications with this approach in past research are addressed.

Research Area 4.2: Human Robot Communication

Journal Articles and Book Chapters:

Long, L. N. and **Troy D. Kelley**, (2010) A Review of Consciousness and the Possibility of Conscious Robots. *Journal of Aerospace Computing, Information, and Communication, 7(*2*),* February.

This paper will discuss the psychological, philosophical and neurological definitions of consciousness and the prospects for the development of a conscious machine in the foreseeable future. Various definitions of consciousness are introduced and discussed within the different fields mentioned. We conclude that a conscious machine may be within the realm of engineering possibilities if current technological developments, especially Moore's Law, continue at their current pace. Given the complexity of cognition and consciousness a hybrid architecture appears to offer the best solution for the implementation of a complex system of systems which functionally approximates a human mind. Ideally, this architecture would include traditional AI symbolic representations as well as distributed representations which approximate the nonlinear dynamics seen in the human brain.

Proceedings Papers:

Avery, E., **Kelley, T. D**., Davani, D. (2006). Using Cognitive Architectures to Improve Robot Control: Integrating Production Systems, Semantic Networks, and Sub-Symbolic Processing. In Proceedings of *15th Annual Conference on Behavioral Representation in Modeling and Simulation (BRIMS).* May 15-19, Baltimore, MD.

In the last several decades, cognitive architectures have been designed around psychological principles in an attempt to reproduce the thought patterns of the human mind. These cognitive architectures have made progress in modeling the human mind by using the production system architecture as a basis; however, they traditionally have little interaction with the outside world which gives them limited functionality as real-world agents. Additionally, these systems place a heavy burden on the modeler to hand code large memory structures and task specific production systems. In this paper, we explore the architecture and capabilities of the Symbolic and Sub-symbolic Robotic Intelligence Control System (SS-RICS) which was inspired by cognitive architectures capable of higher order cognition such as the Adaptive Control of Thought-Rational., SS-RICS integrates production systems, semantic networks, machine learning and sub-symbolic processing to achieve real-time mobile robot control. It is our belief that this integration of cognitive psychological techniques and AI techniques will allow mobile robots to have higher order understanding and interaction with the dynamic world in which we live.

Cassenti, D.N., **Kelley, T.D**., **Swoboda, J.C**, & **Patton, D.J**. (2009). The Effects of Communication Style on Robot Navigation Performance. In Proceedings of the Human Factors and Ergonomics Society 53rd Annual Meeting (pp. 359-363). San Antonio, TX: Human Factors and Ergonomics Society.

With the advance of computer speech recognition programs, robotic operators have a new method of robot-operator communication. An experiment was conducted using a "Wizard of Oz" paradigm to investigate how different styles of communication affect robot navigation performance. Using manual inputs, verbal commands (restricted to directions only), and verbal commands with object referent labels, participants navigated a simulated robot through various simulated indoor environments. Results indicated that manual control was faster than free form verbal commands but not faster than simple directional commands. When provided the opportunity, participants did use object labels particularly objects related to the structure of the building (doors, rooms, and halls). Discussion focuses on improving robotic communication and object recognition in a robotic control system.

Kelley, T.D. (2006). Simulating Intelligent Behavior Requires a Complex Approach. In Proceedings of the *2006 AAAI Spring Symposium on Between a Rock and a Hard Place: Cognitive Science Principles Meet AI-Hard Problems*. Eds. C. Lebiere & R. Wray.

This paper will propose three arguments for a multilevel heterogeneous approach to Artificial Intelligence (AI) hard problems. By a heterogeneous approach, we mean the use of multiple methodologies (symbolic, sub-symbolic, subsumption) to solve AI problems. First, if one accepts the postulate that cognitive psychological principles can be beneficial to AI, then one must look at the heterogeneous nature of the human cognitive system. The brain is not homogeneous; it is a collection of different cellular organizations performing different functions. Secondly, there are several examples from the cognitive systems literature that show hybrid approaches provide effective solutions to complex problems. In some cases, these approaches have been better than a single approach. Finally, cognition is so complex, so full of subtle nuance and interwoven interdependencies, that a multiple level heterogeneous approach is the only approach that will prove to be successful in the long term. In other words, the complexity of perceiving and understanding the environment in a human manner necessitates a multilevel approach.

Long, L. N., **Kelley, T. D.** (2009). The requirements and possibilities of creating conscious systems. *Presented at the AIAA InfoTech@Aerospace Conference: AIAA Paper No. 2009-1949*, Seattle, WA.

This paper will discuss the psychological, philosophical and neurological definitions of consciousness and the prospects for the development of a conscious machine in the foreseeable future. Various definitions of consciousness are introduced and discussed within the different fields mentioned. We conclude that a conscious machine may be within the realm of engineering possibilities if current technological developments, especially Moore's Law, continue at their current pace. Given the complexity of cognition and consciousness a hybrid architecture appears to offer the best solution for the implementation of a complex system of systems which functionally approximates a human mind. Ideally, this architecture would include traditional AI symbolic representations as well as distributed representations which approximate the nonlinear dynamics seen in the human brain.

Long, L. N., **Kelley, T. D**., & Wenger, M. J., (2008). The Prospects for Creating Conscious Machines. *Presented at the "Toward a Science of Consciousness" Conference*, Tucson, AZ.

This paper will discuss the psychological, philosophical and neurological definitions of consciousness and the prospects for the development of a conscious machine in the foreseeable future. Various definitions of consciousness are introduced and discussed within the different fields mentioned. We conclude that a conscious machine may be within the realm of engineering possibilities if current technological developments, especially Moore's Law, continue at their current pace. Given the complexity of cognition and consciousness a hybrid architecture appears to offer the best solution for the implementation of a complex system of systems which functionally approximates a human mind. Ideally, this architecture would include traditional AI symbolic representations as well as distributed representations which approximate the nonlinear dynamics seen in the human brain.

Human System Integration

Thrust Area 1: Soldier Modeling and Simulation (Tool Development)

Research Area 1.1: Improved Performance Research Integration Tool (IMPRINT) Development

Samms, C., Jones, D., Hale, K., & **Mitchell, D.** (2009)**.** Harnessing the Power of Multiple Tools to Predict and Mitigate Mental Overload. Engineering Psychology and Cognitive Ergonomics, Springer Berlin / Heidelberg. 5639/2009: 279-288.

Predicting the effect of system design decisions on operator performance is challenging, particularly when a system is in the early stages of development. Tools such as the Improved Performance Research Integration Tool (IMPRINT) have been used successfully to predict operator performance by identifying task/design combinations leading to potential mental overload. Another human performance modeling tool, the Multimodal Interface Design Support (MIDS) tool, allows system designers to input their system specifications into the tool to identify points of mental overload and provide multi-modal design guidelines that could help mitigate the overload identified. The complementary nature of the two tools was recognized by Army Research Laboratory (ARL) analysts. The ability of IMPRINT to stochastically identify task combinations leading to overload combined with the power of MIDS to address overload conditions with workload mitigation strategies led to ARL sponsorship of a proof of concept integration between the two tools. This paper aims to demonstrate the utility of performing low-cost prototyping to combine associated technologies to amplify the utility of both systems. The added capabilities of the integrated IMPRINT/MIDS system are presented with future development plans for the system.

Samms, C. (2006). IMPRINT and Augmented Cognition: Reducing the Cognitive Demands of the Future Force. Foundations of Augmented Cognition 2nd Edition.

An Army of One is more than a slogan. Tomorrow's Soldier faces quickly deployable military vehicles requiring increased reliance on technology, cross-training and multitasking to complete the mission. Augmented cognition is a field of research that is looking into developing technology to support the Soldier by considering his capabilities and limitations in the design. In military missions such as command and control, dismounted operations and robotic control, augmented cognition could help the future force work more efficiently and effectively. The Improved Performance Research Integration Tool (IMPRINT) is the U.S. Army Research Laboratory's (ARL) task network modeling tool designed to estimate system performance as a function of human performance. In the early design phase of future systems, IMPRINT can be used to identify areas where augmented cognition could be beneficial to human performance and could then assess the effect of the developed technology on system performance.

Wojciechowski, J.Q. (2007). "Development of a User-Defined Stressor in the Improved Performance Research Integration Tool (IMPRINT) for Conducting Tasks While in a Moving Vehicle". Aberdeen Proving Ground, MD: U.S. Army Research Laboratory. ARL-MR-0659. Aberdeen Proving Ground, MD.

Human performance modeling tools are used to predict the effect of human performance on the system. The U.S. Army Research Laboratory developed a human performance modeling tool, the Improved Performance Research Integration Tool (IMPRINT), which allows an analyst to investigate the effect of subjecting operators to environmental stressors on mission performance. The latest version of IMPRINT has the capability to create user-defined stressors to study the effect of stressors on human performance and therefore system performance. This study used data that predict the effect on task time and performance based on task characteristics when Soldiers are riding in a moving vehicle to create a user-defined stressor in IMPRINT. A case study was completed on a simple model of command and control tasks. The user-defined stressor was applied to show the effect of completing these tasks on task time and accuracy after participants were in a moving vehicle for 0, 1, 2, 3, 4, and 5 hours. The data from the study indicate that tasks are affected differently, but most data show an increase in time to complete and a decrease in the accuracy of the operator. This study shows the effect of operating in a moving vehicle. These data are useful not only to a system design but also to the development of tactics and procedures.

Research Area 1.2: Logistics Planning and Maintenance Manpower Decision Support Tools

del Rosario, R.D., Tom, K.F., Mitchell, G., Ruth, B.G., **Grazaitis, P.J.**, Ferryman, T., Scharett, D.E., and Toomey, Jr., C.J. (2009). Underlying Technologies for Military Logistics Prediction and Preemption Capability. (ARL-SR-0166). Army Research Laboratory, APG, MD.

This report captures the results of a comprehensive assessment of technical requirements associated with achieving a logistics predictive and preemptive capability, or LPPC. It represents Phase II in a three-phased approach spanning operationally- and technically-focused assessment. Phase I, conducted from September to December 2006, documented the compelling case for predictive capabilities, tying it to guidance and concept development at the OSD, Joint, and Army levels. Phase II, the subject of this report, has as its objective the forecasting of technologies expected to be available through the year 2030 and their potential to provide predictive planning and analysis capabilities. The Phase II report thus becomes the catalyst for, and enabler of, Phase III – an assessment of the potential operational and resource benefits of predictive and preemptive capabilities, to include the development of actionable recommendations to senior logistics leaders on the steps necessary to achieve the envisioned end-state.

Thrust Area 2: Soldier Centered Analysis for the Future Force

Research Area 2.1: Human Performance Modeling in Support of System Development

Animashaun, A. F. (2007) A Human Factors Engineering Assessment of the Buffalo Mine Protection Clearance Vehicle Roof Hatch, (ARL-TR-4272), Aberdeen Proving Ground, MD.

The project was initiated at the request of two platoons of Combat Engineers, military occupational specialty 21B, who serve as part of the Kansas National Guard. The U.S. Army Research Laboratory's (ARL's) Human Research and Engineering Directorate performed an evaluation of the emergency egress characteristics of the Buffalo. ARL developed a plan to evaluate the emergency egress characteristics of the Buffalo using human figure modeling. A detailed analysis of the vehicle roof hatch was performed to identify whether the larger end of the male Soldier population, with equipment and clothing, could fit through the hatch. The results of the egress modeling identified some shortcomings with the emergency egress characteristics of the Buffalo and two recommendations were made: (1) increase the hatch size to 69 cm by 50 cm or (2) use a circular hatch with a diameter measuring 61 cm instead of a rectangular or square hatch. The results and recommendations from the modeling were used to help drive design modifications that, if implemented, could enhance the emergency egress characteristics of the Buffalo.

Havir, H., **Kozycki, R.** (2006). An Assessment of the Emergency Egress Characteristics of the U.S. Army Airborne Command and Control System (A2C2S) (ARL-MR-635). U. S. Army Research Laboratory. Aberdeen Proving Ground, MD.

The U.S. Army Airborne Command and Control System (A2C2S) is a command and control (C2) system consisting of an A-kit and a B-kit and will be hosted by the utility helicopter (UH)-60L (and newer) Blackhawk. The A2C2S Product Manager (PM) requested the U.S. Army Research Laboratory (ARL) Human Research and Engineering Directorate to perform an evaluation of the emergency egress characteristics of the A2C2S to help support the low rate initial production (LRIP) milestone decision. ARL and the PM developed a plan to evaluate the emergency egress characteristics of the A2C2S using a combination of human figure modeling and egress testing. The evaluation plan used human figure modeling to perform a detailed analysis of all egress routes to identify whether the larger end of the male Soldier population, with equipment, could fit through the egress routes and to identify design characteristics of the A2C2S that enhance or degrade the Soldier's ability to egress the aircraft. The emergency egress test was used to validate the results of the model, verify that the egress could meet the time requirements, and identify additional safety concerns that may be encountered during actual egress trials. The results of the egress modeling identified some shortcomings with the egress characteristics of the A2C2S; however, the results were favorable. The results of the egress testing validated the modeling that was performed. In addition, all egress trials successfully met or exceeded the 30-second time standard for emergency egress. The results and recommendations from the modeling and testing were provided to the PM to help drive design modifications that, if implemented, could enhance the emergency egress characteristics of the A2C2S.

Hicks, J.S., Durbin, D. and Kozycki, R. (in press). An Overview of Human Figure Modeling for Army Aviation Systems. U. S. Army Research Laboratory. Aberdeen Proving Ground, MD.

The U.S. Army Research Laboratory, Human Research and Engineering Directorate (ARL-HRED) conducts human figure modeling to design and test Army systems. The modeling has been used to assess and improve the ergonomic design and usability of all modernized Army Aviation systems, as well as to reduce analysis and development timelines. ARL-HRED has also developed a digital library to assess whether or not Army Aviation aircraft and equipment meet human factors engineering design standards. The modeling conducted by ARL-HRED has resulted in numerous system design improvements to meet the human factors engineering design standards. Human figure modeling will continue to play an increasingly important role in the future, as Army Aviation program managers work to develop effective systems, minimize design costs, and shorten design, development, and production timelines.

Hsiao, H., Badler, N., Chaffin, D.B., Yang, K.H., & **Lockett, J.F.** (2008). Digital human modeling goals and strategic plans: key note panel. In *Proceedings of the SAE Digital Human Modeling Conference*, Pittsburgh, PA. Paper number 2008-01-1933. SAE: Warrendale, PA.

No abstract available

Lockett, J.F. and Archer, S.G. (2008). Impact of digital human modeling on military human-systems integration and impact of the military on digital human modeling. In Duffy (Ed.) *Handbook of Digital Human Modeling*. Taylor and Francis: London.

No abstract available

Mitchell, D. K. Abrams V2 SEP Crew Workload Analysis: Impacts of Two Proposed Technologies, Customer Report.

Using the Improved Performance Research Integration Tool (IMPRINT), the ARL HRED analysts developed a model to represent the tasks performed by each member of the Abrams Version 2 with System Enhancement Package (V2 SEP) crew. They then used this model to predict the impact of two new technologies added to the Abrams on the workload and performance of the Abram's crew. The two technologies investigated within the analysis were a driver's aid and a situation awareness display for the loader. Within a mission, the functions the

Abrams crewmembers perform can vary depending upon the scenario segment. Therefore, it is important to evaluate the potential of the reverse driving aid and the 360 SA display within a scenario that includes all the mission segments. The ARL analysts included several mission segments within their IMPRINT analysis. Based on their analysis of the mission segments, the reverse aid and 360 SA display have the potential to increase mission performance without increasing crewmember workload. IMPRINT predicted an increase in crewmember performance due to the technologies in only the reverse driving segment and for the driver. On the other hand, IMPRINT predicted a decrease in loader workload and an increase in loader survivability for this segment and these predictions would mitigate the increase in driver workload. Although the IMPRINT analysis showed the two technologies have potential to reduce crew workload and increase performance, the IMPRINT models could not evaluate all the impacts of the technologies on crew performance. For example, the reverse aid and 360 SA displays are indirect vision display. Therefore, in some instances, the crewmembers are using indirect vision instead of direct vision to perform their tasks. The ARL analysts recommend the PM evaluate these aspects of the technologies within field tests.

Mitchell, D. K. Analysis of soldier workload and performance for alternative reconnaissance (RECCE) vehicle designs (in press. Aberdeen Proving Ground, MD. U. S. Army Research Laboratory.

Classified No abstract available

Mitchell, D. K. (2009). Successfully Changing Conceptual System Designs Using Human Performance Modeling, *Proceedings of Human System Integration Symposium*.

Human system analysts want to impact system design early in the concept phase when design changes are less expensive and, therefore, more likely to be implemented. In meeting this goal, they face the challenge of predicting human performance, including cognitive performance, when no prototypes or mockups exist. The Army Research Laboratory (ARL) has developed, a human performance modeling tool, IMPRINT (Improved Performance Research Integration Tool), to help human system analysts meet this challenge. For a proposed system design, analysts can use IMPRINT to model the tasks the human operators perform and predict their mental workload and its impact on performance. Recognizing the capability of the IMPRINT tool, ARL analysts used IMPRINT in the early design phases of the FCS program to predict the mental workload and performance of the crews operating the conceptual FCS manned ground vehicles (MGVs).

Prior to system functional review, the FCS Lead System Integrator and ARL agreed upon a common IMPRINT model that would be the foundation of the individual MGV human performance analyses. Based on this common model, the ARL analysts then implemented a rigorous experimental design process to structure IMPRINT analyses of crews of specific MGVs. Using IMPRINT they predicted the mental workload and its impact on the performance of the Soldiers operating the mounted combat system (MCS), non-line-of-sight cannon (NLOS-

C), MCS platoon leader's vehicle (MSC PLV), Infantry Carrier Vehicle (ICV), Reconnaissance and Surveillance Vehicle (RS&V), and Combined Arms Battalion (CAB) Headquarters Staff.

Because ARL analysts completed these analyses early in the program, they resulted in changes to the FCS MGV designs that will reduce Warfighters' workload and enhance their performance. Specifically, the ARL MCS analysis resulted in a change to the crew size for the MCS from a 2-Soldier design to a 3-Soldier Design. It is the only FCS manned ground vehicle with a common crew of three. Furthermore, the analysis identified the need for the MCS platform to provide the crew with the capability to engage multiple line-of-sight targets. The ARL NLOS-C analysis benefited the crews operating the NLOS-C when the vehicle designer agreed to investigate an automated rearming concept for the platform. The ARL CAB analysis benefited the headquarters staff by supporting the need to accelerate the rapid prototyping of the Warfighter machine interface services (WMIS) display for evaluation of level of situation awareness. Because the IMPRINT tool is available at no cost to government personnel and contractors, all human systems analysts can use it and implement the ARL approach to successfully change system design with human performance modeling.

Mitchell, D. K. (2009). Workload Analysis of the Crew of the Abrams V2 SEP: Phase I Baseline IMPRINT Model, Technical Report ARL-TR-5028, Army Research Laboratory, Aberdeen Proving Ground, MD.

Using the Improved Performance Research Integration Tool (IMPRINT), the U.S. Army Research Laboratory (ARL) Human Research and Engineering Directorate, (HRED) analysts developed a model to represent the tasks performed by each member of the Abrams version 2 with System Enhancement Package (V2 SEP) crew. They then used this model to predict the mental workload of the crew and its impacts on the performance of the crew of the Abrams V2 SEP. The phase I analysis and its workload predictions will serve as a baseline for a phase II analysis. The phase II analysis will predict the impact of specific additional technologies added to the Abrams on Soldier workload and performance.

Mitchell, D. K. (2008). United We Stand: Using Multiple Tools to Solve a Multi-dimensional Problem, *Proceedings of the 52nd Annual Meeting of the Human Factors and Ergonomics Society*.

Researchers at the Army Research Laboratory (ARL) investigated the impacts of reducing the number and location of personnel assigned to a Combined Arms Battalion Headquarters on Soldier workload, fatigue, and performance. Initial requirements were for 24 personnel to be located within four armored vehicles. Due to design constraints, however, the number of personnel needed to be reduced or some personnel moved to other vehicles. To recommend a solution to this problem, the researchers had to consider multiple human factors issues such as function allocation, mental workload, work space, and fatigue. Therefore, they used multiple human performance modeling tools including JACK, IMPRINT, C3TRACE and FAST to evaluate the problem. Each of these tools provided the analysts with analytical results on a unique aspect of the problem. By integrating these results, the researchers demonstrated the impacts of multiple aspects of this problem. Their recommended solution was closer to optimal because it incorporated many aspects of the problem than are considered typically.

Mitchell, D. K. (2008). Predicted Impact of an Autonomous Navigation System (ANS) and Crew-Aided Behaviors (CABs) on Soldier Workload and Performance, ARL-TR-4342. Army Research Laboratory, Aberdeen Proving Ground, MD.

To predict the impacts of an autonomous navigation system (ANS) and crew-aided behaviors (CABs) on Soldier workload and performance, an analyst from the U.S. Army Research Laboratory (ARL) used the Improved Performance Research Integration Tool (IMPRINT) to model Soldiers with these technologies. The ARL IMPRINT analysis had three objectives: (a) to use IMPRINT to predict the impact of a mission planning and a automated route planning CAB and ANS on Soldier mental workload and performance; (b) to compare the IMPRINT predictions to the data from field experiments that evaluated the impacts of these same technologies on Soldier workload and performance; (c) to extend the experimental data and predict the impact of moving targets on Soldier performance with and without ANS and the CABs. This was because the field experiments used in the comparison had only stationary targets. For the first objective, IMPRINT predicted that one Soldier would not experience overload during mission planning with or without the mission-planning CAB. In addition, the IMPRINT analysis predicted that both the CAB and ANS would reduce workload and improve Soldier performance. Furthermore, IMPRINT predicted that both the CAB and ANS would reduce overall mission time and improve target detection performance. Therefore, both these technologies have the potential to increase Soldier survivability by reducing workload, reducing mission time, and increasing the number of targets detected. Despite the reduction in workload attributable to CAB and ANS, however, the IMPRINT analysis predicted that one Soldier who was trying to complete all the mission-related tasks would be overloaded, especially visually and cognitively, throughout the mission. Because of the predicted high workload, the ARL analyst recommends that additional experiments with CABs and ANS consider reallocation of monitoring tasks to a second crew member as a possible mitigation strategy for overload. Techniques other than visual displays for monitoring battlefield awareness and the status of the remote follower might help mitigate overload as well. For the second objective, a comparison of the IMPRINT data with the Soldier experimental data showed that IMPRINT correctly predicted the number of targets detected for the manual and ANS experimental conditions. It also correctly predicted the reduction in route planning time because of CAB availability. IMPRINT underestimated overall mission time, however. Therefore, the IMPRINT analyst recommends incorporation of vehicle speed and actual route distance into future IMPRINT analyses to ensure more accurate overall mission time. A comparison of the experimental workload data with the IMPRINT workload predictions matched across conditions. Both IMPRINT and the experiment showed the highest workload numbers when the Soldiers planned a route for the remote follower (RF) in the manual driving condition versus the ANS condition. The IMPRINT analyst could not compare the IMPRINT workload predictions to the Soldier's self-report ratings within each mission because the experimenters did not collect workload ratings during the experiment–only at the end. However, the performance decrements attributable to high workload predicted by IMPRINT were consistent with Soldier performance throughout the experiment. For example, the Soldiers had to stop the vehicle in order to complete the plan for the RF. To meet the third objective, the IMPRINT analyst built models representing moving targets and compared these data to the stationary target data from the experiment. The comparison showed no difference in the rate of detection for moving versus stationary targets for any of the conditions.

Mitchell, D. K. (2007) Verification and validation of the IMPRINT MCS analyses utilizing Omni Fusion 06 Part 1 Data (ARL-TR-4027), Aberdeen Proving Ground, MD. U.S. Army Research Laboratory.

This report summarizes the validation and verification of the U.S. Army Research Laboratory (ARL) Mounted Combat System (MCS) platoon leader vehicle (PLV) analysis based on observational data collected during Omni Fusion 06 (OF 06) Part 1. The main findings are (1) the MCS crew were overloaded during urban missions; (2) communications and driving functions need to be added to crew member self-assessment sheets used by the Unit of Action Maneuver Battle Laboratory (UAMBL); (3) the platoon sergeant (PSGT) was overloaded when the armed reconnaissance vehicle (ARV) was used concurrently with other mission functions; and (4) two new functions must be added to the existing Improved Performance Research Integration (IMPRINT) models. During OF 06, the MCS PLV crew performed the local security, fire missions, and crew communications, company communications, and unmanned asset control functions included in the IMPRINT MCS PLV model, and therefore, these are valid crew functions. Two additional functions that the MCS crew performed during the test are not in the current IMPRINT model. The ARL analyst will add these two functions: (1) conduct battle damage and (2) conduct between-platoon communications observed during OF 06 but not in the current IMPRINT analysis. The MCS crew performed communications and driving functions that are included in the ARL IMPRINT analyses but are not listed on the roles-by-function spreadsheet completed by the UAMBL and the Future Combat Systems (FCS) lead system integrator. The ARL analyst recommends that FCS analysts consider the communications as separate functions for an accurate prediction of Soldier workload and performance. It was difficult to validate the IMPRINT workload predictions based on OF 06 observations because the PLV crew allocated roles among themselves differently than in the IMPRINT analyses. The IMPRINT analysis combined the platoon leader (PL) role with vehicle commander role, but two different crew members assumed these roles during the experiment. The PSGT controlled the unmanned assets in the experiment whereas the PL controlled them in the IMPRINT analyses. Despite these differences, the experiment validated the IMPRINT workload predictions. All crew members exhibited high workload when the MCS was moving within the confines of an urban scenario. The driver of the MCS had high workload when driving the vehicle and often required assistance by the PL. When the PL assisted the driver, his workload increased. The

MCS PSGT exhibited high workload when controlling the ARV concurrently with his other functions. The ARL analyst recorded the dialogue among the crew members, between the platoon vehicles, within the platoon vehicles, and between the PLV and company. These data are included in the report and can be used as input to models requiring military message scripts.

Mitchell, D. K., Abounader, B., **Henry, S., & Animashaun, A.** (2009). A Procedure for Collecting Mental Workload Data During an Experiment that is Comparable to IMPRINT Workload Data, Technical Report ARL-TR-5020, Army Research Laboratory, Aberdeen Proving Ground, MD.

Army Research Laboratory (ARL) analysts use the Improved Performance Research Integration Tool (IMPRINT) to predict the mental workload and performance of Soldiers operating the Future Combat System (FCS) manned ground vehicles (MGVs). IMPRINT is a human-performance-modeling tool that analysts use to build models representing Soldiers interacting with equipment to accomplish a mission. The models contain tasks, task sequences, task times, and workload estimates that allow the software to calculate estimates of mental workload and mission performance. One of the key outputs from the IMPRINT models is the combination of tasks likely to contribute to high Soldier workload. Evaluators of FCS equipment can include the potentially high workload task combinations into their evaluations to be sure that they evaluate the tasks mostly like to contribute to mental overload.

The Aberdeen Test Center (ATC) is one of the groups responsible for testing and evaluating FCS equipment and concepts. They must identify any issues that might degrade mission performance, including Soldier mental overload. To ensure that the ATC evaluations include tasks relevant to Soldier mental workload they can include high workload task combinations identified by IMPRINT into their test plans. However, to be compatible with IMPRINT, they must evaluate workload by a methodology compatible with the IMPRINT technique. This paper outlines the methodology ATC and ARL developed within the ACASA/IMPRINT/JWTTC test conducted in May 2008.

Mitchell, D. K. & Brennan, G. (2009). Infantry Squad Using the Common Controller to Control an ARV-A (L) Soldier Workload Analysis, ARL-TR-5029, Army Research Laboratory, Aberdeen Proving Ground, MD.

U.S. Army Research Laboratory (ARL) analysts predicted the mental workload associated with the robotic noncommissioned officer (RNCO) using the common controller (CC) to control the unmanned armed reconnaissance vehicle-assault (light) (ARV-A (L)) in an infantry weapons squad mission. To predict the RNCO's workload, they used the Improved Performance Research Integration Tool (IMPRINT). IMPRINT predicted the combination of walking with teleoperation of the ARV-A (L) to have the highest workload value and, therefore, the largest predicted performance impacts. In contrast to teleoperation, the autonomous mode of ARV-A (L) operation has a much lower workload prediction for the CC user. Similar to the autonomous mode, the workload predictions during the stationary segments of the mission do not indicate high workload or performance problems. Although this analysis focused on the RNCO as the CC user, the results would be expected to be the same for any weapons squad member using the CC to control the ARV-A (L) who is not a tactical leader.

Mitchell, D. K. & Brennan, G. (2009). Infantry Squad Using the Common Controller to Control a Class 1 Unmanned Aerial Vehicle System (UAVS): Soldier Workload Analysis, Technical Report ARL-TR-5012). Army Research Laboratory, Aberdeen Proving Ground, MD.

U.S. Army Research Laboratory (ARL) researchers predicted the mental workload of a robotic noncommissioned officer (RNCO) using a common controller (CC) to control a Class I Unmanned Aerial Vehicle System (CL I UAVS) within an infantry mission. To predict the RNCO's workload, they used a human performance modeling tool, the Improved Performance Research Integration Tool (IMPRINT). Results of the analysis predicted that communications tasks combined with UAVS control increases workload for the RNCO. Even without the communications tasks, however, the results indicate that the RNCO experiences high workload when controlling the UAVS in the teleoperation mode but not in the autonomous mode. However, when the RNCO had to intervene with the platform because it had deviated from the acceptable flight parameters, the results indicated RNCO workload would be high. Therefore, reliability of the platform is likely to have an effect on CC user workload.

Mitchell, D. K. & Brennan, G. (2009). Infantry Squad Using the Common Controller for Small Unmanned Ground Vehicle Control: Soldier Workload Analysis, ARL-TR-5003, Army Research Laboratory, Aberdeen Proving Ground, MD.

Analysts predicted the mental workload associated with the infantry rifle squad using the common controller (CC) to control a small unmanned ground vehicle (SUGV) within an infantry mission. To predict the workload, they used the Improved Performance Research Integration Tool (IMPRINT), which identified task combinations that contribute to peak workload for the squad leader, team leader, and infantryman. For the squad leader and team leader, these task combinations were typical military tasks such as walking, communicating, and scanning for threats. The CC design does not directly contribute to the leaders' high workload, but it does make it challenging for the infantryman using it to participate in voice communications. Therefore, the CC design may indirectly increase the team and squad leaders' high workload. To mitigate the impacts of these potential high workload situations, the U.S. Army Research Laboratory (ARL) analysts recommend better integration of communications tasks with SUGV control.

Mitchell, D. K. & Chen, J. (2006) Impacting system design with human performance modeling and experiment: Another success story. Proceedings of the 50th HFE Conference, San Francisco, CA 2006.

In this study, task-network models using the Improved Performance Research Integration Tool were built to predict the mental workload and performance of the crew of a conceptual mounted combat vehicle. The modeling project analyzed which crewmember, if any, should be allocated the functions of controlling robotic assets in addition to standard mission functions similar to present tank crew missions. In order to further investigate issues derived from the modeling project and to verify its analytical results, a simulation experiment was conducted to examine the mental workload and performance of the combined position of robotics operator and gunner. The results of this experiment were consistent with the predictions generated by the modeling analysis. The modeling and experimental data have successfully contributed to modifications in the design concept for the modeled platform as well as its crewmember function allocations.

Mitchell, D. K. and **McDowell, K.** (2008) Using Modeling as a Lens to Focus Testing, *Proceedings of the 2008 Symposium on Collaborative Technologies and Systems*.

Designers of collaborative unmanned systems assume they have designed their systems to achieve the goals of reduced operator workload and higher level SA. Soldiers are one group of operators expected to benefit from these characteristics of collaborative systems. Whether the unmanned systems will reduce Soldier workload, however, depends upon how Soldiers interact with them to accomplish military missions. Typically, workload and SA level associated with unmanned assets are evaluated in field experiments in which Soldiers interactive with the systems. These experiments, however, are expensive and obtaining all the technologies and Soldiers required to perform an entire military mission is challenging. These challenges can be overcome, however, by using human performance modeling as a lens to focus field testing. Specifically, system designers can build human performance models to represent Soldiers performing a detailed military scenario and identify the critical Soldier-robot interaction issues. These issues then become the focus of the field experiments. Soldiers participating in the experiments use the robotic systems to perform activity sequences deemed critical by the human performance models. This process ensures that the robotic systems are evaluated in reference to critical mission activities.

ARL and TARDEC demonstrated the effectiveness of this approach when they used human performance modeling of future concept combat vehicles to focus a series of TARDEC autonomous vehicle experiments on critical Soldier survivability issues. The experiments, in turn, demonstrated a way of mitigating some of the Soldier mission performance issues related to unmanned asset operations identified by the human performance modeling.

Mitchell, D.K. & Samms, C.L. (In press). An Analytical Approach for Predicting Soldier Workload and Performance Using Human Performance Modeling. In Human-Robot Interactions in Future Military Operations, Barnes and Jentsch (Eds.), Ashgate Publishing, London, UK.

No Abstract Available.

Mitchell, D. K. & Samms, C. L. Using a Holistic Analytical Approach to Meet the Challenges of Influencing Conceptual System Design. In Savage-Knepshield, P., Martin, J., Lockett III, J. and Allender, L. (Eds), Designing Soldier Systems: Current Issues in Human Factors.

When a new system is being developed, human system analysts are one of several groups, representing different disciplines, who want to influence the design to meet their own objectives. System engineers, for example, want to ensure the design meets system requirements. Cost analysts, on the other hand, want to ensure the design meets budget constraints. Human system analysts (HSAs) want to ensure the system is designed so the human operators can use it effectively. Because the objectives of the various groups may conflict, the HSAs' design objectives are more likely to be implemented if a holistic approach is used that considers the objectives of the other disciplines as well as HSA objectives. Design recommendations made during the concept phase, for example, are less costly and meet the objectives of cost analysts. Incorporating system tasks that meet system requirements within human task analyses is an example of integrating system engineering requirements with human capabilities.

In addition to integrating the objectives of multiple disciplines, however, HSAs must apply an integrated approach within their own analyses. This holistic approach is critical because it is possible for the design of one system to influence performance with another system that is being used concurrently. If, for example, an in-vehicle navigation aid is being designed, the HSA professional would need to evaluate how this system interacts with any other driving displays. This holistic approach makes it more likely that human operators will be able to use the system effectively.

Analysts working at the Army Research Laboratory (ARL) have successfully implemented both aspects of this holistic human system analysis approach. Using IMPRINT and the integrated approach, they have successfully modified the conceptual designs of several manned ground vehicles within a major US Army program. In addition, they have enhanced their human performance modeling tool, the Improved Performance Integration Tool (IMPRINT) to provide other HSA professionals with the capability to effectively implement this approach. This chapter describes the ARL holistic analysis approach, IMPRINT tool, and case studies so other HSA professionals can overcome the obstacles the ARL analysts confronted and meet the challenges of influencing conceptual system designs to benefit the human operators.

Mitchell, D. K. & Samms, C. L. (2009). Workload Warriors: Lessons Learned from a Decade of Mental Workload Prediction Using Human Performance Modeling, Proceedings of the 53rd Meeting of the Human Factors Society.

For at least a decade, researchers at the Army Research Laboratory (ARL) have predicted mental workload using human performance modeling (HPM) tools, primarily IMPRINT. During this timeframe their projects have matured from simple models of human behavior to complex analyses of the interactions of system design and human behavior. As part of this maturation process, the researchers learned: 1) to develop a modeling question that incorporates all aspects of workload, 2) to determine when workload is most likely to affect performance, 3) to build multiple models to represent experimental conditions, 4) to connect performance predictions to an overall mission or system capability, and 5) to format results in a clear, concise format. By implementing the techniques they developed from these lessons learned, the researchers have had an impact on major Army programs with their workload predictions. Specifically, they have successfully changed design requirements for future concept Army vehicles, substantiated manpower requirements for fielded Army vehicles, and made Soldier workload the number one item during preliminary design review for a major Army future concept vehicle program. The effective techniques the ARL researchers developed for their IMPRINT projects are applicable to other HPM tools. In addition, they can be used by students and researchers who are doing human performance modeling projects and are confronted with similar problems to help them achieve project success.

Mitchell, D. & Samms, C. (2007). Please Don't Abuse the Models: The Use of Experimental Design in Model Building. Proceedings of the 51st Annual Meeting of the Human Factors and Ergonomics Society. Vol. 51, pp. 1454-1457(4).

Human factors professionals strive to create effective system design by ensuring that the capabilities and limitations of the human operator are a primary design consideration. By demonstrating the effect of various design decisions concerning the human operator on system performance early in the development cycle, resulting recommendations may be adopted to enhance system performance. To achieve this goal, human performance modeling tools are used. One of the common misconceptions about modeling is that a model alone will impact design. A model is merely a building block within an analysis. An influential analysis incorporates the principals of experimental design, the power of predictive modeling and the varying system design requirements to produce results that empower program managers to make informed decisions regarding system design. Analysts at the U.S. Army Research Laboratory have successfully influenced the conceptual design of several manned ground vehicles by recognizing this difference.

Mitchell, D. K., Samms, C., Kozycki, R., Kilduff, P., Swoboda, J., & Animashaun, A. (2006) Soldier Mental Workload, Space Claims, and Information Flow Analysis of the Combined Arms Battalion Headquarters Command and Control (C2) Cells (ARL-TR-3861). Army Research Laboratory, APG, MD.

Researchers at the Human Research and Engineering Directorate (HRED) of the Army Research Laboratory (ARL) initiated a project to analyze the mental workload and utilization of the combined arms battalion (CAB) Headquarters (HQ) staff that are performing command and control tasks in a multi-task environment. They also analyzed the predicted effects of fatigue and vehicle motion effects on the performance of the CAB HQ staff. Specifically, HRED researchers built Improved Performance Research Integration Tool (IMPRINT) and Command, Control and Communication Techniques for Reliable Assessment of Concept Execution

(C3TRACE) models to analyze the workload profile, utilization rate and predicted performance of the mission staff operating in the back of four command and control vehicles (C2Vs) when the C2V was moving and stationary. They used the Fatigue Avoidance Scheduling Tool (FAST) to analyze the impacts of several sleep and work schedules on the crew. Finally, they used the human figure modeling tool, Jack, to evaluate whether six personnel or four personnel with two in auxiliary seats could be accommodated in the rear compartment of the C2V.

Both the C3TRACE and IMPRINT analyses indicated that all 24 CAB personnel are fully utilized and have high workload for the one hour mission execution phase modeled with the tools. The IMPRINT analysis of vehicle motion effects indicated that operations on the move might reduce accuracy on information processing tasks to 5%. The FAST analysis demonstrated that if the crew received 8 hours or less of continuous sleep after working for 16 continuous hours then their average effectiveness would be less than 70%. The Jack human figure analysis indicated that the rear of the C2V has space at best for only four crewmembers. There is no room in the current design for auxiliary seats.

The analysts concluded that the 24 personnel need to be in a C2V with WMI access. Because the current Command and Control Vehicle (C2V) design cannot accommodate six Soldiers in the rear compartment, eight CAB staff members will not have seats. Therefore, the analysts concluded that more C2Vs will be required. They also recommended that the Army reconsider what battle command tasks need to be perform on the move.

Mitchell, D. K., Samms, C., & Wojcik, T. (2006) System-of-systems modeling: the evolution of an approach for true human system integration. 2006 BRIMS Conference, Baltimore, MD.

For many years, analysts have recognized the need to accurately represent the human in system simulations because the human is the most variable portion of the system representation (Allender, 2000). It is especially critical, but challenging to represent the multi-tasking capability of humans that has been a limitation in accurate representation of system performance (Deutsch, 1997). Within the military analytical community multi-tasking human performance representation, particularly as it relates to crew size has become a critical issue in military vehicle design. Motivated by the needs of organizations such as the Army Materiel Systems Analysis Activity (AMSAA), the Future Combat System Lead System Integrator Boeing-SAIC, and the recognition that traditional military simulations such as CASTFOREM and JANUS have limited capability to accurately represent multi-tasking human behavior (Henthorn, Mitchell, & McDowell, 2005), the U.S. Army Research Laboratory decided to take the initiative to improve the credible representation of human behavior in military system performance simulations. This approach has culminated in a system-of-systems modeling approach that can also be applied in the commercial marketplace. This paper describes the evolution of the ARL system-of-systems modeling approach and the development of the capabilities within the Improved Performance Research Integration Tool (IMPRINT) tool that enable it to be used to build system-of-systems models.

Pomranky, R.A. and Wojciechowski, J.Q. (2007). "Determination of Mental Workload During Operation of Multiple Unmanned Systems." Aberdeen Proving Ground, MD: U.S. Army Research Laboratory. ARL-TR-4309. Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

Many systems are being developed as part of the Army's Future Combat Systems (FCS). To determine the most effective and efficient way to integrate these new systems within the future force, the U.S. Army Research Laboratory's Human Research and Engineering Directorate is using predictive modeling to analyze the workload of FCS operations. This analysis is part of the Robotics Collaboration Army Technology Objective in which Soldier workload models of individual systems are being developed with the intent to be integrated into one complex model. This model will enable the investigation of Soldier workload as well as how these Soldiers and systems can

more effectively combine their efforts to accomplish a mission. The reported effort can be incorporated into the complex model. FCS-equipped brigade combat teams (BCTs) consist of a family of advanced, networked air- and ground-based maneuver, maneuver support, and sustainment systems that will include manned and unmanned platforms. The FCS BCTs will rely heavily on unmanned systems to enable the "quality of firsts" (see first, understand first, act first, and finish decisively) by performing such missions as reconnaissance, surveillance, target acquisition, security, and communications relay. The robotics non-commissioned officer duties within FCS BCT include operating multiple unmanned systems. Given the complexity of future operating environments, the operation of multiple unmanned systems will often occur simultaneously. The number of unmanned systems that a Soldier can effectively operate simultaneously is one area of concern in the fielding of these systems. Further, the level of autonomy required to concurrently operate multiple systems effectively will need to be determined. One system of interest is the Defense Advanced Research Project Agency microair vehicle (MAV) being developed under an advanced concept technology demonstration. This system is a surrogate that represents the future Class I unmanned aircraft system. To investigate the possible effects on performance of simultaneously operating multiple systems, a workload model was developed to examine performance while as many as three MAVs are operated. Results indicate that the workload for the operation of one MAV was well within the cognitive limits of a normal Soldier. Operation of two unmanned systems showed high levels of visual demand and very high levels of cognitive demand. Effectiveness at this level could depend on the level of autonomy and would present high probability of error. Effective operation of more than two unmanned systems at a time results in extremely high workload levels indicating a Soldier's inability to effectively or safely operate those systems, regardless of the autonomy of the systems.

Samms, C. (2008). Challenges to Conducting System of Systems Analysis from a Warfighter Performance Perspective. *Proceedings of the Defense Analysis Seminar XIV*; Seoul, Korea.

The use of a system of systems concept in the development of future capabilities has become an important concept in the U.S. Military. The system of systems approach supports the development of several powerful systems that can singly handle individual missions and when linked together provide the capabilities needed to win the war. The task of designing a good system of systems is a complex and iterative process that should be supported by good analysis throughout the process. There are many tools available that support the analysis of firepower or armor and other material concerns but few that look at the most important part of the system, the Warfighter. The Warfighter must be considered when designing the system of systems in order to ensure an effective and efficient design that will provide the capabilities needed to win the war.

Human performance modeling is a powerful tool that can predict system performance as a function of the human's performance while using that system. Predicting individual system performance is a complex task and only increases in complexity when analyzing a system of systems. For example, in the analysis of an individual system, the functions and tasks of that system's mission are distributed amongst the Warfighters controlling that system. In a system of systems analysis, there is a need to cross systems so there may be times when one Warfighter's duties are split across systems. Therefore, the analysis must expand to accommodate the addition of systems and Warfighters who now may need to multi-task, cross-train and communicate more than for their original single system. The amount of data and the importance of that data that would be generated by a system of systems analysis must also be considered. At the individual system level, mental workload of the individual Warfighters is a necessary measure but at a system of systems level, team workload may be a more effective measure but much more challenging to predict.

This paper identifies some of the challenges associated with analyzing a system of systems and provides some potential solutions to ensure good design of the system of systems.

Savage-Knepshield, P., Martin, J., Lockett , J., & Allender, L. (Eds.). (book proposal accepted by publisher). Designing Soldier Systems: Current Issues in Human Factors.

Wojciechowski, J.Q. (2007). "Modeling Human Performance with Environmental Stressors: Case Study of the Effect of Vehicle Motion." [CD-ROM]. Proceedings from the Human Factors and Ergonomics Society 51st Annual Meeting. Human Factors and Ergonomics Society. [Producer and Distributor].

Human performance modeling tools are used to predict mission performance as a function of human performance. The U.S. Army Research Laboratory has developed a human performance modeling tool, the Improved Performance Research Integration Tool (IMPRINT), for investigation of the impact on a Soldier's performance when the Soldier subjected to environmental stressors such as heat and cold. IMPRINT has the capability to create user-defined stressors to study the stressors' effect on human performance and therefore system performance. This case study used data from literature to create a user-defined stressor in IMPRINT to predict the effect of riding in a moving vehicle on task time and performance. This capability can provide useful information to system designers.

Wojciechowski, J.Q., Karna, V., & Dorney, L.A. (2007) "Analysis of the Light Brigade Combat Team Reconnaissance Capability Gap With the Use of a Human Performance Model of the Joint Chemical, Biological, Radiological, and Nuclear Dismountable Reconnaissance System (JCDRS)." Aberdeen Proving Ground, MD: U.S. Army Research Laboratory. ARL-TR-4340.

Limited Release - No Abstract Available

Research Area 2.2: System Assessment in Support of Test and Evaluation

Branscome T. A. (2009). "Human Factors Assessment; Manpower, Personnel and Training Assessment and Soldier Survivability Assessment for the 60,000-Btu/hr Improved Environmental Control Unit (60K IECU)", U.S. Army Evaluation Command

No Abstract Available

Geduldig, T., **Grynovicki, J.O**., et al., (2008). "Operational Test Agency (OTA) Abbreviated Operational Test Agency Report (AOTAR) for Full Materiel Release (FMR) of the Battle Command Sustainment Support System (BCS3). U.S. Army Test and Evaluation Command.

No Abstract Available

Grynovicki, J. O. (In press). "Metrics for Evaluating Digitization for U.S. Army Battle Command Capability Sets" U.S. Army Conference on Applied Statistics, October 2010.

While many studies have taken a traditional task analysis approach to assessing the effects of technology on battle command performance, this paper describes implementation of a global, systems approach for examining usability, functionality, and performance from an operator, commander and staff, and organizational perspective. This approach has been used successfully to assess technology ("digitization") effectiveness by the U.S. Army Training and Doctrine Command (TRADOC) and the Operational Test Command (OTC) in several Warfighting Experiments. This paper describes the three-step approach and presents data demonstrating the reliability of the questionnaire used to evaluate the Advanced Field Artillery Tactical Data System (AFATDS).

Grynovicki, J.O. (2009). "NECC Program – Manpower and Personnel Integration (MANPRINT) Evaluation Approach" White paper for the NECC Joint System Team

No Abstract Available

Grynovicki, J. O. (2008). "System Engineering Framework for Evaluating the Human Dimension of Network Centric Warfare" October 2008 U. S. Army Conference on Applied Statistics

As part of the transformation and modernization process, the U.S. Army has sponsored field experiments and tests ranging from large-scale operational evaluations to smaller Early User Tests (EUT) which evaluate the maturity of a technology and assess its potential application to a military need. Testing provides important insights in this regard, because many of the operational and human factors issues affected by technology do not appear in isolated limited objective experiments or developmental tests. Rather, the full implications, limitations, and strengths of a system emerge only when that system is employed in concert with other systems under demanding, field conditions with soldiers as the operators. As a result, testing represents an important tool for assessing the interoperability of new systems with existing systems and quantifying soldier performance.

For testing to be effective, it is important to have a measurement framework and corresponding instruments to assess how well new net-centric technology impacts operator, staff, and organizational performance. To meet this need, one goal of the U.S. Army Research Laboratory has been to develop and execute a systems engineering approach, along with standardized field-operational metrics and tools, to quantify and validate integrated Soldier-information system training and performance on the digital battlefield. The current MANPRINT effort involved developing an understanding of how the commander and the battle staff used all the net-centric capabilities to support effective battle command. .This paper describes implementation of a systems framework for examining performance from an operator, commander staff, and organizational perspective. This total net-centric system perspective considering how effectively new technology supported the individual soldier, and commander.

The approach had three steps. The first step was identifying tasks and behavioral characteristics that are associated with effective C4ISR performance at the operator, commander and staff level. The second step was to developing a framework for measuring how well technology provides the usability, functionality, and supported soldier performance. The third step was developing instruments to implement the measurement framework for each of the battlefield functional areas.

Grynovicki, J.O. (2007). "MANPRINT Evaluation of Persistent Surveillance System of Systems" 2007 U.S. Army Conference on Applied Statistics

No Abstract Available

Grynovicki, J.O. (2006). "MANPRINT Assessment -Tactical Ground Reporting Network (TIGRNET), Army Test and Evaluation Command. (classified)

No Abstract Available

Hollister, C., Kim, S., **Grynovicki, O.**, (2006). “System Assessment of the Command Post of the Future, Version 3.2” August 2006, ATEC- 2006-OA-C3E.

No Abstract Available

Kim, J. B., **Grynovicki,J.O.**, et al., (2009). “Capabilities and Limitations Report for the Multilateral Interoperability Programmed (MIP), U.S. Army Test and Evaluation Command.

No Abstract Available

Maceo, M., **Grynovicki, J.O.** , et al., (2010). “Operational Test Agency Evaluation Report (OER) for the for the General Fund Enterprise Business System Release 1.3 Initial Operational Test” US. Army Evaluation Center.

No Abstract Available

Maceo, M., **Grynovicki,J.O.**, et al., (2009). “Operational Test Agency Milestone Assessment Report for the GFEBS Release 1.2 Limited User Test” US. Army Evaluation Command

No Abstract Available

Thrust Area 3: Performance with Systems

Research Area 3.1: Immersive Simulations

No ARL reports available

Research Area 3.2: Weapons

Ortega, S., Garrett, L., & Burcham, P. (2008). Soldier Performance with the M240E6 Lightweight Machine Gun - Phase II (ARL-TR-4561). Aberdeen Proving Ground, MD.

Limited Release - No Abstract Available

Research Area 3.3: Flexible Display Technology for Soldiers and Vehicles

Elliott, L.R., Wilson, R., Forsythe, E.W. (in press). User-based Evaluation of Two Reflective Flexible Display Prototypes.

No Abstract Available

Wilson, R., Elliott, L.R., Cosenzo, K.A., Forsythe, E.W. (in review)**.** User Evaluation of Soldier Flexible Display Technology Demonstrators: Future Combat System Common Controller Spiral 1 Excursion.

No Abstract Available

Other HSI related Publications

Lizza, G., **Lockett, J.,** & Narkevicius, J. (2008). Human systems integration: synergy across the United States military. *Insight*, 11 (2), 28-30.

Social/Cognitive Network Science

Thrust Area 1: Multicultural communication

Research Area 1.1: Miscommunications and context

Allen, J., Mott, D., Bahrami, A., Yuan, J., **Giammanco, G**., & Patel, J. (2008). A Framework for Supporting Human Military Planning. Proceedings of the Annual Conference US/UK International Technology Alliance in Network and Information Sciences, London.

Coalition operations have become the norm for achieving military objectives in recent history. While providing the benefits of distributing costs and achieving community buy-in, adding foreign cultures, expectations, and practices further exacerbate the difficulties associated with military planning and execution. In this paper we describe a number of these difficulties, a Collaborative Planning Framework (CPF) designed to address these issues, the work performed to date on this framework, and future work.

Mott, D. and **Giammanco, C.** (2008). The Use of Rationale in Collaborative Planning. Proceedings of the Annual Conference US/UK International Technology Alliance in Network and Information Sciences, London.

It is hypothesized that plan rationale is key to collaborative planning, to support communication and negotiation between human planners. Work is reported using the Collaborative Planning Model (CPM), on capture, representation, analysis and display of rationale for plan structures.

Poteet, S., **Giammanco, C**., Patel, J., Kao, A., Xue, P., and Whiteley, I. (2009). Miscommunications and Context Awareness. Proceedings of the Third Annual Conference of the International Technology Alliance, Maryland.

As a continuation of an exploratory study into linguistic and contextual sources of coalition miscommunication, we have administered pilot surveys and followed these up with face-to-face interviews of a number of UK, US and other NATO countries' military and civilian staff at the Omni Fusion 2008 Exercise. Initial analysis of the data offers further evidence on various types of linguistic variations and cultural differences we previously identified in the US and UK coalition teams. More importantly, we observe that shared common understanding of the context forms a key foundation for successful communication and misunderstanding frequently results when they are lacking. Furthermore, the data collected from the interviews provide key insights into some potential methods of avoiding or quickly resolving miscommunications when they arise.

Poteet, S., Patel, J., **Giammanco, C**. Whiteley, I., Xue, P., and Kao, A. (2008). Words Are Mightier Than Swords … and Yet Miscommunication Costs Lives!. Proceedings of the Second Annual Conference of the International Technology Alliance, London.

As part of an exploratory study into linguistic sources of coalition miscommunication, we have interviewed a number of UK and US military and civilian staff. Initial analysis of the data has shown that there are various types of linguistic variations and cultural differences manifested by the US and UK groups. American English and British English differ in complex ways not only in terms of lexical differences but also, perhaps more importantly, in terms of language use due to cultural differences. While this study and analysis are preliminary, the results provide support for our initial hypotheses. Importantly, the current analysis suggests that many relevant issues are largely pragmatic in nature, not just involving lexical and grammatical differences but indicating differences in the way the two cultures use the "common" language.

Poteet, S., Xue, P., Patel, J., Kao, A., **Giammanco, C**. and Whiteley, I. (2008). Linguistic Sources of Coalition Miscommunication. Proceedings of the NATO Research and Technology Organization, Human Factors and Medicine Panel Symposium on Adaptability in Coalition Teamwork, Denmark.

Current major military deployments almost always involve collaboration between multinational teams. Joint operations often face operationally and environmentally complex and dynamic scenarios. Effective and efficient communication is a key enabler to success; however, the diverse backgrounds of multinational teams have presented serious challenges in coalition communication. This on-going exploratory study investigates miscommunications between US and UK military personnel (and civilians working with them). It focuses on understanding miscommunication due to differences in language forms and language use, including the context of use. Based on the data collected from a set of semi-structured interviews of military personnel, this study identified a number of categories and patterns of miscommunication. The preliminary results have presented a number of implications for improving communication between UK and US teams, which can serve as insights for improving multinational team communication in general.,

Thrust Area 2: Human-team-network interaction

Research Area 2.1: Network information requirements/interactions

Giammanco, C. (2009). Invited Panel: Tactical Ground Reporting System (TIGR) Cognitive Performance and Trust. U.S. Military Academy TIGR User Workshop.

No Abstract.

Giammanco, C. (2009). Invited Panel: Understanding Cyber Terrorism. U.S. Military Academy Network Science Workshop.

No Abstract.

Giammanco, C. (2009). Invited Panel: network as an enabler for coalition operations. Knowledge Systems for Coalition Operations (KSCO) Conference.

No Abstract.

Hansberger, J.T. (in progress). How C2 communications evolve over time. In P. Savage-Knepshield, J. Martin, J. Lockett, and L. Allender (Eds.), Designing Soldier Systems: Current Issues in Human Factors. Surrey, U.K., Ashgate.

Military command and control (C2) relies heavily on efficient communication through the chain of command (e.g., Kahan, Worley, & Stasz, 2000; McCann & Pigeau, 2000). In order to systematically assess patterns of communication within a C2 experimental structure or exercise, analyses that focus on social interactions must be used. One method that systematically analyzes communication patterns between individuals within a C2 structure is social network analysis (SNA). The National Academy of Sciences recently assembled a committee of experts to investigate the nature of networks and network research both in general and specific to future U.S. Army applications (National Research Council, 2005). Based on analysis of existing literature and extensive interviews and questionnaires from active network researchers, the Committee on Network Science supports the finding of, "the pervasive influence of networks in all aspects of life – biological, physical, and social – and concluded that they are indispensable to the workings of the global economy and to the defense of the United States against both conventional military threats and the threat of terrorism" (p. 2, National Research Council, 2005). The analyses presented in this chapter uses the quantitative and empirically based analyses of social network analysis to examine the development and evolution of the C2 communication structure within a highly complex military exercise in an urban environment.

Hansberger, J.T. and Adali, S. (2010). Human behavior modeling in network science. Proceedings of the 19th Behavior Representation in Modeling and Simulation Conference. Charleston, SC.

The U.S. Army Research Laboratory (ARL) has begun a 5-10 year research program with the Network Science Collaborative Technology Alliance (NS CTA) in Network Science bringing three distinct research areas together, communication networks, information networks, and social/cognitive networks. The NS CTA is an alliance across a wide range of academic and industry researchers working collaboratively with ARL and the Department of Defense researchers. A critical part of the social/cognitive network effort is the modeling of human behavior. The modeling efforts range from organizational behavior to social cognitive trust to explore and refine the theoretical and applied network relationships between and among the human, information, and artifacts used.

Hansberger, J.T. (2010). Understanding distributed collaboration within virtual worlds. Proceedings of the Sunbelt XXX Social Network Analysis Conference. Trento, Italy.

Virtual worlds and environments are fast becoming an effective computer mediated method for distributed collaboration among professionals due to its ability to support collaboration anytime, anywhere. Crisis response situations in particular require different organizations with different backgrounds, training, and norms to come together for a shared ultimate goal., Hurricane Katrina relief efforts in 2005 emphasized the importance of effective communication and collaboration in order to cope with the over $100 billion in damage it caused. The U.S. Army Research Laboratory has collaborated with several universities to create a virtual collaboration environment (VCE) integrating Web 2.0 tools and virtual environments to support synchronous and asynchronous collaboration for crisis response situations. This paper presents the patterns of communication and collaboration using the VCE for a biological outbreak crisis situation through social network analysis (SNA). The paper will describe how the development of trust and uncertainty are related to the patterns of collaboration and breakdown the use of computer mediated communication tools within this virtual environment and complex socio-technical system.

Hansberger, J.T. & Tate, A. (2010). Supporting crisis planning with virtual worlds. Proceedings of the Federal Consortium for Virtual Worlds Conference 2010. Washington, D.C.

The design of the virtual collaboration environment (VCE) was guided through a cognitive work analysis (CWA) for distributed collaboration. A CWA consists of multiple phases that systematically analyze the constraints across work tasks, collaborators/colleagues, organizations, and activities. The CWA identified the critical functions to facilitate distributed collaboration and allowed us to select the appropriate technology to support those functions. It also guided the design, presentation, and structure of information and processes in the three primary components of the VCE, 1) a collaboration protocol, 2) visualization tools, and 3) collaboration tools. The collaboration tools consist of both a collaborative portal consisting of a suite of Web 2.0 tools and a 3-D virtual collaboration space. All tools were selected to support the key functions identified in the CWA and based upon their open-source nature in order to make them accessible and available to the wide range of organizations that make-up the crisis response community. A combination of social networking capabilities for group and activity awareness, microblogging for transmission of messages to mobile devices, and collaboration on shared and persistent concepts through wikis are some examples. The 3-D space is currently represented in Second Life and Opensim and represents a range of collaborative spaces to facilitate meetings with audio and text communication from 100-400 individuals, presentations or live streaming video to a distributed audience, and sharing of information through the expo center and other virtual resources. The intention of the VCE project is to create a socio- technical system that facilitates distributed collaboration across crisis response organizations and agencies that typically do not collaborate well when their collaboration is needed most.

Hansberger, J.T., Tate, A., Moon, B. and Cross, R. (2010). Cognitively engineering a virtual collaboration environment for crisis response. Proceedings of the 2010 ACM Conference on Computer Supported Cooperative Work. Savannah, GA.

Crisis response situations require collaboration across many different organizations with different backgrounds, training, procedures, and goals. The Indian Ocean Tsunami in 2004 and the Hurricane Katrina relief efforts in 2005 emphasized the importance of effective communication and collaboration. In the former, the Multinational Planning Augmentation Team (MPAT) supported brokering of requests for assistance with offers of help from rapidly deployed military and humanitarian assistance facilities. In the aftermath of Hurricane Katrina, the National Guard Soldiers and active component Army Soldiers assisted other state, federal, and non-government organizations with varying degrees of efficiency and expediency. Compounding the challenges associated with collaboration during crisis situations is the distributed nature of the supporting organizations and the lack of a designated leader across these military, government, non-government organizations. The Army Research Laboratory is collaborating with the University of Edinburgh, University of Virginia, Perigean Technologies, and Carnegie Mellon University in the design a virtual collaboration environment (VCE) to support a crisis response community of interest and crisis action planning activities.

Hansberger, J.T. (2008). The distributed cognitive components of C2. 13th International Command & Control Research & Technology Symposium, June 17-19, Bellevue, WA.

Distributed cognition (Hutchins, 1995a) is a theoretical framework that explains cognitive activities embodied and situated within the work setting and the artifacts used in the environment. Distributed cognition emphasizes the distributed nature of cognitive phenomena across individuals, tools/technologies, and internal/ external representations. The unit of analysis goes beyond the cognitions of a single individual and focuses on the functional system as a whole. Distributed cognition examines the relation between individuals, the task environment, and artifacts used for task completion. Among some of the distributed cognitive attributes are: 1) Coordination across agents; 2) situation assessment; 3) mental models; 4) memory demands; 5) adaptability; and 6) workload management. Command & Control (C2) systems can greatly benefit when examined and analyzed as a distributed cognitive system through its emphasis on these cognitive attributes of the system. The theoretical and analytical implications of applying this approach to C2 systems will be discussed based on recent application and analysis to a series of C2 experiments.

Hansberger, J.T., Schreiber, C., Spain, R.D. (2008). C2 network analysis: Insights into coordination & understanding. 13th International Command & Control Research & Technology Symposium, June 17-19, Bellevue, WA.

The distributed cognitive framework (Hutchins, 1995) provides a structured and theoretical approach for analyzing cognitive characteristics beyond that of a single individual to that of a system comprising of multiple individuals, tools, and the task environment. Among some of the attributes of a distributed cognitive system are: 1) coordination across agents 2) mental models, 3) situation assessment, 4) memory demands, 5) adaptability, and 6) workload management. This paper will address recent efforts, tools, and approaches on measuring and analyzing two of these distributed cognitive attributes through network analysis, coordination across agents and mental models. Network analysis was applied with different methods and emphasis to both attribute areas. The analysis of the coordination across agents applied network analysis to analyze the patterns of interactions across human and technological agents over-time. Collecting data related to coordination over time required specific capabilities that was not readily found among observational data collection tools and therefore required a custom program that we designed. Description of the requirements and implementation of this new observational network analysis tool as well as methods to visualize longitudinal network change is addressed. The analysis of mental models also utilizes a basic network analysis approach, namely structural knowledge. The examination of structural knowledge to assess individual mental models will be discussed to provide insight into understanding. Specifically applied to C2, this analysis can provide insight into the commander and/or staff's understanding.

Kilduff, P., **Swoboda, J.** and Katz, J. 2006. *A Platoon-Level Model of Communication Flow and the Effects on Operator Performance,* ARL-MR-0656, Aberdeen Proving Ground, MD: Army Research Laboratory.

The Future Combat System (FCS) initiative is at the center of the Army's Objective Force Vision. The Army Vision (2010) states that U.S. forces must have "*information superiority: the capability to collect, process, and disseminate an uninterrupted flow of information while exploiting or denying an adversary's ability to do the same.*" In other words, the Future Force will be empowered by dominant situational understanding. To predict how proposed systems and displays will impact situational understanding and thereby decision making, the U.S. Army Research Laboratory's Human Research and Engineering Directorate used the tool C3TRACE (command, control, and communication: techniques for reliable assessment of concept execution). C3TRACE is a modeling environment in which one can develop multiple concept models for any size organization, staffed by any number of people, using any type of information technology, performing any number of functions and tasks, and under various communication and information loads. Among the performance measures tracked are Soldier utilization, the number of messages received, dropped, and interrupted, and the degree to which the information is available to support Soldier decision making. C3TRACE was used to develop a platoon-level model of an FCS conceptual configuration in support of the situational understanding as an enabler for the unit of action maneuver team Soldiers Army Technology Objective. The platoon model assumed wrist-mounted displays for the dismounted Soldiers and laptop-type displays for the mounted Soldiers. In general, the Soldiers using the laptop-type display were able to fully process more of their incoming messages and made no decisions with poor information quality. On the other hand, the majority of the Soldiers using the personal digital assistant had high utilization, higher numbers of dropped and interrupted messages, and decisions made with poor information quality. Specifically, the squad leader and team leaders exhibited the highest levels of utilization and decisions made with poor information quality. This was not only because they received more messages than those Soldiers in the mounted phase but also because of the technology being used.

Kott, A., **Hansberger, J.T.**, Waltz, E., and Corpac, P. (2010). Whole- government planning and wargaming of complex international interventions: Experimental evaluation of methods and tools. International C2 Journal 4 (3). 1-25.

We describe the experimental methodology developed and employed in a series of experiments of the DARPA Conflict Modeling, Planning, and Outcomes Exploration (COMPOEX) Program. The primary purpose of effort was development of tools and methods for analysis, planning and predictive assessment of plans for complex operations where integrated political-military-economic-social-infrastructure and information (PMESII) considerations played decisive roles. As part of the program, our team executed several broad-based experiments, involving dozens of experts from several agencies simultaneously. The experimental evolved from one experiment to another as a result of the lessons learned. The paper presents the motivation, objectives, and structure of this interagency experiment series; the methods we explored in the experiments; and the results, lessons learned and recommendations for future efforts of such nature.

Moon, B., **Hansberger, J.T.**, and Tate, A. (in press). Concept mapping in support of collaborative crisis response planning. In B. Moon, R. Hoffman, J. Novak, and A. Canas (Eds.), Applied Concept Mapping: Theory, Techniques, and Case Studies in the Business Applications of Novakian Concept Mapping. CRC Press.

No abstract.

Schreiber, C., Carley, K.M. and **Hansberger, J.T.** (2010). Shifts of critical personnel in network centric organizations. Proceedings of the 19th Behavior Representation in Modeling and Simulation Conference. Charleston, SC.

Identifying critical personnel has been a problem of interest for sometime as organizations seek to optimize their advantage and disrupt their adversary. This problem has become more difficult with the increasing use of network centric organizations as these organizations have flexible structures that can produce significant shifts of critical personnel. A shift of critical personnel is a change of who is critical within an organization over time. Traditional social network analysis has identified critical personnel using measures applied to static structure. This research adds the process of network change to better understand when shifts of critical personnel may occur. Theory and application are discussed.

Scielzo, S., Strater, L. D., Tinsley, M. L., **Ungvarsky, D. M.**, & Endsley, M.R. (2008). Developing a Subjective Shared Situation Awareness Inventory for Teams. Human Factors and Ergonomics Society Annual Meeting Proceedings, Volume 53, Number 4, 2009, pp. 289-293.

No Abstract.

Smart, P., Engelbrecht, P., Braines, D., **Strub, M**., and **Giammanco, C**. (2009). The Network-Extended Mind. In D. Verma (Ed.), Network Science for Coalition Operations. Hershey: IGI Global Publishing.

Whereas the traditional view in cognitive science has been to view mind and cognition as something that is the result of essentially inner, neural processes, the extended cognition perspective claims that at least some human mental states and processes stem from complex webs of causal influence involving extra-neural resources, most notably the resources of our social and technological environments. In this chapter we explore the possibility that contemporary and near-future network systems are poised to extend and perhaps transform our human cognitive potential., We also examine the extent to which the information and network sciences are relevant to our understanding of various forms of cognitive extension, particularly with respect to the formation, maintenance and functioning of extended cognitive systems in network-enabled environments. Our claim is that the information and network sciences are relevant on two counts: firstly, they support an understanding of the mechanisms underpinning socially- and technologically-mediated forms of cognitive extension; secondly, they serve to guide and inform engineering efforts that strive to enhance and expand our cognitive capabilities. We discuss the relevance and applicability of these conclusions to current and future research exploring the contribution of network technologies to military coalition operations.

Swoboda, J. (in press). C3TRACE: Modeling Information Flow and Operator Performance. In P. Savage-Knepshield, J. Lockett, J. Martin, & L. Allender (Eds.), Designing Soldier Systems: Current Issues in Human Factors.

The future military command and control (C2) process will be altered due to the impacts of new information technology and new organizational structures. What is the effect of future organizational and personnel configurations on Soldier performance? How does the insertion of new communication technologies affect the flow and processing of information? To predict how these changes will impact soldier performance, the Human Research and Engineering Directorate of the U.S. Army Research Laboratory sponsored the development of a modeling environment from which one can develop multiple concept models for any number and size of organizations, staffed by any number of people, performing any number of functions and tasks, and under various communication and information loads. The models have been based on representations of C2 tasks and functions performed by a group of people engaged in various military missions, within conceptual and actual military organizational designs, and using various types of communication and information technologies. These organizations have ranged in size from platoon to brigade level, with the inclusion of message flow from platoons to a division staff. The modeling environment that was developed is called Command, Control, and Communications - Techniques for the Reliable Assessment of Concept Execution (C3TRACE). Models can be rapidly constructed with C3TRACE to analyze multiple organizational, personnel, and systems architectures as they emerge through concept exploration for the Army Future Force. Among the performance measures tracked are operator utilization, the number of tasks performed, and the quality of decisions made by the operators. This chapter will discuss the theory and application of the C3TRACE tool.

Swoboda, J. (2009). FY09 Alternative FCS-Approved Reconnaissance Platoon Models. Customer Report.

No abstract.

Swoboda, J. (2008). FY08 FCS-Approved Reconnaissance Platoon Modeling Effort. Customer Report.

No abstract.

US Army Training and Doctrine Command (TRADOC). (2009). *Battle Command Battle Laboratory- Leavenworth Final Report Omni Fusion 2009*. US Army Combined Arms Center.

No Abstract.

Research Area 2.2 Network Degradations – lag, information loss

Krausman, A. Distributed team collaboration: Impact of communication delay on team performance, shared awareness, and trust. In preparation.

With the increasing prevalence of distributed teams, organizations have sought to develop collaborative technologies that support a variety of remote work activities such as disaster response, software design, and telemedicine (Gergle, Kraut, & Fussell, 2006). When these activities are performed in a collocated setting, team members communicate face-to-face and have access to a variety of verbal and nonverbal cues (e.g., facial expressions, gestures, and nods); however, distributed teams, who collaborate remotely, must contend with the absence of these rich cues afforded by face-to-face interaction. Not only do these cues form the basis for the formation of situation awareness (SA), which is defined as "an understanding of what is happening around you and knowing how to respond as the situation changes" (Endsley, 1995b; Bryant, Lichacz, Hollands, & Baranski, 2004), without them, virtual teams are prone to disruptions in conversations and difficulty in following and understanding discussions (Straus & McGrath, 1994; Salas et al.,, 2001). In addition, the lack of visual and non-verbal cues also makes it difficult to maintain an ongoing awareness of the situation and the status of other team members, especially in dynamic situations that may change rapidly (Salas et al.,, 2001). Therefore, in order to design technologies that effectively support remote tasks, we must understand how technological mediation alters the mechanisms responsible for successful coordination in collocated teams (Herbsleb, Mockus, Finholt, & Grinter, 2006). For example, how does communication delay (i.e., due to network congestion or failure) that often occurs in distributed interaction impact a team's ability to coordinate their efforts and accomplish their tasks? How does communication delay or disrupt communication processes such as turn taking and feedback, and how do these delays impact the strategies that team members us to successfully collaborate? How do team members adapt or change their methods of interaction when they interact utilizing technology? The overall goal of this dissertation is to shed some light on these questions and to better understand the intricacies of communication and collaboration in distributed teams.

Wiley P.W., **Scribner D.R**., **Harper W.H**. (2009). Evaluation of Wearable Information Systems During Route Reconnaissance and Assault Missions Using Commercial Games. Proceedings of the 14th Annual International Conference on Industrial Engineering Theory, Applications and Practice, Anaheim, California, October 18-21, 2009.

The future dismounted warrior will be enabled with enhanced situational awareness (SA) through the use of a wearable information system. The combat advantage this information can provide is apparent, however as the amount of information the Soldier must manage increases so does the potential for cognitive overload and human error. Three studies were conducted using two commercial off-the-shelf games to evaluate various display configuration concepts for individual Soldier wearable information systems. This paper provides an overview of each study highlighting the experimental design, methods, and results. Study 1 focused on the use of digital maps and UAV with and without an information manager during reconnaissance and assault missions. Results from the first study showed that providing digital maps and UAV displays to the team leader (TL) enhances situational awareness (SA) and provides some performance gains, but at an increase in mission time. However providing an information manager to assist the TL enhances SA, survivability, and lethality, with a reduction in workload and no time penalty. Study 2 focused on display modality for presentation of known enemy locations and display type during route reconnaissance missions. Results from the second study showed that visual presentation of enemy enhanced SA of friendly and enemy forces, increased survivability, and increased percentage of missions completed. Providing an auditory warning when an operator gets within firing range of an enemy enhances survivability. There are no significant differences between PDA and the HMD and the addition of the UAV feed did not provide any additional performance gain. Study 3 focused on the effects of information reliability during assault missions. Results from the third study showed that displaying enemy location with 100%, 80%, and 60% reliability enhanced SA, however, displaying enemy location with 80% to 100% reliability is required to provide significant mission performance gains. Direct use of a UAV imagery increases mission time and does not provide any significant military relevant gains.

Wiley P.W., **Scribner D.R**., **Harper W.H**. (2008) Manipulation of a Commercial Game to Provide A Cost Effective Simulation To Evaluate Wearable Information Systems. Proceedings of the 13th Annual International Conference on Industrial Engineering Theory, Applications and Practice, Las Vegas, Nevada, September 7-10, 2008.

The future dismounted warrior will be enabled with enhanced situational awareness (SA) through the use of a wearable information system. The combat advantage this information can provide is apparent, however as the amount of information the Soldier must manage increases so does the potential for cognitive overload and human error. A commercial, off -the-shelf, militaristic game was customized to provide a controllable and cost effective simulation to evaluate wearable information system concepts. This paper describes the process of construction of the environment, scenario development with customized features to conduct studies with military relevant data collection, and the results of one such study. The present study proposed the examination of team leader mission performance for various display configuration concepts with and without assistance from another team member, serving as an information manager (IM). The team leader was provided with a small display with one of four levels of content: no information (None); a digital map (DM); UAV direct feed (UAV); and the ability to switch back and forth from digital map to the UAV feed (DM +UAV). These four conditions were repeated with the addition of an IM for a total of eight conditions per mission. Each team leader completed a route reconnaissance and an assault mission for a total of sixteen trials. Results showed that providing displays (DM & UAV) to the TL enhances SA and provides some performance gains, but at an increase in mission time. IM presentation of information to the TL enhances SA, survivability, and lethality, with a reduction in workload and no time penalty.

Neuroscience

Thrust Area 1: Neurocognitive Performance

Research Area 1.1: Neural Behavior under Operational Stressors

Kerick, S.E., & McDowell, K. (2009). Understanding brain, cognition, and behavior in complex dynamic environments. In D.D. Schmorrow et al, *Foundations of Augmented Cognition. Neuroergonomics and Operational Neuroscience,* (pp. 35-41) Heidelberg, Springer Berlin.

Many challenges remain for understanding how the human brain functions in complex dynamic environments. For example, how do we measure brain physiology of humans interacting in their natural environments where data acquisition systems are intrusive and environmental and biological artifacts severely confound brain source signals? How do we understand the full context within which the human brain is operating? How do we know which information is most meaningful to extract from the data? How can we best utilize that extracted information and what are the implications for human performance? The papers comprising this section address these questions from conceptual, technical, and applied perspectives. It is clearly seen that significant progress has been made since the inception of the Augmented Cognition program and that, to overcome these challenges, a continued multidisciplinary approach is required across basic and applied research from cognitive scientists, neuroscientists, computer scientists, and engineers.

Schleifer, L. M., Spalding, T. W., **Kerick, S. E.,** Cram, J. R., Ley, R., & Hatfield, B. D. (2008). Mental stress and trapezius muscle activation under psychomotor challenge: A focus on EMG gaps during computer work. Psychophysiology, 45, 356-365.

Momentary reductions in the electrical activity of working muscles (EMG gaps) contribute to the explanation for the relationship between psychosocial stress and musculoskeletal problems in computer work. EMG activity and gaps in the left and right trapezii were monitored in 23 participants under low and high mental workload (LMWand HMW) demands during computer data entry. Increases in EMG activity and decreases in EMG-gap frequencies in both left and right trapezius muscles were greater during HMWthan LMW. In addition, heart period and end-tidal CO2 were lower duringHMW, whereas self-reportedmood states were higher duringHMW. The correspondence between lower end-tidal CO2 and lower EMG-gap frequencies suggests that hyperventilation (overbreathing) may mediate trapezius muscle activation. The reduction of EMG gaps suggests that the salutary benefits of momentary rest from musculoskeletal work are diminished during mental stress.

Kerick, S. E., Hatfield, B. D., & Allender, L. E. (2007). Event-related cortical dynamics of Soldiers during shooting as a function of varied task demand. Aviation, Space, and Environmental Medicine, 78 (Suppl. 1), B153-B164.

Introduction: Cortical dynamics of soldiers were examined during a reactive shooting task under varied task demands to investigate the effects of cognitive load on functional states of soldiers in real-time. Methods: Task demand factors consisted of task load (single, dual), decision load (no-decision, choice-decision), and target-exposure time (short, long). The Dismounted Infantryman Survivability and Lethality Testbed (DISALT) shooting simulator was programmed to generate the eight shooting scenarios and record weapon aim-point data while EEG was acquired continuously during each scenario. Event-related spectral perturbation (ERSP) was derived from single-trial data time-locked to the onsets of targets and peak amplitude and latency measures were analyzed in theta (4–7 Hz) and upper alpha (11–13 Hz) frequency bands. Results: The results are as follows: 1) a stimulus-evoked ERSP theta peak exhibited higher amplitude in the parietal region for choice- vs. nodecision scenarios and longer latency in the right central and temporal regions for dual- vs. single-task scenarios; and 2) ERSP alpha exhibited a progressive increase following the onset of targets with less of an increase in the left central region for dual- vs. single-task scenarios. Discussion: ERSP theta synchronization reflects stimulus encoding and exhibits increased peak power with more complex decision demands and longer latency with secondary task demands, whereas ERSP alpha synchronization reflects motor preparation and exhibits less of an increase with secondary task demands during reactive target shooting tasks. This research contributes the first study of cortical dynamics of soldiers performing a reactive shooting task and has implications for theories of attention and cognitive workload, human factors engineering, and soldier performance.

Research Area 1.2: Multisensory Integration

Jeka, J.J., **Oie, K.S.,** Kiemel, T. (2008). Asymmetric adaptation with functional advantage in human postural control. Exp Brain Res, 186(2), 293-303.

Human movement control is inherently stochastic, requiring continuous estimation of self-motion based upon noisy sensory inputs. The nervous system must determine which sensory signals are relevant on a time scale that enables successful behavior. In human stance control, failure to effectively adapt to changing sensory contexts could lead to injurious falls. Nonlinear changes in postural sway amplitude in response to changes in sensory environmental motion have indicated a dynamic changing of the weighting of the nervous system's multiple sensory inputs so that estimates are based upon the most relevant and accurate information available. However, the time scale of these changes is virtually unknown. Results here show systematic changes in postural gain when visual scene motion amplitude is increased or decreased abruptly, consistent with sensory re-weighting. However, this reweighting displayed a temporal asymmetry. When visual motion increased, gain decreased within 5 s to a value near its asymptotic value. In contrast, when visual motion decreased, it took an additional 5 s for gain to increase by a similar absolute amount. Suddenly increasing visual motion amplitude threatens balance if gain remains high, and rapid down-weighting of the sensory signal is required to avoid falling. By contrast, slow up-weighting suggests a conservative CNS strategy. It may not be functional to rapidly up-weight with transient changes in the sensory environment. Only sustained changes necessitate the slower up-weighting process. Such results add to our understanding of adaptive processing, identifying a temporal asymmetry in sensory re-weighting dynamics that could be a general property of adaptive estimation in the nervous system.

Vettel, J.M., Green, J., Heller, L. & Tarr, M.J. (in revision). Temporal and semantic effects on multimodal integration. J. of Neuroscience.

How do we integrate modality-specific perceptual information arising from the same physical event into a coherent percept? One possibility is that observers rely on information across perceptual modalities that shares temporal structure and/or semantic associations. To explore the contributions of these two factors in multimodal integration, we manipulated the temporal and semantic relationships between auditory and visual information produced by real-world events, such as paper tearing or cards being shuffled. We identified distinct neural substrates for integration based on temporal structure as compared to integration based on event semantics. Temporally asynchronous events recruited right frontal cortices, while semantically incongruent events recruited left frontal regions. At the same time, both forms of incongruence recruited subregions in the temporal, occipital, and lingual cortices. Finally, events that were both temporally and semantically congruent modulated activity in the parahippocampus and anterior temporal lobe. Taken together, these results indicate that low-level perceptual properties such as temporal synchrony and high-level knowledge such as semantics play a role in our coherent perceptual experience of physical events.

Research Area 1.3: Structure-Function Modeling

Cassenti, D.N., Kerick, S.E., & McDowell, K. (in press). Observing and modeling cognitive events through event related potentials and ACT-R. Cognitive Systems Research.

The study of cognition is generally thought to rely on techniques for inferring cognitive processes that are unobservable. One approach to cognitive science is to leverage an understanding of structure and function of the nervous system based on observable neurological events to determine mental processing. Event-related potential (ERP) research offers one technique to objectively measure cortical responses that are believed to be associated with perceptual and cognitive processes. Here, two ACT-R (Adaptive Control of Thought – Rational) models of mental processing are adapted based on the results of two ERP experiments. The models provide both a sequence of mental steps required to complete each task and a greater specificity of time course of mental events than traditional ACT-R models. We conclude with implications of this research for cognitive theory and ACT-R as well as future work to be conducted.

Thrust Area 2: Advanced Computational Approaches

Research Area 2.1: Data Extraction, Fusion, and Interpretation

Shackman, A. J., McMenamin, B. W., **Maxwell, J. S.,** Greischar, L. L., & Davidson, R. J. (in press). Identifying robust and sensitive frequency bands for interrogating neural oscillations. NeuroImage.

Recent years have seen an explosion of interest in using neural oscillations to characterize the mechanisms supporting cognition and emotion. Oftentimes, oscillatory activity is indexed by mean power density in predefined frequency bands. Some investigators use broad bands originally defined by prominent surface features of the spectrum. Others rely on narrower bands originally defined by spectral factor analysis (SFA). Presently, the robustness and sensitivity of these competing band definitions remains unclear. Here, a Monte Carlo-based SFA strategy was used to decompose the tonic ("resting" or "spontaneous") electroencephalogram (EEG) into five bands: delta (1-5Hz), alpha-low (6- 9Hz), alpha-high (10-11Hz), beta (12-19Hz), and gamma (>21Hz). This pattern was consistent across SFA methods, artifact correction/rejection procedures, scalp regions, and samples. Subsequent analyses revealed that SFA failed to deliver enhanced sensitivity; narrow alpha sub-bands proved no more sensitive than the classical broadband to individual differences in temperament or mean differences in task-induced activation. Other analyses suggested that residual ocular and muscular artifact was the dominant source of activity during quiescence in the delta and gamma bands. This was observed following threshold-based artifact rejection or independent component analysis (ICA)-based artifact correction, indicating that such procedures do not necessarily confer adequate protection. Collectively, these findings highlight the limitations of several commonly used EEG procedures and underscore the necessity of routinely performing exploratory data analyses, particularly data visualization, prior to hypothesis testing. They also suggest the potential benefits of using techniques other than SFA for interrogating high-dimensional EEG datasets in the frequency or time-frequency (event-related spectral perturbation, event-related synchronization/desynchronization) domains.

Casanova, R., Yang, L.L., **Hairston, W.D.,** Laurienti, P.J., and Maldjian, J. (2009). Examing the impact of spatio-temporal smoothness constraints on the BOLD hemodynamic response function estimation: an analysis based on Tikhonov regularization. *Physiological Measurement, 30(5): N37-N51.*

Recently we have proposed the use of Tikhonov regularization with temporal smoothness constraints to estimate the BOLD fMRI hemodynamic response function (HRF). The temporal smoothness constraint was imposed on the estimates by using second derivative information while the regularization parameter was selected based on the generalized cross-validation function (GCV). Using one-dimensional simulations, we previously found this method to produce reliable estimates of the HRF time course, especially its time to peak (TTP), being at the same time fast and robust to over-sampling in the HRF estimation. Here, we extend the method to include simultaneous temporal and spatial smoothness constraints. This method does not need Gaussian smoothing as a pre-processing step as usually done in fMRI data analysis. We carried out two-dimensional simulations to compare the two methods: Tikhonov regularization with temporal (Tik-GCV-T) and spatio-temporal (Tik- GCV-ST) smoothness constraints on the estimated HRF.We focus our attention on quantifying the influence of the Gaussian data smoothing and the presence of edges on the performance of these techniques. Our results suggest that the spatial smoothing introduced by regularization is less severe than that produced by Gaussian smoothing. This allows more accurate estimates of the response amplitudes while producing similar estimates of the TTP. We illustrate these ideas using real data.

Hairston, W.D. & Maldjian, Joseph A. (2009). An adaptive staircase procedure for the E-Prime programming environment. *Computer Methods and Programs in Biomedicine. 93(1) 104-8.*

Many studies need to determine a subject's threshold for a given task. This can be achieved efficiently using an adaptive staircase procedure. While the logic and algorithms for staircases have been well established, the few pre-programmed routines currently available to researchers require at least moderate programming experience to integrate into new paradigms and experimental settings. Here, we describe a freely distributed routine developed for the E-Prime programming environment that can be easily integrated into any experimental protocol with only a basic understanding of E-Prime. An example experiment (visual temporal-order-judgment task) where subjects report the order of occurrence of two circles illustrates the behavior and consistency of the routine.

Kerick, S.E., Oie, K.S., & McDowell, K. (2009). Assessment of EEG Signal Quality in Motion Environments. ARL Technical Report (ARL-TR-4866), Aberdeen Proving Ground, MD.

Assessing the neurocognitive demands of humans operating in real-world environments is critical for understanding Soldier performance. However, the capability to reliable measure brain dynamics of Soldiers in operational environments is a major challenge because of inherent artifacts in real environments. This study quantified the integrity of electroencephalographic (EEG) signals as a function of varied motion artifacts that are characteristic of realistic environments. Participants performed a standard auditory discrimination task in three ambulatory and three vehicle motion environments. Classic event-related potential (ERP) waveforms were observed as evidenced by higher amplitude P300s to target vs. non-target stimuli and increasing amplitudes from frontal to parietal midline recording sites in some conditions. However, artifacts in other conditions resulted in significant data loss and contamination that prevented analysis of ERP data. Spectral analyses were also applied to characterize the nature and extent of artifacts present in each condition, showing that induced signal artifacts were generally related to the specific motion environments. In conclusion, our results suggest that EEG can be reliably recorded in certain operational environments such as driving on paved or washboard surfaces, but advanced technologies and artifact reduction algorithms are required to improve signal reliability in ambulatory and more extensive vehicle motion environments.

Luu, P., Frank, R., **Kerick, S.,** & Tucker, D.M. (2009). Directed components analysis: An analytic method for the removal of biophysical artifacts from EEG data. Paper presented at the 13th International Conference on Human Computer Interaction (HCI), San Diego, CA.

Abstract.

Artifacts generated by biophysical sources (such as muscles, eyes, and heart) often hamper the use of EEG for the study of brain functions in basic research and applied settings. These artifacts share frequency overlap with the EEG, making frequency filtering inappropriate for their removal., Spatial decomposition methods, such as principal and independent components analysis, have been employed for the removal of the artifacts from the EEG. However, these methods have limitations that prevent their use in operational environments that require real-time analysis. We have introduced a directed components analysis (DCA) that employs a spatial template to direct the selection of target artifacts. This method is computationally efficient, allowing it to be employed in real-world applications. In this paper, we evaluate the effect of spatial undersampling of the scalp potential field on the ability of DCA to remove blink artifacts.

McMenamin, B.W., Shackman, A.J., **Maxwell, J.S.,** Greischar , L.L., & Davidson, R.J. (2009). Validation of regression-based myogenic correlation techniques for scalp and source-localized EEG. Psychophysiology, 46, 578-592.

EEG and EEG source-estimation are susceptible to electromyographic artifacts (EMG) generated by the cranial muscles. EMG can mask genuine effects or masquerade as a legitimate effectFeven in low frequencies, such as alpha (8–13 Hz). Although regression-based correction has been used previously, only cursory attempts at validation exist, and the utility for source-localized data is unknown. To address this, EEG was recorded from 17 participants while neurogenic andmyogenic activity were factorially varied.We assessed the sensitivity and specificity of four regressionbased techniques: between-subjects, between-subjects using difference-scores, within-subjects condition-wise, and within-subject epoch-wise on the scalp and in data modeled using the LORETA algorithm. Although within-subject epoch-wise showed superior performance on the scalp, no technique succeeded in the source-space. Aside from validating the novel epoch-wise methods on the scalp, we highlight methods requiring further development.

McMenamin, B.W., Shackman, A.J., **Maxwell, J.S.,** Bachhuber, D.R., Koppenhaver, A.M., Greischar, L.L., & Davidson, R.J. (2009). Validation of ICA-Based Myogenic Artifact Correction for Scalp and Source-Localized EEG. NeuroImage, 49, 2416-2432.

Muscle electrical activity, or "electromyogenic" (EMG) artifact, poses a serious threat to the validity of electroencephalography (EEG) investigations in the frequency domain. EMG is sensitive to a variety of psychological processes and can mask genuine effects or masquerade as legitimate neurogenic effects across the scalp in frequencies at least as low as the alpha band (8–13 Hz). Although several techniques for correcting myogenic activity have been described, most are subjected to only limited validation attempts. Attempts to gauge the impact of EMG correction on intracerebral source models (source "localization" analyses) are rarer still. Accordingly, we assessed the sensitivity and specificity of one prominent correction tool, independent component analysis (ICA), on the scalp and in the source-space using high-resolution EEG. Data were collected from 17 participants while neurogenic and myogenic activity was independently varied. Several protocols for classifying and discarding components classified as myogenic and non-myogenic artifact (e.g., ocular) were systematically assessed, leading to the exclusion of one-third to as much as threequarters of the variance in the EEG. Some, but not all, of these protocols showed adequate performance on the scalp. Indeed, performance was superior to previously validated regression-based techniques. Nevertheless, ICA-based EMG correction exhibited low validity in the intracerebral source-space, likely owing to incomplete separation of neurogenic from myogenic sources. Taken with prior work, this indicates that EMG artifact can substantially distort estimates of intracerebral spectral activity. Neither regression- nor ICA-based EMG correction techniques provide complete safeguards against such distortions. In light of these results, several practical suggestions and recommendations are made for intelligently using ICA to minimize EMG and other common artifacts.

Shackman, A.J., McMenamin, B.W., Slagter, **Maxwell, J.S.,** Greischar, L.L., & Davidson, R.J. (2009). Electromyogenic artifacts and electroencephalographic inferences. Brain Topography, 22:1, 7-12.

Muscle or electromyogenic (EMG) artifact poses a serious risk to inferential validity for any electroencephalography (EEG) investigation in the frequency domain owing to its high amplitude, broad spectrum, and sensitivity to psychological processes of interest. Even weak

EMG is detectable across the scalp in frequencies as low as the alpha band. Given these hazards, there is substantial interest in developing EMG correction tools. Unfortunately, most published techniques are subjected to only modest validation attempts, rendering their utility questionable. We review recent work by our laboratory quantitatively investigating the validity of two popular EMG correction techniques, one using the general linear model (GLM), the other using temporal independent component analysis (ICA). We show that intra-individual GLM-based methods represent a sensitive and specific tool for correcting on-going or induced, but not evoked (phaselocked) or source-localized, spectral changes. Preliminary work with ICA shows that it may not represent a panacea for EMG contamination, although further scrutiny is strongly warranted. We conclude by describing emerging methodological trends in this area that are likely to have substantial benefits for basic and applied EEG research.

Research Area 2.2: Statistical Modeling and State Classification

None

Thrust Area 3: Neurotechnologies

Research Area 3.1: Sensors and Data Acquisition

Vettel, J.M. & Hairston, W.D. IRB Protocol: Comparison of operationally-relevant EEG systems.

The purpose of this project is to compare an industry-standard, wired, 64-channel EEG system with two recently acquired EEG systems that have 9 electrodes, can transmit data wirelessly, and may be well-suited to collect neural data from complex, operational settings. The protocol will develop quantitative measures of both EEG signal quality and algorithm classification performance in order to compare the systems and assess their relevance for particular operationally-relevant tasks and environments. In the preliminary data collection study for these new systems, no more than 30 participants recruited through flyers and word of mouth will complete experimental tasks in the MIND laboratory in Building 459. These tasks involve making judgments based on visual or auditory information presented on a computer screen, driving a simulated vehicle through a computer-generated environment, and moving particular body parts for a fixed time duration in order to assess movement artifacts. Based on the experimental results from this preliminary study, follow-up studies using the same procedure will be designed with complementary experimental tasks to further quantify the comparison among the EEG systems.

Research Area 3.2: Brain Computer Interfaces

None

Research Area 3.3: Task Allocation Systems and Adaptive Displays

Oie, K.S. & McDowell, K. (in press). Neurocognitive engineering for systems development. Defense Intelligence Journal., *(Invited Article)*

Other Neuroscience-Related Publications

Hatfield, B. D. & **Kerick, S. E.** (2007). The psychology of superior sport performance: A cognitive and affective neuroscience perspective. In G. Tenenbaum and R. C. Eklund (Eds.) Handbook of Sport Psychology (3rd ed.). Hoboken, NJ: John Wiley and Sons, Inc.

Kerick, S. E., Douglass, L. W., & Hatfield, B. D. (2004). Cerebral cortical adaptations associated with visuomotor practice. Medicine and Science in Sports and Exercise, 36, 118-129.

Purpose: Electroencephalographic (EEG) recordings were examined at the temporal (T3, T4) regions of the cerebral cortex in novice pistol shooters (N=11) over a training period of 12–14 wk to determine changes in activation. Mean alpha power and its rate of change were hypothesized to increase in the left temporal region during aiming from early to late season as participants improved their accuracy and reduced cognitive effort. Methods: Event-related alpha II power (ERAP; 11–13 Hz) was examined over a 5-s period preceding the trigger pull during shooting (SH) and two control conditions (resting baseline, BL; and postural simulation, PS) at early (time 1), middle (time 2), and late (time 3) practice. Results: Mean levels of ERAP increased at T3 from the beginning to the end of the training period during both SH and PS, but not BL, whereas no such change in mean level of ERAP was noted at T4 during any of the three conditions. The practice-related cortical adaptation during SH covaried with an increase in shooting percentage over the season. A higher rate of increase in ERAP during the 5-s aiming period of SH relative to that at PS and BL was also observed throughout training at both T3 and T4. Exploratory analysis of global power (sites F3, Fz, F4, C3, Cz, C4, P3, Pz, and P4) revealed that ERAP increased during SH from time 1 to time 3 at all sites except Fz and Pz, whereas only one site (C4) revealed an increase during BL. Conclusions: The reduction in cortical activity is likely due to sensorimotor integration and less cognitive effort due to automaticity.

McDowell, K. & Maxwell, J.S. (2009). Neuroscience, cognitive engineering, and performance. White paper for Neuroscience and Performance Symposium sponsored by Col. Chandler (TRADOC), University of Maryland, College Park.

No Abstract

McDowell, K., Oie, K.S., Crabb, B.T., Paul, V., & Brunye, T.T. (2009). The need for cognitive engineering in the United States Army. "Insight," International Council on Systems Engineering, Vol 12(1), 7-10. (*Invited Article)*

No Abstract

McDowell, K., & Zywiol, Jr., H. (2009). The Army's need for cognitive engineering. In Proceedings of the 2009 Ground Vehicle Systems Engineering and Technology Symposium (GVSETS), Troy, MI.

Imagine Soldiers reacting to an unpredictable, dynamic, stressful situation on the battlefield. How those Soldiers think about the information presented to them by the system or other Soldiers during this situation – and how well they translate that into thinking into effective behaviors – is critical to how well they perform. Importantly, those thought processes (i.e., cognition) interact with both external (e.g., the size of the enemy force, weather) and internal (e.g., ability to communicate, personality, fatigue level) factors. The complicated nature of these interactions can have dramatic and unexpected consequences, as is seen in the analysis of military and industrial disasters, such as the shooting down of Iran Air flight 655, or the partial core meltdown on Three Mile Island. In both cases, decision makers needed to interact with equipment and personnel in a stressful, dynamic, and uncertain environment. Similarly, the complex and dynamic nature of the contemporary operating environment faced by the United States Army makes it clear that mission performance depends on systems that are engineered to ensure that the complex systems of people and technology (i.e., sociotechnical systems) can sustain high levels of cognitive performance needed for succeed. This session overview highlights cognitive engineering and illustrates how modeling and simulation can address different aspects of this important field.

Metcalfe, J., **Brick-Larkin, G**., Johnson, T., **Oie, K.,** Paul, V., **Davis, J.** (in press). Experimentation and evaluation of threat detection and local area awareness using advanced computational technologies in a simulated military environment. Proceedings of the 2010 SPIE Defense, Security & Sensing Conference, Orlando, FL.

Tomorrows military systems will require novel methods for assessing Soldier performance and situational awareness (SA) in mobile operations involving mixed-initiative systems. Although new methods may augment Soldier assessments, they may also reduce Soldier performance as a function of demand on workload, requiring concurrent performance of mission and assessment tasks. The present paper describes a unique approach that supports assessment in environments approximating the operational context within which future systems will be deployed. A complex distributed system was required to emulate the operational environment. Separate computational and visualization systems provided an environment representative of the military operational context, including a 3-D urban environment with dynamic human entities. Semi-autonomous driving was achieved with a simulated autonomous mobility system and SA was assessed through digital reports. A military crew station mounted on a 6-DOF motion simulator was used to create the physical environment. Cognitive state evaluation was enabled using physiological monitoring. Analyses indicated individual differences in temporal and accuracy components when identifying key features of potential threats; i.e., comparing Soldiers and insurgents with non-insurgent civilians. The assessment approach provided a natural, operationally-relevant means of assessing needs of future secure mobility systems and detecting key factors affecting Soldier-system performance as foci for future development.

Oie KS, Paul V (2009). The utility of ride motion simulation in a neuroergonomic approach to systems design. Presented at the 2009 Ground Vehicle Systems and Engineering Technology Symposium, Troy, MI.

The complexity of the current and future security environment will impose new and ever-changing challenges to Warfighter capabilities. Given the critical nature of Soldier cognitive performance in meeting these increased demands, systems should be designed to work in ways that are consistent with human cognitive function. Here, we argue that traditional approaches to understanding the human and cognitive dimensions of systems development cannot always provide an adequate understanding of human cognitive performance. We suggest that integrating neuroscience approaches and knowledge provides unique opportunities for understanding human cognitive function. Such an approach has the potential to enable more effective systems design – that is, neuroergonomic design – and that it is necessary to obtain these understandings within complex, dynamic environments. Ongoing research efforts utilizing large-scale ride motion simulations that allow researchers to systematically constrain environmental complexity are then discussed.

Ries, A. & Vettel J.M. (in press). Augmenting Test and Evaluation Assessments Using Eye-tracking and Electroencephalography. ITEA.

Tools that provide continuous, objective measurements of human-system interactions can augment measures obtained through subjective assessments and/or expert observation by providing near-real time performance metrics. Two tools for the test and evaluation (T&E) community will be discussed: eye-tracking applications that are viable for use in T&E today and electroencephalography (EEG)-based metrics that hold promise for the future.

Shackman, A.J., McMenamin, B.W., **Maxwell, J.S.,** Greischar, L.L., & Davidson, R.J. (2010). Right dorsolateral prefrontal cortical activity and behavioral inhibition. Psychological Science, 20, 1500-1506.

Individuals show marked variation in their responses to threat. Such individual differences in behavioral inhibition play a profound role in mental and physical well-being. Behavioral inhibition is thought to reflect variation in the sensitivity of a distributed neural system responsible for generating anxiety and organizing defensive responses to threat and punishment. Although progress has been made in identifying the key constituents of this behavioral inhibition system in humans, the involvement of dorsolateral prefrontal cortex (DLPFC) remains unclear. Here, we acquired self-reported Behavioral Inhibition System Sensitivity scores and high-resolution electroencephalography from a large sample (n 5 51). Using the enhanced spatial resolution afforded by source modeling techniques, we show that individuals with greater tonic (resting) activity in right-posterior DLPFC rate themselves as more behaviorally inhibited. This observation provides novel support for recent conceptualizations of behavioral inhibition and clues to the mechanisms that might underlie variation in threat-induced negative affect.

Yu, A.B., Zacks, J.M. (in press). The Role of Animacy in Spatial Transformations. Memory & Cognition.

We present evidence that different mental spatial transformations are used to reason about three different types of items representing a spectrum of animacy: human bodies, non-human animals, and inanimate objects. Participants made two different judgments about rotated figures: handedness judgments ("Is this the left or right side?") and matching judgments ("Are these figures the same?"). Perspective-taking strategies were most prevalent when participants made handedness judgments about human bodies and animals. In contrast, participants generally did not imagine changes in perspective to perform matching judgments. Such results suggest that high-level information about semantic categories, including information about a thing's animacy, can influence how spatial representations are transformed when performing on-line problem solving.

Soldier Performance

Thrust Area 1: Sensory-Vision

Research Area 1.1: Visual target Acquisition

Vaughan, B. M. (2006). Soldier-in-the-Loop Target Acquisition Performance Prediction Through 2001: Integration of Perceptual and Cognitive Models (ARL-TR-3833). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

Modeling Soldier-in-the-loop target acquisition performance is necessary for the development of improved sensors, more effective training methods, and better war game simulations. Accurately modeling this performance requires a detailed understanding of the environment, how a sensor responds to the environment, how it displays information to an observer, and how the observer employs that information to acquire a target. The first three requirements have been met; the fourth requirement, however, has not yet been achieved. Attempts to model the observer' s visual and decision-making processes have been compromised by the analysis of the scene, based on physical parameters alone rather than how the visual system interprets the scene. Models based on such scene-derived factors have had limited success. This report takes a two-pronged approach to how future models can be improved by the sensible integration of human visual processing. One prong concerns basic research from the perceptual psychology community. Over the last few decades, this research has generated a detailed theoretical understanding of visual processing and decision making, based on visual information. The other prong concerns important models, modeling frameworks, and scene metrics from the military target acquisition community. Particular attention is paid to issues of clutter, the extendibility of the Johnson criteria, classical and neoclassical search frameworks, the selection of methods and performance metrics, and existing Night Vision and Electronic Sensors Directorate models. Issues related to the validation of target acquisition models are also discussed. Existing target acquisition models tend to base performance on (a) one-dimensional (1-D) metrics defining the amount of information in the target (e.g., resolvable bar cycles, contrast, area, size, perimeter, speed of motion) and how that information correlates to level of performance in a target acquisition task (i.e., detection, classification, recognition, and identification), (b) search processes that are unrealistic (e.g., that assume random eye movements), and (c) 1-D metrics to define the whole scene (clutter) or regions of the scene (e.g., clutter, conspicuity, attractiveness). These tendencies fail to account for known human behavior, although models incorporating them may be insensitive to the details of human performance because they predict ensemble rather than individual performance. Phenomena from perceptual psychology known to affect target acquisition are reviewed in terms of how target acquisition models do and do not account for them. Such factors include motion, color, and visual transients. Basic models of visual search are included as guides for how target acquisition models may incorporate some of these factors. Visual selective attention is recommended as a means for the theoretically meaningful inclusion of psychologically important factors into target acquisition modeling.

Monaco, W.A., Kalb, J.T., Johnson, C.A. (2007). Motion Detection in the Far Peripheral Visual Field (ARL-MR-0684). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory

Our objectives were to apply Bayesian threshold estimation procedures and new technology to the determination of motion detection (angular velocity) and to determine whether threshold measures, combined with large screen technology and specialized software, could be used to evaluate human motion sensitivity in the far peripheral visual field beyond 50 degreesradius. With the use of the Parameter Estimation by Sequential Testing threshold estimation procedure, black dot targets were presented at 53.4, 72.6, and 90 degrees eccentricity in the temporal visual field of two subjects who had normal visual function. Motion detection thresholds demonstrated a systematic increase with increasing visual field eccentricity and could be obtained within 10 stimulus trials. The average angular velocity motion thresholds were approximately 0.5 degree per second for the 54.3-degree eccentricity, 1.2 to 1.5 degrees per second for the 72.6-degree eccentricity, and 2.1 degrees per second for the 90-degree eccentricity. Our findings indicate that it is possible to obtain motion detection (displacement) thresholds in the far peripheral visual field using Bayesian threshold estimation procedures. In view of the importance of motion detection in the periphery for stimulus localization, attentional demands, orientation and mobility tasks, this procedure may have significant applications for many military visual tasks.

Monaco, W.A., Heimerl, J.M., & Kalb, J.T. A Clinically Useful Tool to Determine an Effective Snellen Fraction (ARL-TR-4756). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

A patient's visual function has been routinely assessed by a visual acuity measurement, usually by means of a Snellen chart. More recently, visual acuity measurements have been extended to measure the progress of disease or the efficacy of therapeutic interventions. Thus, accurate and reproducible visual acuity measurements are needed. However, the intrinsic variability in line-by-line scoring is high because only 50%-80% of the letters in a line need be correctly identified to score a successful reading of the entire line. To reduce this high test-retest variability, we developed a tool whereby the cumulative letter-by-letter logarithm of minimum angle of resolution (LogMAR) values of a patient's responses are converted into an effective Snellen fraction. With these concepts, test-retest visual acuity measurements are known to be more precise by up to a factor of 2. These concepts have been combined into a spreadsheet that automatically and transparently calculates the effective Snellen fraction. This spreadsheet is simple to use, making its introduction into the clinic straightforward. This report documents the details of the processes constituting this tool, which is available for download from the Pennsylvania College of Optometry web site: www.salus.edu.

Monaco, W. A., Higgins, K. E., & **Kalb, J. T**. (in press). Central and off-axis spatial contrast sensitivity measures with Gabor patches. Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

The Army acquisition community uses models of human and systems performance to evaluate materiel. One such model, used to assess equipment for the dismounted Soldier, is the Individual Warrior Simulation (IWARS). When Soldier modeling target acquisition, IWARS applies the ACQUIRE model to some portion of the visual scene, determines the probability of detecting a target if one is present, then repeats the process for a different portion of the field. ACQUIRE predicts the probability of visually acquiring a target presented anywhere within its field of view without regard for the location of the target in the scene. Human visual performance varies dramatically across the field of view, with acuity decreasing rapidly as objects move away from the center of gaze or away from the central vertical and horizontal axes of vision. The current research used Gabor patches to characterize visual detection thresholds at various locations around central vision. Results showed a marked increase in contrast threshold for targets of a y of spatial frequencies ranging from 0.5 to 18.2 cycles/degree appearing greater than +3°–4° horizontal eccentricity. These results can be used to intelligently constrain the portion of the visual field over which IWARS applies the ACQUIRE detection model.

Vaughan, B.D., Kalb, J.T., & Fedele, P.H. (IRB Protocol) Characterizing detection of dismounted human targets in the far visual periphery.

The Army acquisition community uses models of human and systems performance to evaluate materiel. One such model, used to assess equipment for the dismounted Soldier, is the Individual Warrior Simulation (IWARS). IWARS simulates human visual search by applying the ACQUIRE target acquisition model to some portion of the visual scene, determining the probability of detecting a target. If no target is detected, it applies ACQUIRE to an adjacent portion of the scene following a fixed path from one corner of the scene to the other until either a target is found or the scene has been searched completely. Though target detection in human vision depends on central vision, the locations of visual fixations are not fixed; rather, they depend greatly on the intent and experience of the observer and on the salience of visual elements and events in the scene itself. Because of how IWARS uses ACQUIRE, the model runs very slowly and produces results that are unrealistic. Our hypothesis is that by improving the ecological validity of how IWARS 'searches' a scene, its performance (running time and predictive accuracy) will be improved. To this end will perform experiments to empirically characterize the probability of visual detection of low-contrast, moving or flickering stimuli presented in the far visual periphery. Stimuli characteristics are based on militarily relevant targets for a dismounted Soldier – individual dismounted enemy forces running for short distances at a range of approximately 50-100 meters. We will present stimuli in the far visual periphery (up to 80 degrees), an eccentricity that is important yet poorly studied, and determine the contrast required to reliably detect such targets. Data will be fed back to the IWARS developers at Natick Soldier Center and the Army Materiel and Systems Analysis Activity (AMSAA) for incorporation into subsequent IWARS models.

White T.L. (Project) Effects of Signal reliability on visual scanning behavior, target detection and subjective workload.

Aim: The aim of this research is quantify the effects of reductions in the reliability of a miss-prone automated target detection system on visual scanning behavior, target detection, and subjective workload. **Methods:** A study was conducted that employed a simulated crew station that consisted of three screens that provided a view in front of a vehicle traveling through a virtual environment. Targets were presented in the proximity of five clock positions (i.e., 10, 11, 12, 1, and 2 o'clock). Target location cues were provided verbally in a clock-type format (e.g., "2 o'clock- 2' o'clock!"). The experimental design was a within-subjects design with four experimental conditions (1) Baseline (no target location cues) (2) R90, (3) R75, (4) R60. Data collection included measures of target acquisition performance, visual scanning (eye and head movements), and subjective ratings of workload. **Progress:** Preliminary results indicate that detection time increased as the reliability of the cues decreased. No significant effects of overall workload were revealed. Data collection and analysis are complete, technical report is in progress. **Current Goals:** The goal is to quantify the effects of reductions in the reliability of a miss-prone and false alarm-prone automated target detection system on visual scanning behavior, target detection, and subjective workload.

Research Area 1.2: Perception and Night Vision Sensor Design

CuQlock-Knopp, V. G., Wallace, S., Karsh, R., Merritt, J., & Kregel, M. (in press). Video-based criterion measure. In *Identifying Experts in the Detection of Improvised Explosive Devices (IED2)*, United States Army Research Institute for the Behavioral and Social Sciences.

A high definition stereoscopic video task, the Video-Based Criterion (VBC) measure, was designed to assess IED detection performance using 3-D video clips of realistic scenarios, wherein IEDs are camouflaged by the background or concealed in visual clutter. Both 2D and 3-D renditions of the video clips were used to test two hypotheses: one, that viewing a scene in 3-D will facilitate an individual's efficiency in extracting visual details compared to viewing a 2D rendition of the video clips; two, that extraordinary binocular depth acuity and fine texture-contrast discrimination are characteristics of Warfighters who are proficient in finding IEDs and related components and cues. The items identified by participants (either an IED, IED components, markers, cues to an IED emplacement, or suspicious areas) were operationally defined as areas-of-interest (AOIs). Results indicated that the number of AOIs mentioned in 3-D was significantly higher than the number of AOIs mentioned in 2D. With regard to the second hypothesis, results indicated that texture-contrast discrimination is highly predictive of the number of AOIs mentioned; however, depth acuity did not predict performance on the VBC task. Warfighters who participated in the data collections and demonstration sessions overwhelmingly recommended the use of the VBC as a training tool. These recommendations are presented in this chapter.

Arunkumar Mohananchettiar, Volkan Cevher, **CuQlock-Knopp, G**., Chellappa, Rama and Merritt, J., (2007) *Hyperstereo Algorithms for the Perception of Terrain Drop-offs*, Head-and Helmet-Mounted Displays XII: Design and Applications, Proceeding of the SPIE, VOL 6557, 655701.

The timely detection of terrain drop-offs is critical for safe and efficient off-road mobility, whether with human drivers or with terrain navigation systems that use autonomous machine-vision. In this paper, we propose a joint tracking and detection machine-vision approach for accurate and efficient terrain drop-off detection and localization. We formulate the problem using a hyperstereo camera system and build an elevation map using the range map obtained from a stereo algorithm. A terrain drop-off is then detected with the use of optimal drop-off detection filters applied to the range map. For more robust results, a method based on multi-frame fusion of terrain drop-off evidence is proposed. Also presented is a fast, direct method that does not employ stereo disparity mapping. We compared our algorithm's detection of terrain drop-offs with time-code data from human observers viewing the same video clips in stereoscopic 3-D. The algorithm detected terrain drop-offs an average of 9 seconds sooner, or 12m farther, than the human observers. This suggests that passive image-based hyperstereo machine-vision may be useful as an early warning system for off-road mobility.

Vaughan, B., Murphy, J., Standard, T., **CuQlock-Knopp, V. G.**, & Anderson, B. (in press).*Improving IED detection through training and personnel selection*. Dayton, OH: U. S. Air Force.

Improvised explosive devices (IEDs) are frequently used against US military forces in Iraq and Afghanistan. Avoiding casualties from IEDs relies, in part, on visual identification. The capability to select Warfighters with superior visual search skill, or the ability to train Warfighters to be better visual searchers, would lead to a decrease in IED casualties. The objective of this report is to survey the military, industrial, and scientific literature and address three primary questions. First, what have laboratory investigations revealed about visual search in complex environments? Second, have differences in human visual search ability been found to correlate with psychological variables or measurable aspects of visual perception? And third, have training programs and environmental conditions been shown to improve human visual search skill in tasks similar to those of a Warfighter searching for IEDs?

Thrust Area 2: Sensory- Audition

Research Area 2.1: Speech Communications in Adverse Environments

Henry, P.P., Weatherless, R. (IRB Protocol ARL-20098-07040): Evaluation of Auditory Characteristics of Communications and Hearing Protection Systems (C&HPSs)

This is a collection of three studies to evaluate auditory characteristics of commercially available communications and hearing protection systems (C&HPSs). In order to be included in the study, the C&HPS had to be commercially available, provide radio communication, provide hearing protection, and allow for situational awareness through a talk-through system. Three systems were selected for the collection of studies: Silynx QuietOps, Nacre QuietPro, Sennheiser SLC-110. Study 1 examined the real-ear attenuation at threshold (REAT) values of the devices. One of the devices showed only minimal amounts of attenuation and was not evaluated further: Sennheiser SLC-110. Study 2 examined the speech intelligibility of the two remaining systems: Silynx QuietOps and Nacre QuietPro. Results of the speech intelligibility testing indicated that the Silynx QuietOps™ provides a significantly higher degree of speech intelligibility, but this difference is probably not significant for field applications. The differences noted in speech intelligibility are likely due to a combination of differences in the frequency responses measured from the two systems, differences in the frequency responses of the microphones from the two systems along with small differences in the output intensity of the speech items provided to the listeners. Studies 1 and 2 have been completed and published as technical reports:

Henry, P. & **Weatherless, R**. (2010). Evaluation of Auditory Characteristics of Communications and Hearing Protection Systems (C&HPSs) Part I – Sound Attenuation to Low Intensity Sounds (ARL-TR-5050). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

Henry, P. & **Weatherless, R.** (2010). Evaluation of Auditory Characteristics of Communications and Hearing Protection Systems (C&HPSs) Part II – Speech Intelligibility (ARL-TR-5075). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

Weatherless, R., Fedele, P., Kehring, K., Grantham, M., Fluitt, K. (IPB Protocol) Interaction Between Simulated Hearing Loss And Navigation Task Performance

Hearing losses are significant military problems. Hearing loss degrades speech intelligibility. In military simulations, degraded intelligibility caused degraded task and mission performance. Degraded performance is expected when critical command information is not successfully transferred by speech communication. However, communication failure is not the only mechanism through which hearing loss can degrade task performance. When attempting to understand speech, as with a hearing loss, additional attention may be required. Previous studies did not determine if degraded task performance was due to failures to communicate critical command information, or to decreased availability of attention resources needed for successful task performance. Current popular studies show that attention requirements of cell phone use degrade driving performance. This protocol investigates whether hearing loss may increase attention requirements and cause decreases in performance of concurrently performed tasks that are not dependent on information in speech stimuli. This protocol applies a dual task methodology involving a primary task, performing the Callsign Acquisition Test (CAT), and a secondary task, walking on an Omni-Directional Treadmill and navigating through a virtual urban environment. While performing the CAT, participants will walk along an unfamiliar path through the virtual environment. The CAT task will be presented at three filtered levels simulating speech presentation through hearing loss. Analyses of CAT and walking performance will determine if walking performance degradation correlates with increased levels of simulated hearing loss applied in the CAT. Since walking task performance does not depend on correctly hearing the CAT stimuli, a correlation between degraded walking performance and hearing loss simulation will indicate that an increase in attentional requirements can degrade performance on tasks not directly dependent on communicated information. This would indicate that hearing loss might have significant general impact on many tasks requiring attention.

Weatherless, R., Grantham, M., Kehring, K., & **Fedele, P.** (2010, July). Interaction Between Simulated Hearing Loss and Navigation Task Performance. Poster presented at the 3rd International Conference on Applied Human Factors and Ergonomics (AHFE 2010).

Hearing losses, temporary and permanent, are significant problems in military combat. However, the impact of hearing losses on the task performance of Soldiers remains uncertain. Previous Army studies have evaluated how decreased speech intelligibility degrades task performance for fighting vehicle crews. These studies did not determine if the degraded task performance was due to failures in communicating task variables, or to a decreased availability of attentional resources needed for successful task execution. Studies have demonstrated performance degradation when listening, speech, and other mental tasks are performed while walking. This study investigates whether hearing loss, which may cause a further increase in attentional requirements over listening without hearing loss, can cause further decreases in the performance of concurrent, non-hearing-related tasks. In this study, participants will walk along a path in a virtual reality environment. The path will be given to them on a paper map, just before they begin walking. While they walk, they will be required to listen and respond verbally to a Callsign Acquisition Test (CAT) task. The CAT task will be presented to them at three filtered levels simulating how the CAT stimuli would sound if the listener had various levels of hearing loss. Analyses of CAT and walking performance will be used to determine if walking performance degradation correlates with CAT stimuli presented with increased levels of simulated hearing loss. Since the walking task performance will not depend on correctly hearing the CAT stimuli, a correlation between degraded walking performance and hearing loss simulation will indicate that increases in attentional requirements caused by hearing loss can result in degraded performance on tasks not directly dependent on the information presented in the auditory communication. Such findings would indicate that hearing loss might have significant general impact on many tasks requiring attention.

Henry, P. & **Weatherless, R**. (2010). Evaluation of Auditory Characteristics of Communications and Hearing Protection Systems (C&HPSs) Part I – Sound Attenuation to Low Intensity Sounds (ARL-TR-5050). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

Devices that provide hearing protection, situational awareness, and radio communications are often referred to as Communications and Hearing Protection Systems (C&HPSs). Soldiers use these systems while deployed to navigate within their environment, communicate with their team members, and protect their hearing. Each of the three features of select C&HPSs (hearing protection, speech communication, and situational awareness) was evaluated by the U.S. Army Research Laboratory in order to obtain data that is independent from that provided by the manufacturer. This report is the first in a series of three and focuses on the sound attenuation performance obtained from two commercially available C&HPSs: Nacre QuietPro and Silynx QuietOps selected from three C&HPSs evaluated for attenuation characteristics in the first report. Results of the speech intelligibility testing indicated that the Silynx QuietOps provides a significantly higher degree of speech intelligibility, but this difference is probably not significant for field applications. The differences noted in speech intelligibility are likely due to a combination of differences in the frequency responses measured from the two systems and differences in the frequency responses of the microphones from the two systems, along with small differences in the output intensity of the speech items provided to the listeners.

Henry, P. & **Weatherless, R.** (2010). Evaluation of Auditory Characteristics of Communications and Hearing Protection Systems (C&HPSs) Part II – Speech Intelligibility (ARL-TR-5075). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

Devices that provide hearing protection, situational awareness and radio communications are often referred to as Communications and Hearing Protection Systems (C&HPSs). Soldiers use these systems while deployed to navigate within their environment, communicate with their team members and protect their hearing. Each of the three features of select C&HPSs (hearing protection, speech communication and situational awareness) were evaluated by the Army Research Laboratory in order to obtain data that is independent from that provided by the manufacturer. This report is the second in a series of three and focuses on the speech intelligibility performance obtained from two commercially available C&HPSs: Nacre QuietPro®, and Silynx QuietOps™ selected from three C&HPSs evaluated for attenuation characteristics in the first report. Results of the speech intelligibility testing indicated that the Silynx QuietOps™ provides a significantly higher degree of speech intelligibility, but this difference is probably not significant for field applications. The differences noted in speech intelligibility are likely due to a combination of differences in the frequency responses measured from the two systems, differences in the frequency responses of the microphones from the two systems along with small differences in the output intensity of the speech items provided to the listeners.

Rao, M. & **Letowski, T.** (2006). Callsign Acquisition Test (CAT): Speech intelligibility in noise. *Ear and Hearing*, 27(2): 120-128.

OBJECTIVE: The study was designed to assess the effects of noise on the intelligibility of speech elements used in the Callsign Acquisition Test (CAT), developed by the U.S. Army Research Laboratory. The CAT consists of 126 test items, or callsigns, each of which is made up of a two-syllable word selected from the 18-item military alphabet (Alpha-Zulu) followed by a one-syllable number (all numbers from 1 to 8, excluding 7). DESIGN: The CAT items were mixed with one of three different types of background noises (pink noise, white noise, and multitalker babble) and presented to 18 listeners. Speech-to-noise ratio for all three noises and the overall level of pink noise were varied in two separate experiments to determine how these variables affected speech intelligibility of the CAT items pronounced by a male talker. CONCLUSIONS: Test results demonstrate speech-to-noise ratio has a significant effect on speech intelligibility of the CAT items under all conditions. Pink noise generated the lowest speech intelligibility scores followed by multitalker babble and then white noise. A change in the overall level of pink noise had only small effect on CAT intelligibility.

Research Area 2.2: Auditory Situation Awareness

Grantham, M., Gaston, J., & Letowski, T.R. (IRB Protocol) Auditory Recognition of the Direction of Walking.

Aim: The ability to hear an enemy is a matter of battlefield survivability for a Soldier. Soldiers must often listen for the enemy in environments where there is little or no visual information available, for example, at night or in inclement weather. Important signatures of an approaching enemy include footsteps. The aim of the present study was to investigate how well listeners can auditorily identify the direction of approaching footsteps moving toward them. The main difficulty of this listening task is that both direction and distance information change continuously and are confounded by a continuously changing environmental background. The results of this study will be used to discuss listener performance limits, in addition to future research to support training for listeners with poor auditory motion recognition skills. **Methods:** Although the Soldier's acoustic conditions are unique, traditional psychophysical and perceptual measurement paradigms are used. The Environment for Auditory Research (EAR) facility was designed to allow simulation of the Soldier's real-world acoustical conditions such as reverberation, distance and movement. Location of approaching enemy walkers and Soldier perception of safety from an enemy approaching on foot are assessed in order to determine the limits of human auditory perception of moving sound sources. These data are transitioned to the scientific literature and used to develop a clearer understanding of auditory performance. **Current Goals:** Research is being conducted in order to develop training methods (approaching enemy location and reaction tactics, techniques, and procedures) and to populate the research literature with auditory performance data in complex acoustic environments (e.g., auditory localization of movement, in distance, in reverberation, and with Soldier hearing protection and helmets).

Grantham, M., Gaston, J., & **Letowski, T.R.** (2010, July). Auditory Recognition of the Direction of Walking. Proceedings of the 17th International Congress on Sound and Vibration, Cairo, Egypt.

The ability to hear an enemy is a matter of battlefield survivability for a Soldier. Soldiers must often listen for the enemy in environments where there is little or no visual information available, for example, at night or in inclement weather. Important signatures of an approaching enemy are the footsteps or other sounds made by approaching Soldiers. The goal of the present study was to investigate how well listeners can identify whether footsteps are moving toward or away from them, and from which direction the footsteps are approaching. The main difficulty of this listening task is that both direction and distance information change continuously and are confounded by a continuously changing environmental background. The results of this study will be used to discuss listener performance limits, in addition to training for listeners with poor auditory motion recognition skills.

Scharine, A. A., Mermagen, T., Binseel, M. S. & **Ericson, M. A.** (IRB-Approved Protocol ARL-20098-10024) “Sound Localization response time and accuracy data for free-field and MOUT conditions. Part 1: Baseline data and validation of virtual presentation techniques.” (TPA NA-HR-2010-01: FY2010-2012)

Aim: The Infantry Warrior Simulation (IWARS) model is used to assess the operational effectiveness of dismounted Soldier across the spectrum of operational environments. Its auditory component, the Auditory Detection Model (ADM; Garinther & Thompson, 1992) predicts, for given environmental conditions, whether a specific sound will be detected. It does not, however, answer the question of whether such a sound will be located in space well enough for detection to be useful. Thus the objective is to develop a localization data-base with accuracy and response time statistics for both bare headed and helmeted listeners and for a variety of acoustic contexts. Measurement techniques used in the new EAR facility will be characterized and validated. **Methods:** Localization will be measured by presenting a stimulus and asking the participant to indicate the direction it came from. The Sphere Room of the Environment for Auditory Research will be used to present stimuli from each of its 57 spherical locations and the participant will respond by turning the response chair and pointing the laser device at the perceived sound origin. Each of the following test conditions will be measured with and without a helmet. 1) Audio-visual: to validate the response methodology and estimate portion of error due to motor response; 2) loudspeakers/anechoic; 3) headphones/virtual anechoic: to validate virtual presentation techniques. Virtual presentation will be achieved by collecting individual head-related transfer functions from each participant and using them to render the virtual stimuli. The effects of complex acoustic environments will be measured in future protocols. **Progress:** The protocol has been approved. At this writing, the LED lights are being wired for installation. The localization software has been written. Additional software for virtual rendering is still needed. By the date of the TAB, data collection should be complete. **Current Goals:** Complete equipment set-up and data collection.

Localized moving sounds (Localization of moving sounds, with headgear, with hearing protection…)

Binseel, M., Scharine, A., Mermagen, T., & **Letowski, T.** (in review). Sound localization ability of Soldiers wearing infantry helmets. Military Psychology.

Infantry helmets protect a Soldier's head against ballistic and fragmentation injuries. However, greater head coverage decreases the Soldier's situation awareness (SA), increasing the chance of injury. Therefore helmet coverage must be a compromise between ballistic protection and optimal human factors design. Twelve Soldiers, each wearing no helmet, the Advanced Combat Helmet (ACH) and the Personal Armor System for Ground Troops (PASGT) helmet, localized sounds presented from sources located both vertically and horizontally Results show a significant effect of helmet condition for azimuth ($p < 0.001$) and elevation ($p < 0.001$). As expected, localization accuracy was greatest when wearing no helmet, followed by the ACH; performance was worst with the PASGT helmet.

Scharine, A. A. (2009). Degradation of auditory localization performance due to helmet ear coverage: The effects of normal acoustic reverberation (ARL-TR-4879). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

Previous research has shown that listeners wearing the Personnel Armor System for Ground Troops (PASGT) helmet performed worse than those wearing the Advanced Combat Helmet on sound localization tasks. The PASGT has greater coverage over the ears. However, these helmets also differ in their suspension systems and profiles. Three versions of a single helmet design, differing only in the ear coverage, were compared in this study. As ear coverage increased, localization performance decreased. Most of the change was due to increases in large errors (>25°). In addition, these effects were tested in both "ideal" laboratory acoustics and in a moderately reverberant environment. Moderate reverberation intensified the effects of ear coverage—improving localization performance without a helmet and impairing it the most in the greatest ear coverage condition.

MacDonald, J. A. (2008). A localization algorithm based on head-related transfer functions. Journal of the Acoustical Society of America, 123, 4290-4296.

Two sound localization algorithms based on the head-related transfer function were developed. Each of them uses the interaural time delay, interaural level difference, and monaural spectral cues to estimate the location of a sound source. Given that most localization algorithms will be required to function in background noise, the localization performance of one of the algorithms was tested at signal-to-noise ratios (SNRs) from 40 to −40 dB. Stimuli included ten real-world, broadband sounds located at 5° intervals in azimuth and at 0° elevation. Both two- and four-microphone versions of the algorithm were implemented to localize sounds to 5° precision. The two-microphone version of the algorithm exhibited less than 2° mean localization error at SNRs of 20 dB and greater, and the four-microphone version committed approximately 1° mean error at SNRs of 10 dB or greater. Potential enhancements and applications of the algorithm are discussed.

MacDonald, J. A., & **Tran, P. K.** (2008). The effect of HRTF measurement methodology on localization performance in spatial audio interfaces. Human Factors, 50, 256-263.

Objective: Four head-related transfer function (HRTF) data sets were compared to determine the effect of HRTF measurement methodology on the localization of spatialized auditory stimuli.

Background: Spatial audio interfaces typically require HRTF data sets to generate the spatialized auditory stimuli. HRTF measurement is accomplished using a variety of techniques that can require several nearly arbitrary decisions about methodology. The effects of these choices upon the resulting spatial audio interface are unclear.

Method: Sixteen participants completed a sound localization task that included real-world, broadband stimuli spatialized at eight locations on the horizontal plane. Four different HRTF data sets were utilized to spatialize the stimuli: two publicly available HRTF data sets and two data sets obtained using different in-house measurement systems. All HRTFs were obtained from the Knowles Electronics Mannequin for Acoustics Research.

Results: Unsigned localization error and proportion of front/back reversals did not differ significantly across HRTF data sets. Poorest accuracy was observed in locations near the medial (front/back) axis of the listener, mainly because of the relatively large proportions of reversals at these locations.

Conclusion: This study suggests that the particular generalized HRTF data set chosen for spatialization is of minimal importance to the localizability of the resulting stimuli.

Application: This result will inform the design of many spatial audio interfaces that are based upon generalized HRTFs, including wayfaring devices, communication systems, and virtual reality systems.

Henry, P. & **Scharine, A.** (2009, March). Perception of Auditory Motion in a Straight Trajectory. Podium presentation at the American Auditory Society Annual Meeting, Scottsdale, AZ.

Perception of auditory motion has typically been studied with sounds travelling in an arc around the listener keeping the loudspeaker to listener distance constant. However, most real-world sounds travel in a straight path. This study examined auditory motion perception in a single-interval, forced choice paradigm. Thresholds for duration were obtained from twelve listeners with normal hearing. Stimuli were recorded in two environments: a room with minimal reflections and a hallway. Recordings of white noise emitted from a loudspeaker moving at a rate of 3 feet per second (similar to a pedestrian's pace) were made through a KEMAR and played back to listeners through insert earphones. Participants were asked to indicate the direction of movement (left or right) and the duration was adapted accordingly following a two-down, one-up paradigm. The average threshold for duration in the minimally reverberant environment agrees well with previous studies of minimal audible movement angle (MAMA) with similar velocities. The threshold for duration in the maximally reverberant environment was twice as long as that found for the minimally reverberant environment. This finding suggests that reverberation reduces the information available for the detection of auditory movement either by masking the existing information or adding irrelevant and contradictory information.

Scharine, A. A. (2005). An evaluation of localization ability with selected level-dependent hearing protection systems: A field study conducted for the Future Force Warrior Integrated Headgear Integrated Process Team (ARL-TR-3579). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

The purpose of this study was to evaluate the effect of various types of level-dependent hearing protectors on human ability to localize sound sources in the horizontal plane. Five hearing protection systems (two earmuffs and three earplugs) were evaluated and compared against the open ears condition. Four listeners participated in the study, listening to a speech sound (a female saying "Joe") presented from one of an array of 12 loudspeakers surrounding the listener. Participants indicated the perceived sound source by pointing to one of the 12 loudspeakers on a computer display. Overall errors were larger in the back than in the front and were dominated by front-back confusions. Earplugs provided better localization precision than earmuffs in the frontal hemisphere but not in the rear. These results have practical implications when one is choosing hearing protection in environments where interpersonal communication is important.

Sound identification: weapon signatures

Scharine, A. A., (2009). Predicting sound attention and identification: Modeling identification of category, subcategory and specific source as a function of mission context (ARL-MR-730). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

Auditory situation awareness has been defined as the ability to detect, localize, and recognize relevant sound information in one's environment. Currently, the U.S. Army Natick Soldier Research, Development, and Engineering Center and the U.S. Army Materiel Systems Analysis Activity are working on the implementation of the Auditory Detection Model that will provide the detection component of auditory situation awareness to the Infantry Warrior Simulation (IWARS) model. However, Soldiers detect many sounds that they do not attend to or recognize. This memorandum report details preparation for a project in which sound recognition and importance data will be collected to supply the IWARS model with an estimate of the probability that sound information from a particular sound event will be attended to and utilized. This is an ongoing project; therefore, this document contains all research materials collected for this project and lists all elements of the project that will be required prior to data collection.

Gaston, J. G., Letowski, T. R., & **Fluitt, K. F.** (2009, November). Mapping listener perception of weapon signature for single-shot impulse sounds. Poster presented at the 9th annual Auditory Perception, Cognition and Action Meeting, Boston, MA.

The ability of Soldiers' to identify weapon signature from projectile weapons fire can provide critical information about ones operational environment and can cue potential danger. The present research investigates listener perception for high-quality recordings of single-shot small arms impulse sounds. In the first experiment, fifteen listeners' made similarity ratings for pairings of impulse sounds from a set of four unique tokens each of six different small arms weapons. In the second experiment, listener discrimination ability for contrasted pairs of weapons was measured for 15 listeners in a 2IFC task. Discrimination performance was best, and near ceiling, for handguns contrasted with small arms rifles. Much poorer discrimination performance was found when small arms rifles were contrasted with other rifles, even when there were large differences in projectile caliber. These discrimination results correlate well with an MDS solution based on listener similarity ratings.

Scharine, A., Letowski, T. R., Mermagen, T., & **Henry, P. P.** (2010). Learning to detect and identify acoustic environments from acoustic sound. Military Psychology, 22, 24-40.

Reflected sounds are often treated as an acoustic problem because they produce false localization cues and decrease speech intelligibility. However, their properties are shaped by the acoustic properties of the environment and therefore are a potential source of information about that environment. The objective of this study was to determine whether information carried by reflected sounds can be used by listeners to enhance their awareness of their auditory environment. Twelve listeners participated in two auditory training tasks in which they learned to identify three environments based on a limited subset of sounds and then were tested to determine whether they could transfer that learning to new, unfamiliar sounds. Results showed that significant learning occurred despite the task difficulty. An analysis of stimulus attributes suggests that it is easiest to learn to identify reflected sound when it occurs in sounds with longer decay times and broadly distributed dominant spectral components.

Gaston, R.J., Letowski, T.R.,& Fluitt, K.F. (IRB Protocol) Listener perception of single and multiple event small arms fire.

Our previous work investigated listener ability to differentiate small arms fire for single impulse events recorded from a fixed position behind the shooter. This work found that listeners could reliably distinguish handgun fire from rifle fire, but had difficulty distinguishing between individual rifles. Further, it was found that source properties of the weapons and the resulting sounds produced were moderately good in predicting listener recognition ability. The present study represents a logical progression of this initial work. In the initial study, listener perception of only single impulse event sounds was investigated for "listener" positions behind the shooter, and this is not representative of small arms fire typically encountered in operational environments. Thus, the present study is designed to look at listener perception for "listener" positions in front of the shooter for not only multiple-shot contexts, but also how perception changes as the context changes (i.e. 1 to 3 to 6 shot contexts). It is expected that as the context changes, the qualitative changes in the availability of potentially diagnostic acoustic cues will improve listener ability to differentiate small arms rifle fire. For example, in a 3 shot context, differences in cyclic rate of fire may offer diagnostic information to distinguish the AK-47 (600 rounds/min) from variants of the M4 carbine (700-950 rounds/min). Under 6 shot contexts a qualitative difference between firing modes of the AK-47 (fully automatic) and M4 carbine variants (3 round bursts) should provide very salient cue for differentiating the rifles.

<u>Sound attenuation in "noise" (other sounds)</u>

Scharine, A., Fluitt, K., & **Letowski, T.** (2009). The effects of helmet shape on directional attenuation of sound. Proceedings of the 16th International Congress on Sound and Vibration, Krakow, Poland,

Helmets and other headgear that cover the ears or place reflective boundaries next to them degrade the sound localization abilities of the wearer. However, it is less clear to what degree the presence of a helmet affects the ability of the wearer to detect sound sources. The goal of the reported series of experiments was to assess the effects of a helmet's shape on the detec-tion of sounds coming from various directions. Two military sounds, the bolt click and rifle muzzle blast sounds, and eight warble tones or one-third bands of noise centered at octave frequencies from 125 Hz to 8000 Hz were used as the test stimuli. Two U.S. Army infantry helmets, the PASGT and ACH, and two prototype helmets were worn by the listeners during the study. The detectability of the test sounds coming from various directions was assessed for conditions in which the helmet was and was not worn. The results of the study demonstrate that the detectability of sound sources was affected by all of the investigated helmets and varied depending on the type of helmet, the type and direction of the incoming sound, and the helmet fit. In most cases, the presence of a helmet had an adverse effect, but in some cases caused a slight improvement in sound detectability. Implications of these finding for Soldier's auditory awareness are discussed.

Scharine, A. A., Letowski, T. R., & Sampson, J. B. (2009). Auditory situation awareness in urban operations [Electronic version]. *Journal of Military and Strategic Studies, 11(4),* 1-28.

Soldiers conducting urban operations (UO) require focused attention and heightened awareness due to the complexity of the operational environment and its dangers. Often visual information is lacking, forcing combatants to rely heavily on auditory information. Unfortunately, Soldiers have reported difficulty using sound information; they cannot locate the sources of sounds and are distracted by irrelevant sounds. This report details how the urban acoustic environment affects situation awareness. It summarizes research literature on auditory localization and describes how auditory observations affect Soldier operations. It stresses that the same physical properties of the environment that interfere with vision may interfere with sound recognition and localization. Further, the quantity of information, relevant and irrelevant, makes it difficult for the Soldier to process all of the information available. Although the most effective tool is training and experience, we also suggest a few simple strategic and technical solutions.

Henry, P., Scharine, A., & Letowski, T. (2006, November). Auditory localization in the presence of spatialized background noise. Presentation at the American Speech-Language and Hearing Association (ASHA) 2006 Annual Convention. Miami, FL.

Auditory localization abilities of individuals with normal hearing were examined in the presence of a spatialized background noise replicating an urban environment. Twelve signal loudspeakers covering 360 degrees azimuth (in 30 degree increments) were used to present two stimuli (pink noise burst and "aah") at two signal-to-noise ratios (SNR) and four durations (200, 400, 600 and 800 ms). The signal loudspeakers and additional inactive loudspeakers located every 10 degrees between signal loudspeakers provided 36 locations for participant responses. The results indicate an improvement in performance with both increases in SNR and duration with no significant difference between the two stimuli. The improvement in auditory localization with increased duration was likely due to the beneficial use of head movements by the participants. This finding reinforces the importance of selecting appropriate durations for signals that are intended to provide location information.

Henry, P. (2005, October). Non-linear hearing protection for the individual Soldier. The International Symposium – Pharmacologic Strategies for the Treatment of Hearing Loss and Tinnitus, Niagara Falls, Ontario, Canada.

Soldiers must be able to hear and communicate in a quiet environment while concurrently having their hearing protected from unexpected and potentially damaging sounds. The implementation of non-linear hearing protection meets both of these needs. Sounds that are low in intensity are passed through to the listener with minimal attenuation while high intensity sounds are attenuated more. Nonlinear (or level dependent) hearing protection can be implemented through either passive or active technology, each with its own strengths and weaknesses. The combat arms earplug (CAE) is a double-sided triple flange plug used by the US Army. Its nonlinear side allows for listening and communication within a relatively quiet environment and provides protection against unexpected noise. The application of various forms of nonlinear technology as well as experiences with the CAE will be discussed.

<u>Sound distance estimation</u>

Fluitt, K., Letowski, T., & **Mermagen, T.** (2005, May). Auditory and visual performance in an open field. Poster presented at the 149th meeting of the Acoustical Society of America. Vancouver, BC.

The ability to estimate a distance to a sound source in an open field is an important element of situational awareness on the battlefield and is affected by many technical and environmental conditions. A limited body of knowledge regarding auditory perception of sources located over long distances makes it difficult to develop models predicting auditory behavior on the battlefield. Results of previous studies have shown that people have a tendency to underestimate distances. However, it is not known if there is a connection between a visual estimation, auditory estimation, and numeric reporting of an estimate by the same person. The purpose of the present study was to compare listeners' visual estimates, auditory estimates, and numeric reports of the distance to sound sources 25 to 200 meters from the listening position. Nineteen subjects (11 men and 8 women, ages 18-25) participated in the study. A test sound (dog bark) was presented from five loudspeakers in random order. Test results indicate that both auditory and visual numeric reports underestimated the distance whereas both types of comparative estimates were fairly accurate. The size of numeric estimation errors increased with distance and at some distances the visual estimation errors exceeded auditory estimations errors, but the differences were not statistically significant.

Research Area 2.3: Unconventional Communications

Pollard, K.P., Tran, P. K., & Letowski, T. R. (IRB Protocol) Factors Affecting Speech Intelligibility in Bone Conduction Communication.

Successful radio communication is important for military personnel to safely and effectively complete their missions. Bone conduction (BC) communication utilizes vibrations transmitted through the skull and soft tissues of the head, and its use in radio devices offers many advantages over traditional air-conduction audio communication. Advantages include reduction in background noise, little sound leakage, and the ability to be used along with hearing protection devices or with uncovered ears to improve situational awareness. However, BC systems are not yet in widespread use, partly due to poor speech intelligibility over these systems. Solving intelligibility issues in bone conduction communication is a critical step for improving acceptability and useful employment of this technology. To this aim, our study seeks to examine the effects of device placement, background noise, and users' individual differences (vocal attributes, facial dimensions, and demographic characteristics) on speech intelligibility over bone conduction. Talker participants will speak words from the Modified Rhyme Test (MRT) list under different background noise conditions and will be recorded using bone conduction microphones placed on different locations on the head. These recordings will be played to listener participants under different background noise conditions who will be wearing bone conduction vibrators on different locations on the head. Speech intelligibility will be measured using listeners' scores on the MRT. These data will be analyzed to uncover the effects of noise, device placement, talker individual characteristics, and listener individual characteristics on intelligibility. Results will indicate whether speech intelligibility over bone conduction can be improved by modifying device use, implementing signal filters, or customizing these strategies to meet the needs of users with different vocal attributes, facial dimensions, or demographic characteristics.

Tran, P. & **Letowski, T.** (2010, April). Speech intelligibility of air conducted and bone conducted speech over radio transmission. Presentation at NOISE-CON Proceedings.

Personal radio-communication devices are traditionally used with a built-in or an external air conduction microphone. Recently, there have been some efforts to use a head-mounted bone conduction microphone as a replacement for an external air conduction microphone. The goal of this study was to compare speech intelligibility for a new bone conduction microphone with a boom-type noise-cancelling air conduction microphone using Thales MBITRs (Multiband Inter/Intra Team Radios). Eight participants were divided into four pairs with each participant serving as both a talker and a listener. The Callsign Acquisition Test (CAT) was used to collect speech intelligibility data with the talker in quiet and in 100 dB A-weighted (A) noise. The listener was always in a quiet environment. The obtained results showed that both the type of microphone and the noise level had a statistically significant effect on speech intelligibility. However, the overall differences in speech intelligibility scores between the two microphones were less than 2% and under some operational conditions may not be of practical importance. In addition, the collected data suggest that some of the lower speech intelligibility scores obtained with the bone conduction microphone were due to problems with microphone fitting for some of the participants. Nonetheless, despite the observed differences, both microphones tested in this study met the 97% speech intelligibility criterion set by MIL-STD-1472[1] for military communication equipment.

McBride, M., **Tran, P.,** & **Letowski, T.** (2010, June). BC Intelligibility Headset comparison study, Industrial Engineering Research Conference IERC 2010.

Air conduction (AC) communication technology tends to impede situational awareness because it requires one or both ears to be covered. Bone conduction (BC) communication technology allows users to maintain radio communication without severely compromising situational awareness. This study compares four BC headsets using a military speech intelligibility test. The tests were administered within three background noise level conditions. Twenty undergraduates participated in this study. Significant performance differences between the three noise levels were found. No significant differences between the headsets or headsets-noise level interactions were identified. Usability survey data indicate the BC headsets are comfortable and easy to position.

Henry, P., Tran, P., & **Letowski, T.** (2009). Comparison of bone conduction technologies (ARL-TR-4705). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

Bone-conduction technologies have been proposed for use with radio communication for the military. Three manufacturers have made commercially available bone-conduction systems that transmit and receive radio signals through bone conduction. The purpose of this study was to evaluate these three bone-conduction microphones and vibrators separately in order to determine which devices performed best in each capacity. The evaluation of the vibrators was conducted through presentation of speech items over each device while the listener was in background noise levels of 100 and 110 dB A-wtd. The vibrators from manufacturer A outperformed the others on the speech recognition task. The evaluation of microphones was conducted through a presentation over headphones of speech items that were recorded through each microphone in background noise levels of 100 and 110 dB A-wtd. There were no significant differences between the speech recognition performances with the microphones. Sound quality judgments made on paired comparisons of the microphones and vibrators indicated listener preference for the vibrators from manufacturer A but no single microphone. In order to provide the best bone conduction communication system to the Soldier, vibrators from manufacturer A should be used. The results of this study do not allow a recommendation for the best microphone.

Tran, P., Letowski, T., & McBride, M. (2008) Bone conduction microphone: Head sensitivity mapping for speech intelligibility and sound quality, Audio, Language and Image Processing, (ICALIP 2008). International Conference, 7-9 July 2008 Page(s):107 – 111.

The goal of the study was to assess intelligibility and quality of speech recorded through a bone conduction microphone (BCM) located at various points on the talker's head. Ten words spoken by a female and a male talker in a quiet environment were recorded through a BCM placed at eight different locations on the talker's head. The sound levels of the recorded signals were normalized and the signals were presented to 33 listeners through a pair of AKG K-240DF headphones. In two separate listening sessions, the participants were asked to evaluate the speech intelligibility and sound quality of each word. A total of 640 signals were presented to each listener during each session (2 talkers x 10 words x 8 locations x 4 repetitions). The results of the study indicated that BCM placement on the forehead and temple of the talker resulted both in the highest intelligibility and quality of the recorded speech with rating scores significantly higher than those for all other locations.

McBride, M., **Tran, P.,** & **Letowski, T.** (2008) Head Mapping: Search for an Optimum Bone Microphone Placement, the Human Factors and Ergonomics Society 52nd Annual meeting, 22-26 September, page(s):503-507.

Bone microphones have been reported to be effective mechanisms for converting head vibrations into audio signals during speech production in high noise environments. This paper presents results of a study conducted to evaluate recordings of speech signals received by a bone microphone at various locations on the human head. Twelve different locations, four voices, and three words were used during the recording sessions. Twenty-two students evaluated 144 randomly presented recordings in a single group setting. Each recording was evaluated regarding its intelligibility (rating scale from 0 to 100%) and speech quality (rating scale 1 to 5) using a paper survey instrument. Results of the evaluation indicated significant differences in both intelligibility and quality between many of the locations and the results for intelligibility and quality were highly correlated. The two locations that resulted in the highest intelligibility and quality ratings were the forehead and temple.

McBride, M, **Letowski T,** & **Tran P.** (2008). Bone Conduction Reception: Head Sensitivity Mapping. *Ergonomics, 51,* 702-18.

This study sought to identify skull locations that are highly sensitive to bone conduction (BC) auditory signal reception and could be used in the design of military radio communication headsets. In Experiment 1, pure tone signals were transmitted via BC to 11 skull locations of 14 volunteers seated in a quiet environment. In Experiment 2, the same signals were transmitted via BC to nine skull locations of 12 volunteers seated in an environment with 60 decibels of white background noise. Hearing threshold levels for each signal per location were measured. In the quiet condition, the condyle had the lowest mean threshold for all signals followed by the jaw angle, mastoid and vertex. In the white noise condition, the condyle also had the lowest mean threshold followed by the mastoid, vertex and temple. Overall results of both experiments were very similar and implicated the condyle as the most effective location.

Henry, P. & **Letowski, T.** (2007). Bone Conduction: Anatomy, Physiology, and Communication (ARL-TR-4138). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

Humans hear through air and bone conduction pathways. Both pathways can be used to transmit sound to a listener and from a talker although traditionally, the air conduction pathway has been used. Communication through bone conduction is a feasible alternative to air conduction reception and transmission and provides benefits to the user that an air conduction system cannot provide. This report combines results of an extensive literature review of the anatomy and physiology of human hearing, theories behind the mechanisms of bone conduction transmission, devices for use in bone conduction transmission, and the use of the bone conduction pathway for communication. Bone conduction for the transmission of communication is effective and feasible for Soldiers because it provides a means of providing radio communication in combination with hearing protection devices.

Research Area 2.4: Environment for Auditory Research (EAR Facility)

Scharine, A. & **Mermagen, T**. (2008). Characterization of the Environment for Auditory Research (EAR) at the U.S. Army Research Laboratory. Proceedings of the 15th International Congress on Sound and Vibration, Daejon, Korea, pp. 1842-1849.

A new research facility, the Environment for Auditory Research (EAR), has been built by the U.S. Army Research Laboratory for use in spatial auditory research. The EAR consists of four test chambers - Sphere Room, Dome Room, Distance Hall, and Listening Laboratory - and a control room. The Sphere Room houses a large spherical array of 57 loudspeakers. The Dome Room has a horizontal array of 180 loudspeakers and two vertical movable hemispherical arcs of loudspeakers. The Distance Hall is an elongated shoebox-like space 21.3 meters long which has three tracks of loudspeakers extending from the ceiling and running the distance of the hall. The Listening Laboratory is equipped with removable acoustic panels and is designed to facilitate testing of various sound reproduction systems in variable amounts of reverberation. The purpose of the reported effort was to assess the ambient noise levels, reverberation times, and patterns of early reflections in all four test chambers. Noise level measurements were made with heating and air conditioning systems on and off. Two sets of measurements were made: at the completion of room construction and after the installation of audio equipment. The collected data confirmed the laboratory's overall adherence to the NC-15 noise criteria and good acoustic properties for spatial research. The authors discuss some of the acoustical characteristics inherent to each chamber and the challenges they presented to the design of high quality auditory research facilities.

Amrein, B. & **Letowski, T.**(2009). "The Environment for Auditory Research", *Canadian Acoustics, 37,* 152-153.

The United States Army Research Laboratory (ARL), at Aberdeen Proving Ground, Maryland USA, developed an auditory perception and communication research laboratory—the Environment for Auditory Research (EAR). This unique research facility was designed to conduct spatial perception and communication research in various indoor and outdoor acoustic environments. The EAR is a part of the modern laboratory system being developed at ARL's Human Research and Engineering Directorate. The facility consists of the Control Room and five listening spaces; Sphere Room, Dome Room, Distance Hall, Listening Laboratory, and OpenEAR. Indoor research space encompasses over 230 square meters of laboratory space plus a 54 square meter control center. Directly adjacent to the indoor facility is OpenEAR—an outdoor instrumented research space covering more than 4400 square meters of grassy terrain. EAR provides the ideal environment for conducting psychoacoustic studies. These include compliance with the NC-15 noise criteria resulting in background noise levels close to the threshold of hearing, semi-anechoic listening conditions reducing early acoustic reflections to negligible levels, extensive and flexible means for sound production by 600+ sound sources, and acoustic and electroacoustic means for changing the spatial properties of sound. Basic research conducted in EAR increases our understanding of Soldier perception of sound in the hostile environment typically found on the modern battlefield. Typical auditory research activities include study of spatial orientation, distance and depth estimation, virtual displays design, signature detection and identification, icons and warning signals design, perception of moving sound sources, and Soldier performance studies in natural environments.

Henry, P., Amrein, B., & **Ericson, M.A.** (2009). The Environment for Auditory Research, *Acoustics Today, 5(3),* 9-15.

No abstract

Letowski, T., Amrein, B., Ericson, M., Environment for Auditory Research: Design Principles and Capabilities, Proceedings of the 17th International Congress on Sound and Vibration, Cairo, Egypt, 18-22 July 2010 (in press).

The Environment for Auditory Research (EAR) is a new U.S. Army research facility dedicated to spatial perception and speech communication research. The EAR is comprised of four indoor research spaces (Sphere Room, Dome Room, Distance Hall, and Listening Laboratory), one outdoor research space (OpenEAR), and one common control center (Control Room) that permits concurrent execution of three independent studies. The facility offers various acoustic test environments ranging from anechoic, through various simulated, to real field environments. The acoustic and audio capabilities of the EAR support a wide range of experimental studies and the facility is available to both government and non-government researchers to conduct their own and joint research studies. The paper presents the design principles used in developing the EAR and the physical properties of the completed EAR laboratory. The goal of the paper is to present basic technical information about the facility to the research community considering conducting their research studies in the EAR.

Thrust Area 3: Sensory- Tactile

Research Area 3.1: Tactile

Head Tactile Research

Myles, K., & Kalb, J.T. *IRB Protocol (in review)*: The Effect of Motor Activity on the Detection of Tactile Signals.

The purpose of this study is to determine how motor activity affects one's ability to detect vibratory tactile signals on the head. Tactile applications for the torso have been tested or examined in simulated, real-world environments. Krausman and White (2006) examined the effect of the performance of combat maneuvers on the ability to detect and recognize tactile patterns on the torso. Soldiers performed specific combat maneuvers that are often faced on the battlefield via a mobility-portability training course. Completion of the maneuvers exposed Soldiers to various motor activities such as running, jumping, climbing, and crawling. Krausman and White (2006) reported that detection and recognition accuracy rates for tactile patterns were lower when compared with baseline data that involved no motor activity and made note that outside of the laboratory environment performance may be more challenging. Merlo, Stafford, Gilson, and Hancock (2006) examined the effects of physiological stress on the ability to receive tactile messages and localize tactile signals. A treadmill was used to simulate "moderately high levels of physical exertion and associated stress...such as might be anticipated in actual combat" (Merlo et al.,, 2006, p. 1562). Results were promising in that user performance did not deteriorate as a result of facing challenges imposed by a simulated combat environment. Tactile applications for the head will require the same type of evaluations, with a focus upon how well laboratory findings (Myles & Kalb, 2010) translate to successful use in simulated, real-world environments.

Myles, K., Kalb, J.T., Lowery, J., & Kattel, B.P. *IRB Protocol (in review)*: The Effects of Hair Density on Head Tactile Sensitivity.

Most of the research on tactile sensitivity has been done on the torso, arms, hands, and fingers (Cholewiak & Collins, 2003; Morioka, Whitehouse, & Griffin, 2008; Piateski & Jones, 2005; Rabinowitz, Houtsma, Durlach, & Delhorne, 1987; Stuart, Turman, Shaw, Walsh, & Nguyen, 2003; Van Erp, 2005; Van Erp & Werkhoven, 1999; Verrillo, 1962; Verrillo, 1966; Wilska, 1954). While a host of tactile sensitivity information exists for other parts of the body, the same information is scarce for the region of the head or scalp. From Weber (1978) we do know that: (1) the entire scalp is not equally sensitive and (2) the crown is less sensitive than the skin near the forehead, temples and lower part of the back of the head. Myles and Kalb (2009) obtained measures of tactile sensitivity on the scalp and confirm the findings of Weber (1978). More of this type of objective tactile information for the head is needed and hence the purpose of this study is to determine the effect of hair density on thresholds associated with the perception of vibration stimuli applied to the head. This study is one of a series of experiments to obtain basic sensitivity thresholds for the head for use in the design of a head-mounted tactile display (HMTD) for the Soldier. Measures of head tactile sensitivity obtained to date (Myles & Kalb, 2009, 2010) are only supportive of an HMTD design for those with no/very little hair (i.e., male Soldiers). Thus, to ensure that future HMTDs are compatible with the tactile sensitivity of all potential users, this study will extend the user population (i.e., female Soldiers) for head tactile communication technology.

Myles, K., & Kalb, J. T. (2010). Guidelines for Head Tactile Communication. ARL Technical Report (ARL-TR-5116), Aberdeen Proving Ground, MD.

A helmet-mounted tactile display is desired for military applications such as cueing to alert Soldiers to the direction and location of an event or indicating movement direction in GPS-supported navigation. However, the system must be compatible with the head sensitivity of the user to ensure the user's optimal perception of the provided information. The purpose of this report is to document the overall findings of the basic research program regarding head tactile sensitivity and to provide answers to two basic questions: (1) What locations on the head are most sensitive to vibration stimulation? (2) What is the optimal frequency for tactile signals to be applied to the head? The overall findings are discussed and are considered as initial guidelines for head tactile communication and for using vibration stimulation on the head.

Myles, K., & Kalb, J. T. (2009). Vibrotactile Sensitivity of the Head. ARL Technical Report (ARL-TR-4696), Aberdeen Proving Ground, MD.

The brain rarely processes events of the physical world using signals from a single sensory modality. While the visual and auditory modalities are considered frequently in communication research, the tactile modality is considered the least as a possible mode of communication. In addition, previous studies of tactile sensitivity and solutions in utilizing the tactile modality have been focused on torso and limb locations. However, there are currently no tactile sensitivity data for the head. The goal of the present study was to investigate tactile sensitivity of the various locations on the head and the effect of signal frequency on the tactile threshold. An adaptive psychophysical procedure was used to determine differences in tactile sensitivity at various points on the head. Obtained results indicate that the crown of the scalp is less sensitive to vibration than the areas near the forehead, temples, and lower part of the back of the head.

Kalb, J. T., Amrein, B. E., Myles, K. (2008). Instrumentation and Tactor Considerations for a Head-Mounted Display. ARL Memorandum Report (ARL-MR-705), Aberdeen Proving Ground, MD.

This report documents the design and construction of a computer interface used to drive a head-mounted tactile display. Components of the interface include the tactor, the voltage driver, the controller, and the excitation signal, and each is discussed in detail. The procedures used to qualify and quantify tactor performance and excitation signal selection and generation are also discussed. This work is part of a larger effort to evaluate the synergistic use of a bone conduction communication system and a tactile communication system.

Myles, K., Binseel, M.S. (2007). The Tactile Modality: A Review of Tactile Sensitivity and Human Tactile Interfaces. ARL Technical Report (ARL-TR-4115), Aberdeen Proving Ground, MD.

Even though vision is only one modality we use to interact with our environment, most people identify it to be the most important. Hearing is also viewed as necessary for interpreting environmental stimuli. In contrast, touch, smell, and taste are largely ignored as being essential to the interaction we have with our environment. The brain seldom processes environmental information in sequence among the modalities but concurrently from several or all of the sensory modalities. Because humans have a limited capacity to receive, hold in working memory, and cognitively process information taken from the environment, the use of one sensory modality to convey information within a system can overload that modality. Multimodal systems can help to alleviate overload for any one modality, and such systems have been favorable in showing that the touch or tactile modality can be used as an independent input modality to convey information to the user or as a redundant modality to increase information prominence of the visual and auditory modalities. This review, which reflects work that occurred before mid-2006, discusses the following aspects of tactile modality: specific measures of tactile sensitivity for the human body, capabilities and limitations of tactile modality, and applications of human tactile interfaces. The review also highlights a gap in the tactile literature regarding tactile research for the head and other potential body locations.

<u>Dismounted Tactile Research</u>

White, T.L. (Project) Exploring the Use of Tactile Displays in Military Environments.

Aim: The goal of this research was to examine the effects of stimulus intensity and inter-stimulus duration on perceived urgency and the ability to detect and identify tactile patterns. Methods: A laboratory study was conducted in which participants were asked to detect and identify tactile patterns and provide a rating of perceived urgency. An arithmetic task was provided in some blocks as a distractor task. The experimental design was a 2 x 2 x 2 x 4, within-subjects design. The independent variables will be temporal (0 and 500 ms between signals) urgency, intensity (12 and 23.5 dB above threshold) urgency, distractor task (present or absent), and tactile pattern (Turn Right, Turn Left, Move Forward, or Turn Around). Data collection included measures of patterns detected, patterns correctly identified, correct arithmetic problems, and ratings of perceived urgency. Progress: Results indicated that intensity had a significant effect on the detection and correct identification of tactile patterns. Participants were able to complete the arithmetic task with 91% accuracy. Data collection and analysis are complete, technical report is in progress. Current Goals: The goal is to conduct a field study to examine the effects of stimulus intensity and inter-stimulus duration on perceived urgency and the ability to detect and identify tactile patterns while negotiating obstacles.

White, T.L. (In Press). Suitable Body Locations and Vibrotactile Cueing Types for Dismounted Soldiers. ARL Technical Report, Aberdeen Proving Ground, MD.

Although research has shown the potential of tactile displays as a means for providing information, there are several factors that must be taken into consideration in order to maximize the benefits of tactile cueing. The proper body location and tactile cue type must be carefully identified for specific types of users. This is due to the varying mission requirements and environments in which users must operate. For example, dismounted Soldiers perform maneuvers such as walking, running, crawling, and climbing. They must also remain attentive so that they can engage enemy threats as well as negotiate terrain obstacles. It is imperative that tactile stimulation be provided to the appropriate body locations and that the proper tactile cue types (i.e., signals or patterns) are provided to dismounted Soldiers. This summary report discusses the skin, the perceptual resolution and sensitivity of humans, and suitable body locations and tactile cueing types for dismounted Soldiers.

White, T.L., Kehring, K.L., Glumm, M.M. (2009). Effects of Unimodal and Multimodal Cues About Threat Locations on Target Acquisition and Workload. *Military Psychology*, 21(4), 497-512.

Two studies were conducted to examine the effects of unimodal and multimodal cueing techniques for indicating the location of threats on target acquisition, the recall of information from concurrent communications, and perceived workload. One visual, two auditory [i.e., Non-Spatial speech and Spatial Tones (3-D)], and one tactile cue were assessed in Experiment 1. Experiment 2 examined the effects of combinations of the cues assessed in the first investigation: Visual+Non-Spatial Speech, Visual+Spatial Tones, Visual+Tactile, and Non-Spatial Speech+Tactile. A unimodal, "Visual Only" condition was included as a baseline to determine the extent to which a supplementary cue might influence changes in performance and workload. The results of the studies indicated that time to first shot and the percentage of hits can be improved and workload reduced by providing cues about target location. The multimodal cues did not yield significant improvements in performance or workload beyond that achieved by the unimodal Visual cue.

Krausman, A.S., White, T.L. (2008). Detection and Localization of Vibrotactile Signals in Moving Vehicles. ARL Technical Report (ARL-TR-4463), Aberdeen Proving Ground, MD.

The focus of this research was to examine how well participants could detect and localize tactile signals while riding in moving vehicles. A ride motion simulator (RMS) was used to simulate a Bradley fighting vehicle or high mobility multipurpose wheeled vehicle traversing a cross-country course or gravel road. Two tactile display systems were used to provide signals. The wireless tactile control unit (WTCU) employed a vibrating motor similar to that of a cell phone or pager, and the Tactile Communications Systems (TACTICS) employed a plunger motor, which creates a tapping sensation. The signal strength of the TACTICS was driven at the optimal operating characteristics (TACTICS 1) or at operating characteristics similar to those of the WTCU system (TACTICS 2). For each system, eight tactors were positioned at 45-degree intervals (cardinal compass points) in two adjustable belts (plunger motor belt and pancake motor belt) worn around each participant's waist. Participants received tactile signals during a baseline (stationary) condition and while moving on the RMS. Results show that the TACTICS 1 performed consistently across all conditions, which may be because of the stronger, more distinct tactile signal generated by the TACTICS 1. Detection of tactile signals was affected by terrain, with few signals detected on the cross-country terrain. Additionally, the south tactor was detected less frequently than the other locations when participants were moving over the cross-country terrain.

Glumm, M.M., Kehring, K.L., White, T.L. (2007). Effects of Multimodal Displays About Threat Location on Target Acquisition and Attention to Visual and Auditory Communications. ARL Technical Report (ARL-TR-4074), Aberdeen Proving Ground, MD.

The laboratory experiment examined the effects of paired sensory cues that indicate the location of targets on target acquisition performance, the recall of information presented in concurrent visual and auditory communications, and perceived workload. The multimodal cueing techniques assessed in this study were Visual+Spatial Language, Visual+3-D Audio, Visual+Tactile, and Spatial Language+Tactile. A unimodal "visual only" cue was included as a baseline. Except for reaction times to cues, no significant differences were found between the multimodal cue conditions and the Visual Only mode in primary and secondary task performance or subjective workload. Reaction times were faster in the Visual+3-D Audio and the Visual+Tactile conditions than in modes that included a spatial language cue. Reaction times to the Visual+Spatial Language cue were faster than the Spatial Language+Tactile cue, but no significant differences were found between the Visual Spatial Language and the Visual Only modes. Adding the 3-D audio cue to the visual cue significantly improved reaction time beyond that of the Visual Only condition, but no significant difference was found between the Visual Only and the Visual+Tactile modes. Reaction times to cues were slower when communications were presented visually, but however, did have a different effect on subjective ratings of effort in the Visual+Tactile mode than in the other cue conditions. In the Visual+Tactile mode, ratings of effort were significantly lower when communications were presented auditorily than when they were presented visually, but communications modality did not appear to affect ratings of effort in the other cue conditions.

Krausman, A.S. & White, T.L. (2006). Tactile Displays and Detectability of Vibrotactile Patterns as Combat Assault Maneuvers are Being Performed. ARL Technical Report (ARL-TR-3998), Aberdeen Proving Ground, MD.

This study examined the issues related to tactile displays and the detectability of vibrotactile patterns as combat assault maneuvers were being performed. Three obstacles were used in this study: tires, windows, and high crawl. A baseline condition, in which participants received tactile patterns while standing, was also included in the analysis. In the baseline condition, participants detected and identified 100% of the tactile patterns. Analysis of the obstacle data showed that the obstacles had a significant effect on the detection and identification of tactile patterns. Participants detected 62.5% of the tactile patterns during the high crawl, which was significantly lower than for the tires and windows, with 92% and 88% of patterns detected, respectively. With regard to the correct identification of tactile patterns, participants correctly identified 51% of the patterns during the high crawl, as compared to 88.5% for the tires and 77% for the windows. There were no significant differences in the response times.

Glumm, M.M., Kehring, K.L., & Glumm, M.M. (2006). Effects of Tactile, Visual, and Auditory Cues About Threat Location on Target Acquisition and Attention to Visual and Auditory Communications. ARL Technical Report (ARL-TR-3863), Aberdeen Proving Ground, MD.

This study examined the effects of tactile, visual, and auditory (spatial language and three-dimensional [3-D] audio) cues about threat location on target acquisition and the recall of information presented in visual and auditory communications. On average, participants hit 98% of the targets presented when cued about the location of targets compared to 64% in a baseline condition (no cues). When target location cues were provided, time to first shot was an average 26% faster; 23% more information was recalled from the auditory and visual communications, and overall workload scores were 17% lower. On average, time to first shot in the visual and spatial language modes was 13% faster than in the tactile condition and 26% faster than in the 3-D audio mode. Overall workload scores were an average 14% higher in 3-D audio mode than in the other conditions in which target location cues were provided. Communications modality did not have a significant effect on either the amount of information recalled from the communications or on target acquisition. No interactions were found between communications modality and cue condition. However, on average, 10% more information was recalled from communications when target location cues were provided in the visual mode than in the other cue conditions.

Thrust Area 4: Computational Representations

Research Area 4.1: Cognition

Cassenti, D.N. (in press). The intrinsic link between motor behavior and temporal cognition. *New Ideas in Psychology.*

The debate about the cognitive mechanisms behind human temporal processing has raged for decades without a clear resolution. The theory presented here describes a different perspective to the traditional accounts on the issue, namely, that motor behaviors or sequences of motor behaviors provide a means of reproducing time intervals. Evidence behind this perspective includes tapping strategies (exemplified by musicians), counting strategies, and neuropsychological results showing activation of motor areas during temporal cognitive tasks. I propose that motor behaviors aid human timing by offering a set of processes that consistently take a set amount of time to accomplish. Motor behaviors also allow segmentation of larger intervals into smaller intervals that are easier to estimate. I conclude with a discussion of implications of this perspective on temporal cognition.

Cassenti, D.N., Kerick, S.E., & McDowell, K. (in press). Observing and modeling cognitive events through event related potentials and ACT-R. *Cognitive Systems Research.*

The study of cognition is generally thought to rely on techniques for inferring cognitive processes that are unobservable. One approach to cognitive science is to leverage an understanding of structure and function of the nervous system based on observable neurological events to determine mental processing. Event-related potential (ERP) research offers one technique to objectively measure cortical responses that are believed to be associated with perceptual and cognitive processes. Here, two ACT-R (Adaptive Control of Thought–Rational) models of mental processing are adapted based on the results of two ERP experiments. The models provide both a sequence of mental steps required to complete each task and a greater specificity of time course of mental events than traditional ACT-R models. We conclude with implications of this research for cognitive theory and ACT-R as well as future work to be conducted.

Cassenti, D., **Kerick, S.**, **May, K.**, & **Patton, D.** (2009). Changes in ERP signal from decision difficulty. Research protocol (ARL-20098-09017).

Event related potentials (ERPs) recorded from the scalp routinely typically show a negative charge 100 to 200 ms after a stimulus (N100) and a positive charge 300 to 400 ms after the stimulus (P300). ERP researchers generally attribute the N100 to perceptual encoding of the stimulus and the P300 to a process of context updating (i.e., updating the frequency of stimulus categories). Cassenti, Kerick, and McDowell (in press) built two ACT-R (Adaptive Control of Thought – Rational) models of ERP experiments to demonstrate that these cognitive correlates of N100 and P300 may be modeled within ACT-R and that ACT-R may gain more accuracy in predicting time course of mental steps by using the results of ERP studies. This experiment was designed to verify the cognitive correlates of the N100 and P300 by varying the difficulty of mathematical decisions. We predict that the N100 latency should be largely unchanged based on difficulty (i.e., it should take no longer to encode a number depending on decision difficulty), but the P300 latency should increase with difficulty because context updating cannot take place until the decision has been made (i.e., which takes longer for more difficult decisions). We propose to analyze the latency of N100, P300, and response using traditional statistical techniques and subsequently build an ACT-R model to simulate the findings.

Cassenti, D.N. (2007). ACT-R model of EEG latency. *Proceedings of the Human Factors and Ergonomics Society 51st Annual Meeting* (pp. 812-816). Santa Monica, CA: Human Factors and Ergonomics Society.

Anderson and Lebiere's (1998) modeling system ACT-R (Adaptive Control of Thought – Rational) has been a leading contributor to advances in cognitive science. Despite the modeling system's success there are areas in which it may be improved. The present research advocates a suggested approach to improving ACT-R's predictive capacity by using EEG (electroencephalography) latency data to predict the time it takes to achieve certain mental steps. A model is presented which successfully represents EEG data from a simple auditory experiment. Implications of this modeling approach to ACT-R and to the field of cognitive science are discussed.

Cassenti, D.N., & Kelley, T.D. (2006) Towards the shape of mental workload. *Proceedings of the Human Factors and Ergonomics Society 50th Annual Meeting* (pp. 1147-1152). Santa Monica, CA: Human Factors and Ergonomics Society.

Mental workload is a measure of how much mental effort a person devotes to one or more tasks. In two experiments, we investigated the effect of multiple identical tasks on human performance in terms of both accuracy and response time for a visuo-spatial task set and an auditory task set. The findings showed that participants performed linearly worse on some measures of performance when the number of tasks increased, while other measures showed two distinctive variations on this linear decrease in performance. We discuss these results in terms of their effect on the traditional linear representation of workload in IMPRINT (IMproved Performance Research INtegration Tool, Archer & Adkins, 1999), a task-based human performance modeling system.

Cassenti, D.N., Kelley, T.D., & Ghirardelli, T.G. (2006). Awareness yet underestimation of distractors in feature searches. In R. Sun (Ed.) *Proceedings of the 28th Annual Conference of the Cognitive Science Society* (pp. 1086-1091). Austin, TX: Cognitive Science Society.

Feature search studies typically address the speed and accuracy of identifying a target item while dismissing attention focused on distractors. In the studies presented here, the level of attention focused on distractors is measured in a feature search task by occasionally asking participants how many items appeared in the search display. Results show some awareness for number of distractors; however, participants tended to underestimate the number of items. Results from two of the studies suggest that individuating distractors from one another and not viewing the entire display contribute to the underestimation effect.

Area 4.2: Hearing Protection

Price, G. R. (2007). "Validation of the auditory hazard assessment algorithm for the human with impulse noise data", J. Acoust. Soc. Am. 122, 2786-2802.

Predicting auditory hazard from intense acoustic impulses, such as weapons fire or airbags, has been an intractable problem. The U.S. Army developed a theoretically based mathematical model of the ear designed to predict such hazards the Auditory Hazard Assessment Algorithm for the Human AHAAH. To validate it as a predictor of hazard, data from the literature wave forms and changes in hearing sensitivity were processed with the model in order to predict the onset of unacceptable threshold shift 25 dB or more in the 95th percentile human ear. For comparison, alternate standards MIL-STD-1747D and A-weighted energy were also used to compute hazards for the same data. The primary dataset was that of the US Army's "Albuquerque studies" 53 different cases and other impulses from the literature 19 additional predictions. The AHAAH model predicted correctly in over 95% of the cases, the MIL-STD-1474D was correct in 42% of the cases, and A-weighted energy was correct in 25% of the cases. Errors for all methods tended to be in the direction of overprediction of hazard. In addition to greatly increased accuracy, the AHAAH model also has the advantage of being theoretically based and including novel diagnostic features.

Binseel, M., Kalb, J., and Price, G. R. (2009) Using the Auditory Hazard Analysis Algorithm for Humans (AHAAH) software, beta release W93e. U.S. Army Research Laboratory Technical Report ARL-TR-4987. Aberdeen Proving Ground, MD: ARL.

The Auditory Hazard Analysis Algorithm for Humans (AHAAH) calculates the risk to human hearing of impulse noises, such as gunfire or airbag deployment. It achieves this by modeling the effects of the sound pressure wave from the free field, through the middle ear, and into the inner ear. The output of the algorithm is the number of auditory risk units (ARUs) associated with exposure to the given impulse sound. ARUs predict hearing damage; values over 500 ARUs for a 24-h exposure are likely to produce permanent hearing loss. The algorithm is implemented in computer software. This report is a user's manual for the AHAAH software release W93e.

Kalb, J.T. (2010). "A hearing protector model for predicting impulsive noise hazard", POMA and Program of 159th ASA/NOISE-CON meeting, Baltimore, MD Apr 2010.

Reduction in impulsive noise hearing hazard by earplugs and earmuffs is calculated with an electroacoustic lumped-parameter model of HPD attenuation using real ear attenuation at threshold (REAT) data. Energy flows into the occluded volume along three paths, each considered as a piston: (1) the rigid protector mass moving against the skin, (2) leakage at the support, and (3) transmission through the protector material (a second piston within the rigid piston). Circuit elements are adjusted so loss matches REAT data assuming path 1 is important at low, 2 at middle, and 3 at high REAT frequencies. Applying the model to 384 REAT data sets for ANSI S12.6 method B naive users gives statistical frequency distributions of occluded volume and leakage elements. For a given free-field impulsive noise, the model pressure predictions under the protector are compared to measurements on human and acoustical manikin ears to check validity of assumptions. The hearing hazards of the measured waveforms and the predicted waveforms are calculated with our previously developed auditory hazard analysis algorithm for humans ear model. The result is a cumulative frequency distribution of hazard based on user fit data useful in finding the best protector for a given impulsive noise.

Kalb, J.T. (2010), "Measurement and characterization of army impulsive noise sources", POMA and Program of 159th ASA/NOISE-CON meeting, Baltimore, MD Apr 2010.

Peak pressure levels in army noise environments range from 140- to 195-dB near Soldiers firing energetic weapons and are all dangerous to unprotected ears. Blast reverberation in confined spaces and steady noise in armored vehicles is also hazardous, so complete assessment requires the widest possible measurement range. To accurately measure pressures in the free-field or under hearing protectors, microphone considerations include type, location, orientation, mounting, shape, and shielding from flash or mechanical shock. Blast-waves rise instantaneously and return to free-field ambient within 0.3–15 ms, while in enclosures this can increase to 100 ms, requiring wide bandwidth signal processing. In addition to hazard, acoustic detection and annoyance at greater distances from weapons involve propagation effects in the atmosphere and at the ground which alter the wave-shape.

Price, G. R. (2010). “Susceptibility to intense impulse noise: evidence from the Albuquerque dataset,” POMA and Program of 159th ASA/NOISE-CON meeting, Baltimore, MD.

For theoretical and applied reasons, there has long been an interest in the problem of susceptibility to hearing loss from intense sounds; yet no useful predictive indices have been found. Some evidence suggests that susceptibility cannot be considered as a constant for individual ears; however, thinking and experimental designs often assume that it is. A critical data set in this regard are the US Army’s Albuquerque studies [Johnson, D. L. (1994) USAARL Contract Report No. 94-2, U.S. Army Aeromedical Research Laboratory, Rucker, AL] in which human Ss were exposed repeatedly to explosive sources. An analysis of individual threshold shift data finds that of 28 instances in which ears showed a threshold shift 15 dB or higher, 25 Ss subsequently passed higher levels of exposure, sometimes much higher levels. This outcome was clearly contrary to the expectation that they were susceptible ears. Issues such as HPD fit and random elements in exposures are demonstrably a part of the problem. Susceptibility, at present, should probably be considered a statistical concept, appropriate to groups of Ss.

Thrust Area 5: Physical Performance

Research Area 5.1: Load Carriage

Boynton, A.C., Rice, V.J., DeVilbiss, C.A., and **Faughn, J.A.** (2007). An Evaluation of the Issue and Wearing of the Personnel Armor System for Ground Troops (PASGT) and Advanced Combat Helmets (ACH). (ARL-TR-4225). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

The abstract for this report is limited and cannot be published in this document.

Boynton, A.C., and Faughn, J.A. (2007). Quantification of Correct Wear of Properly Fitted Advanced Combat Helmets (ACH) and Personnel Armor System for Ground Troops (PASGT) Helmets. (ARL-TR-4020). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

The abstract for this report is limited and cannot be published in this document.

LaFiandra, M., Harman, E., Cornelius, N., Frykman, P., Gutenkunst, D., and Nelson, G. (2007) The Effects of the Personal Armor System for Ground Troops (PASGT) and the Advanced Combat Helmet (ACH) With and Without PVS-14 Night Vision Goggles (NVG) on Neck Biomechanics During Dismounted Soldier Movements. USARIEM Technical Report. T07-09.

Kevlar helmets provide the soldier with basic ballistic and impact protection. However, the helmet has recently become a mounting platform for devices such as night-vision goggles, drop down displays, weapon-aiming systems, etc. Although designed to enhance soldier performance, these systems increase the mass of the helmet and typically shift the position of the helmet's center of mass forward. The effects of changing the mass properties of the helmet on head and neck forces and moment on neck muscle activity and fatigue are well documented for aviators and soldiers in vehicles. No research to date has been focused on the effects of helmets of varying mass and mass distribution on head and neck forces and moments during a combat foot soldier's physical activities. Physical demands on the combat foot soldier are substantially different from those on aviator or soldiers in vehicles. Therefore, changing the mass properties of the helmet likely has different effects on combat foot soldiers than on aviators. The study answers the militarily relevant question of what forces and moments on the head and neck are associated with currently used Army helmets and night vision goggles during combat physical activities of the ground soldier.

Ortega, S.V., Garrett, L., and Burcham, P.M. (2006). Mobility, Portability, and Human Factors Investigation of an Improved 81-mm Lightweight Mortar System Prototype: Phase II. (ARL-TR-4111). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

The abstract for this report is limited and cannot be published in this document.

Boynton, A.C., and Crowell, H.P. (2006). A Human Factors Evaluation of Exoskeleton Boot Interface Sole Thickness. (ARL-TR-3812). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

The purpose of this study was to identify potential human factors issues related to the sole thickness of an exoskeleton boot interface. Twelve Soldiers were evaluated in three footwear conditions (no additional sole, 1-inch sole, and 2-inch sole). Lower extremity biomechanics were assessed for walking, running, squatting, and kneeling with the use of a force plate and motion capture system. Mobility performance was assessed with five obstacles on a mobility-portability course. Participants also provided subjective feedback on each footwear condition’s comfort, stability, and difficulty during the biomechanics and mobility assessments. Results indicate that an exoskeleton could incorporate a boot interface as thick as 2 inches without substantially impacting the human factors issues evaluated in this study.

Garrett, L., Harper, W.H., Ortega, S.V., and White, T.L. (2006) Joint Service General Purpose Mask (JSGPM) Human Systems Integration (HIS) Evaluation: Comfort and Vision Correction Insert Stability Evaluation. (ARL-TR-3900). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

Soldiers, first responders, and search-and-rescue personnel are among those whose job requirements include exposure to hazardous and toxic elements. The Joint Service General Purpose Mask (JSGPM), XM50/XM51 is being developed as the next generation of respirators for all ground personnel of the U.S. Armed Forces. The JSGPM, together with personal protective equipment, allows the operators the flexibility to tailor their protection, based on mission threat, thereby minimizing weight, bulk, and heat stress. This study looked at JSGPM from a systems development perspective and evaluated comfort, stability, donning and doffing procedures in comparison to the M40 series mask. Four configurations (M40 series mask with Joint Service Lightweight Integrated Suit Technology [JSLIST, jacket only], XM50 with hood, XM50 with JSLIST [jacket only], and the XM50 with JSLIST [jacket only] and modified mask beard) were tested. The analysis showed that there were no significant differences among any of the characteristics rated for the responses to the comfort and vision correction inserts questionnaire. The results of the comparative questionnaires showed that 94% of the Soldiers rated the XM50 mask as better than the M40 series mask.

Garrett, L., Jarboe, N., **Patton, D.J.**, and **Mullins, L.L.** (2006) The Effects of Encapsulation on Dismounted Warrior Performance. (ARL-TR-3789). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

This study examined difference effects of encapsulation, treating the assessment from a systems development perspective. The study, in part, sought to develop a systematic and diagnostic method for evaluating the interactions between various key components of the ensemble and *mobility, survivability, and information management technology* (e.g., personal digital assistant). Our purpose is to assess the utility of using standardized facilities and tasks for taking a more integrative, systems approach to Soldier-equipment compatibility. Three configurations (baseline-no encapsulation; current nuclear, biological, and chemical; future land warrior) were tested; dependent measures are discussed in terms of time to complete common Soldier tasks, shooter accuracy, and cognitive workload performance. The thesis was that it is possible, in a fieldtest environment in which subjects engage in tasks relevant for their operational missions, to conduct such an assessment and, in the end, provide needed insights that can shorten useful development and fielding times for these systems.

Research Area 5.2: Fatigue Exertion

Boynton, A.C., Kehring, K.L. & White, T.L. (draft). Biomechanical and Physiological Validation of the Omni-direction Treadmill Upgrade as a Mobility Platform for Virtual Environments. Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

A novel mobility platform, the Omni-Directional Treadmill (ODT) Upgrade, has been developed to allow users to move through a virtual environment in a manner equivalent to doing so in the real-world. The purpose of this investigation was to determine the extent to which walking on the ODT Upgrade is comparable to walking overground for selected biomechanical and physiological variables. Temporal-spatial parameters, sagittal plane joint kinematics and metabolic cost were assessed for ten subjects as they walked along identical circular courses overground and on the ODT Upgrade. With the exception of a reduction in ankle plantarflexion following toe-off on the ODT Upgrade, relatively small differences in gait mechanics were found between the overground and ODT Upgrade trials. However, oxygen consumption was more than 20% greater during walking on the ODT Upgrade than overground and will need to be taken into account when comparing the results of training and research conducted on the ODT Upgrade to that of the real-world. Future studies are required to develop a better understanding of the potential mechanisms (e.g. mechanical work, muscle activation, regulation of whole body angular momentum) behind this substantial increase in metabolic cost. In conclusion, the ODT Upgrade permits users to walk through a virtual environment in a relatively nature way, but with a significant increase in physiological demand.

LaFiandra, M. (2009). The Working Back: A Systems View [Review of the book The working back: a Systems View]. *Ergonomics in Design,* 17, 3, P30.

No abstract.

LaFiandra, M. (2008). Methods, Models & Technology for Lifting Biomechanics. In *Handbook For Digital Human Modeling: Research for Applied Ergonomics and Human Factors Engineering*. V. Duffy (Eds.).

No abstract.

Research Area 5.3 Locomotion and Manipulation

Crowell, H.P., Milner, C.E., Hamill, J., and Davis, I.S. (2010). Reducing Impact Loading During Running With the Use of Real-Time Visual Feedback. *Journal of Orthopaedic & Sports Physical Therapy*, 40(4), 206-213.

STUDY DESIGN: Single-subject with repeated measures. **OBJECTIVES:** To determine if runners can use real-time visual feedback from an accelerometer to achieve immediate reductions in tibial acceleration and vertical-force loading rates. **BACKGROUND:** Stress fractures are a common injury among runners. Previous studies suggest that runners with higher than normal tibial acceleration and vertical-force loading rates are at increased risk for tibial stress fractures. If these runners can be trained to reduce the loading on their lower extremities, it may reduce their risk of stress fractures. **METHODS:** Five subjects participated in this study. All subjects ran on a treadmill, instrumented with force transducers, during a single 30-minute session that was divided into warm-up, feedback, no-feedback, and cool-down periods. During running, the subjects also wore an accelerometer taped to their distal right tibia. Peak positive acceleration of the tibia, vertical force impact peak, and average and instantaneous vertical-force loading rates were assessed at the end of the warm-up, feedback, and no-feedback periods. **RESULTS:** Single-subject analysis revealed that 4 of the 5 subjects had significant reductions in their peak positive acceleration at the end of the no-feedback period compared to the warm-up. In addition, all of the subjects had significant decreases in impact peak and vertical ground reaction force loading rates at the end of the no-feedback period. **CONCLUSION:** In a single session of training with real-time visual feedback, it appears that most runners can reduce the types of lower extremity loading associated with stress fractures. This may lead to training programs that reduce the risk of stress fractures for runners.

Cruz-Neira, C., Springer, J.P., and Reiners, D. (2010). Let Them Move: Incorporating Physical Walking into a Virtual Environment. *Proceedings of The Engineering of Virtual Reality,* SPIE. San Jose, CA, January 2010.

Pohl, M.B., **Crowell, H.P.,** and Davis, I.S. (2008). What Strategies Do Runners Utilize to Reduce Tibial Acceleration Following A Gait Retraining Protocol? *Medicine & Science in Sports and Exercise*, 40, S19.

High tibial shock has been associated with the incidence of tibial stress fractures in runners. We have shown that tibial shock can be reduced by 50% in these runners through a gait retraining program using realtime feedback. However, the mechanism by which runners are able to reduce their shock is unknown. **PURPOSE:** To examine the strategy that runners utilize to reduce their tibial shock while running. It was expected that runners would alter their footstrike from a rearfoot to a mid or forefoot strike pattern. **METHODS:** This is an ongoing study of which 6 rearfoot strike runners (mean 25.8 yrs) with high tibial shock (>8g) have been collected. All subjects underwent 8 sessions of gait retraining over 2 weeks resulting in a 50% reduction in their tibial shock. Gait analyses were performed initially and following completion of re-training. Variables of interest were those that were associated with adopting a forefoot strike pattern. Ankle angle at foot-strike (FS) and at foot-flat (FF) were recorded along with the peak sagittal ankle moment (AM) during this time period. Strike index (SI), a measure of the center of pressure at contact was also examined. **RESULTS:** Only one of the subjects (A) adopted a forefoot strike running. This was evidenced by an increase in the strike index (table 1) coupled with a plantarflexed ankle at contact. The other 5 subjects landed with greater dorsiflexion at footstrike and at foot-flat following re-training. This was associated with an increased dorsiflexion moment. This suggests they were attempting to reduce their foot slap in early stance. **CONCLUSIONS:** Two very different strategies emerged at the ankle to reduce tibial shock during running. Additional strategies may become apparent as subjects are added to the study.

Jarboe, N. and **Faughn, J.A.** (2007). A Human Factors Assessment of Female Soldier's Ability to Pull Hand Grenade Fuze Safety pins and to Throw Inert M67 Hang Grenades. (ARL-TR-4311). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

The abstract for this report is limited and cannot be published in this document.

Wilson, R., Faughn, J.A., and Harper, W. (2007). Evaluation of Crew's Ability to Ingress and Egress Selected U.S. Army Wheeled and Tracked Vehicles While Carrying a Personal Defense Weapon. *Customer report, prepared for PM Individual Weapons*.

The abstract for this report is limited and cannot be published in this document.

Crowell, H.P., and Davis, I.S. (2006). Between day reliability of accelerometry. *Medicine & Science in Sports and Exercise.* 38(5) Supplement: S256

PURPOSE: An accurate and reliable measuring system is essential for collecting data to be used in gait analyses. However, there is little information available regarding the reliability of accelerometry during gait analyses. Therefore, the purpose of this study was to examine the between day reliability within and between testers for both treadmill and overground running. **METHODS**: Two experienced testers aligned and attached a small, lightweight, uniaxial accelerometer to the distal tibia of each subject (N=10: 2 females, 8 males). Testers palpated the anteromedial aspect of the distal tibia to find a flat spot without much soft tissue. Then they visually aligned the accelerometer with the long axis of the tibia. The accelerometer was initially held on the subject's skin with double sided tape. A piece of elastic tape was then put over the accelerometer to hold it more firmly. The alignment of the accelerometer was checked, and it was repositioned, if necessary. Finally, four strips of elastic tape were placed over the accelerometer and around the lower leg to secure the accelerometer. Each tester attached the accelerometer to the subjects for treadmill and overground trials on Day 1. The process was repeated the next day (Day 2). The dependent measure in this study was the peak positive acceleration measured by the accelerometer as subjects ran on a treadmill at 2.7 m/s and overground at 3.7 m/s through the laboratory. Intraclass correlation coefficients (ICC[2, k]) were calculated to determine the intra-tester and inter-tester reliability. **RESULTS**: The intra-tester and inter-tester ICCs are shown in the table below. **CONCLUSIONS**: The intra-tester ICCs show that each tester obtains reliable day to-day measures (ICCs range from 0.80 to 0.94). The inter-tester ICCs show that the testers measures are consistent within each day for treadmill (ICC= 0.82 and 0.94) and overground (ICC= 0.88 and 0.96) trials. Therefore, based on these results, it appears that comparisons of peak positive acceleration between days and between testers can be made with confidence.

Crowell, H.P., Faughn, J.A., Tran, P.K., **Wiley, P.W.** (2006). *Improvements in the omni-directional treadmill: Summary report and recommendations for future development.* (ARL-TR-3958). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

The omni-directional treadmill (ODT) is a device that converts a user's movements into movements through a virtual environment. Its design allows users to move in any direction, which is important for simulations that require dismounted infantry Soldiers to move and exert themselves in much the same way that they would in the real world. This report provides details of the work done to improve the ODT. This work focused on four areas: (1) improvement of the tracking system's accuracy, (2) reduction in the computational latency, (3) development of a new control scheme, and (4) reduction in the audible noise coming from the ODT. The ODT was improved in each of the focus areas. Items (1) through (3) allowed users to assume more of the postures (e.g., crouching) and motions (e.g., side stepping) that are common to dismounted Soldiers. These improvements also reduced false starts and overshooting of stops by the control system. Construction of an enclosure around the sides of the ODT substantially reduced the audible noise. Recommendations for development of a new ODT include making the area in which the user operates larger and making the device even quieter. In addition, the position-sensing and safety systems should be designed in such a way that the user has even more freedom of movement, and the control algorithm should be refined to allow users to make sharp turns and fine movements more easily.

Crowell, H.P., Davis, I.S. (2006). Reducing lower extremity loads through gait retraining using real-time feedback methods. In *Proceedings of the 30th Annual Meeting of the American Society of Biomechanics*, Virginia Tech, Wake Forest.

INTRODUCTION: Stress fractures are a common injury associated with the repetitive loads encountered during unning and marching in basic combat training (BCT). A recent study of U.S. Army recruits found that 30% of the injuries sustained in BCT were stress fractures. Stress fractures are costly in terms of time and money. Rehabilitation time is 8 to 10 weeks (Hauret et al.,, 2001), and recruits who are discharged because they cannot complete their training cost the Army approximately $10 M per year. Prospective and retrospective studies have shown that subjects who sustain a tibial stress fracture have higher tibial shock than those who do not sustain a stress fracture (Milner et al.,, 2006; Davis et al.,, 2004). The rapid deceleration of the tibia at heel strike can lead to high strain rates in the bone which are suspected of being a cause of stress fractures (Fyhrie et al.,, 1998). Therefore, reducing these loads may result in reducing stress fracture risk. Acute changes in lower extremity loads during running are possible in a single session of training with visual feedback (Crowell et al.,, 2005). However, long term retention of these changes has not been studied. Therefore, the purpose of this pilot study was to determine whether a longer period of training would result in reductions in loading that would be evident one month after training.

METHODS: This is an ongoing study in which five subjects (3 females, 2 males) have participated to date. All subjects were between 20 and 34 years of age, ran at least 10 miles per week, and exhibited tibial shock greater than 8.9 g. Baseline three-dimensional kinematic and kinetic data were collected as subjects ran through the laboratory at 3.7 m/s (±5%). For the retraining sessions, subjects ran on a treadmill at a self-selected pace. A uniaxial accelerometer was attached to the distal tibia on the side that had the highest shock, noted in the baseline data collection. Visual feedback of their tibial shock was provided on a monitor placed in front of them as they ran. Subjects were instructed to maintain their shock levels under 6 g as indicated by a line placed on the monitor. The time for which subjects ran started at 10 minutes and increased to 30 minutes for the final sessions. Subjects were restricted from running outside the retraining sessions. Subjects received constant visual feedback for the first half of their sessions. The feedback was progressively removed over the remaining sessions such that subjects had three minutes of feedback in their final session. Immediately after the last retraining session, kinematic and kinetic data were collected again. Then they ran on their own for four weeks and returned for a follow-up data collection. The first two subjects underwent retraining for 12 sessions over 4 weeks. However, because of the ease with which these subjects reduced their loading, the protocol was shortened to two weeks (8 sessions) for the remaining three subjects.

RESULTS: All subjects reduced their peak tibial shock from baseline at both post training and at 1 month follow-up. For the group, tibial shock decreased by approximately 50%. Instantaneous vertical loading rate, vertical impact peak, and average vertical loading rate decreased by approximately 30%.

DISCUSSION: As expected, both the four week and two week protocol resulted in reductions in lower extremity loading that were maintained over the one month follow-up period. Feedback was only provided on tibial shock, which exhibited the greatest reduction from baseline. However, retraining also significantly reduced the other three loading variables. The reductions in loading that the subjects achieved during this study likely reduce the strain and strain rates on their tibias, and thereby decrease their risk of stress fractures. Further analysis is underway to identify the kinematic strategies used by the subjects to reduce their lower extremity loading.

CONCLUSIONS: Based on these preliminary results, subjects are able to reduce their lower extremity loading by retraining with real-time visual feedback. These changes were maintained at one-month follow-up.

Research Area 5.4 Weapons:

Project 5.4.1: The Effect of Weapon Mass and Center of Mass on Shooting Performance with an Assault Rifle

This study was conducted as part of an effort for NATO SCI-178/RTG-043 Integration and Interoperability Issues for Dismounted Soldier System Weapon Systems. This working group examined several human factors issues associated with future assault rifles. The study examined the effects of different weapon masses and different vertical centers of mass on aiming error and subjective ratings of the weapon system's weight, balance and combat performance. The masses used in the study were an M16 with 1.5 kg added, 3.0 kg added, or 4.5 kg added. The centers of mass for the study were the natural vertical center of mass, 4 cm higher than the natural center of mass, and 4 cm lower than the natural center of mass of the M16A2 rifle. Overall, the study shows that increasing the mass of an assault rifle can have a negative effect on aiming accuracy and the shooters in this study strongly preferred a lighter weapon. Also the study shows that in most of the tasks investigated, shooters were not sensitive to changes in vertical center of mass (near the natural longitudinal center of mass) of the weapon.

Project 5.4.2: The Effects of Individual Zero versus Universal Zero on Shooting Performance.

A Soldier typically performs an individual zero on a weapon before using it in training or combat. The individual zero is performed so that when the Soldier cheeks and aims the weapon in his/her individual way, the shot hits the target where the Soldier had intended. This study will examine the differences in shooting performance for a Soldier firing an individually zeroed weapon versus a universally zeroed weapon. A weapons expert, using a bench rest and firing only 3 rounds, will universally zero the weapons for the universal zero condition. Soldiers will follow standard zeroing procedures for zeroing weapons for the individually zeroed condition. Each weapon will be re-zeroed at the start of each day. The shooting tasks will encompass firing at targets between 100 and 400 meters, using 4 different commonly used weapon sights (iron sights, the M68 CCO, EOTech and ACOG sights). The main goal of this study is to determine whether significant differences in shooting accuracy are evident relative to zeroing methodology for each sighting system. Shooting performance will be measured in percentage of targets hit, distance of shot from center of mass of target, and time to fire. This research is important because if there are no performance differences between an individually zeroed weapon and a commonly zeroed the implications for U.S. Army marksmanship training may be 1) reduced training time, and 2) significant cost savings due to decreased ammunition expenditure during the zeroing process for individual weapons.

Project 5.4.3: The Effects of Modified Eye Position on Shooting Performance

The objective of this research effort is to quantify the effect that modifying the eye position of the shooter has on the ability to hit targets at various ranges. This study is in support of the Helmet Electronics and Display System – Upgradeable Protection (HEADS-UP) ATO that will design and demonstrate a new headgear system incorporating head, face, and neck protection as well as sensor inputs and an optimized display. Helmet systems that provide facial or neck protection tend to impact the ability of the shooter to properly cheek the weapon and push the shooter's eye position away from the center axis of the weapon. For this study, modified buttstocks will be used to move the eye position systematically away from the normal sighting position without any other degradation that may occur with facial or eye protection (e.g. fogging). This study will use four different eye positions (baseline, up 1cm and left 1 cm, up 2 cm and left 2 cm, and up 3 cm and left 3 cm) and two different sighting systems (iron sights and M68 reflex sight. Soldiers will fire at targets from 50 to 300 meters in each experimental condition. Shooting performance will be measured in percentage of targets hit, distance of shot from center of mass of target, and time to fire.

Project 5.4.4: Quantifying Soldier Shooting Performance of the M4 Carbine with and without a Vertical Grip

Anecdotal evidence among Army users of the vertical grip on the M4 weapon indicates that it affords better control and increased accuracy as compared to firing a standard M4 without the vertical grip. Users claim that the vertical grip allows for the weapon to be pulled tighter toward the shoulder for better stability and consequently better accuracy. However, there is no published data to determine the performance implications of the vertical grip. This study will quantify Soldier shooting performance of the M4 carbine with and without the use of the vertical grip. All Soldiers will fire both weapon configurations during the course of this research. Soldiers will fire in a reflexive mode while standing unsupported at targets at 10, 25, and 50 meters and aimed firing mode while standing unsupported at targets at 50, 100, and 150 meters. They will complete questionnaires that will ask their shooting experience with both weapon configurations. All firing will be done during daylight hours. Shooting performance will be measured in percentage of targets hit, distance of shot from center of mass of target, and time to fire.

Harper, W.H., Ortega, S.V., and Wiley, P.W. (In review). *Shooting Performance Characterization of 5.56 mm Subcompact Weapons.* Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

Statkus, M.J., **Salvi, L.,** and Peloquin, A. (2009) *Dismounted Warrior Performance Data: Moving Targets in Close Combat Data Collection Effort.* (NATICK/TR-09/016L). U.S. Army Natick Soldier Research, Development and Engineering Center.

The abstract for this report is limited and cannot be published in this document.

Harper, W., and Wiley, P. (2009) Determining thumb control location for vertical foregrips of assault rifles. *Proceedings of the 14th Annual International Conference on Industrial Engineering*, Anaheim, CA.

Placing controls on the vertical grip of a weapon provides the Soldier with the ability to control additional equipment without removing his hand from the weapon. These controls can be used to activate peripheral systems on the weapon (e.g. laser range finders, laser pointing systems, flashlights, etc.) or Soldier system related functions like cursor controls for a Soldier computer or push to talk switches. There is currently no data on locations for mounting controls on the vertical grip of a rifle for activation with the thumb. This study examined the possible use of a control panel at the top of the vertical grip to be used as a place for several controls to be activated by using the thumb. This study investigated the reach envelopes with the thumb for control panels that are mounted at various angles at the top of the vertical grip. Different panel angles were examined to determine the effect of panel angle on the thumb reach envelope. Panel angles were evaluated from -20 degrees to + 20 degrees in 10 degree increments on both the left and right sides of the vertical foregrip. At each panel angle, subjects swept with their thumb on each panel to create a reachable area on each side. Another condition allowed the subject to place the panel angle at their preferred angle for each side of the grip. The preferred angles were recorded and the reachable area was measured for the preferred panel angle. The results of this study showed different thumb reach envelopes for different panel angles and a preference for the panel angles to be able to be modified by the shooter.

Faughn, J.A. (2008). *United States Patent No. 7,415,929.* Washington, DC: U.S. Patent and Trademark Office.

Systems for launching one or more projectiles from a bore are provided. An exemplary system incorporates a shell, a projectile, an explosive charge and a wad. The shell includes a base and a casing, with the casing defining an interior. The projectile is located within the interior and is configured to be expelled from the shell casing. The explosive charge is located within the interior and is configured to expel the projectile from the casing. The wad is located within the

interior and is configured to expel the projectile from the casing in response to detonation of the explosive charge. The wad includes petals and a petal stop, with the petals being movable between a closed position, in which free ends of the petals are arranged proximate to each other such that the petals at least partially surround the projectile, and an open position, in which the free ends of the petals are displaced from each other, the petal stop being configured to limit movement of the petals beyond the open position. Responsive to being expelled from a bore by detonation of the explosive charge, the petals move from the closed position to the open position, thereby retarding the wad and releasing the projectile.

Garrett, A.W., Zaky, A., and **Salvi, L.** (2008). Documentation of the Close Combat Reflexive Firing Experiment in Support of the Soldier Focused Area Collaborative Team, Critical Research Area. (AMSAA TR-2008-34). Army Materiel Systems Analysis Agency.

The abstract for this report is limited and cannot be published in this document.

Harper, W., LaFiandra, M., and Wiley, P. (2008). The effect of weapon mass and center of mass on shooting performance with an assault rifle. *Proceedings of the 13th Annual International Conference on Industrial Engineering*, Las Vegas, NV.

The study examined the effects of different weapon masses and different vertical centers of mass on aiming error and subjective ratings of the weapon system's weight, balance and combat performance. The masses used in the study were an M16 with 1.5 kg added, 3.0 kg added, or 4.5 kg added. The centers of mass for the study were the natural vertical center of mass, 4 cm higher than the natural center of mass, and 4 cm lower than the natural center of mass of the M16A2 rifle. Results indicated that the change in vertical center of mass did not affect aiming error or engagement time. Aiming error with the 4.5 kg weight condition was greater compared to the 1.5 and 3.0 kg conditions. Engagement time was not affected by the change in weight of the weapon. Subjective responses showed that the test participants strongly favored the lighter weapons over the heavier weapons for these shooting tasks.

LaFiandra, M., Harper, W., and Wiley, P. (2008). The effect of weapon mass and center of mass on aiming movement. *Proceedings of the 13th Annual International Conference on Industrial Engineering, Las Vegas, NV.*

Mounting equipment on a weapon increases mass and shifts the center of mass. This study investigates the effect of weapon mass and vertical location of the weapon's center of mass on weapon movement during aiming. The task required the subjects move the weapon from one target to another. Peak velocity and overslew of the weapon was measured. No statistically significant effect of mass or vertical center of mass location was observed on peak velocity or overslew. The lack of differences in peak velocity suggests the inertia of the weapon in the greater mass conditions was greater than the inertia of the weapon in the smaller mass conditions. The lack of differences in overslew suggests a different mechanism for controlling

the weapon may be employed by the shooter in the greater mass conditions.Interestingly, peak overslew for successful engagements (hits) was determined to be greater than peak overslew for misses.

LaFiandra, M.E. (2008). A Tool for Calculating the Center of Mass and Moment of Inertia of Small Arms Weapons. (ARL-TR-4517). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

This report describes and demonstrates the use of a software tool designed to calculate the effect of weight added to a weapon on the weapon's mass properties (center of mass [COM], moment of inertia [MOI], and total mass). The Weapon COM Tool was developed in support of the North Atlantic Treaty Organization (NATO) Research and Technology Organization (RTO) Systems Concepts and Integration (SCI)-178 RTO Task Group (RTG)-043 task group on dismounted Soldier system weapon systems interoperability. The NATO SCI-178 RTO-043 task group has identified assault rifle weapon weight and COM as a primary research area.

The COM of a body or segment is the point about which the mass of the body or segment is evenly distributed. MOI is measure of a segment's or object's resistance to changes in angular velocity. Mass properties, such as COM, MOI, and mass, allow for characterization of various weapons and allow for an easy comparison between weapon systems.

The Weapon COM Tool is based on fundamental equations found in many physics or biomechanics texts 1, 2 and can determine the effects of as many as four added weights. The added weight can be accoutrements (such as new sights), additional weapons (such as an M203 grenade launcher), or any other object that is mounted to the weapon.

This report documents the development of a tool for calculating the mass properties of a weapon and subsequently does not report the results of a specific analysis or evaluation.

Ortega, S.V., Garrett, L., and Burcham, P. (2008). Soldier Performance With the M240 Lightweight Machine Gun - Phase II. (ARL-TR-4561). Aberdeen Proving Ground, MD: U.S Army Research Laboratory.

The abstract for this report is limited and cannot be published in this document.

Ortega, S.V., Garrett, L., and Burcham, P.M. (2007). Mobility, Portability, and Human Factors Investigation of an Improved 81-mm Lightweight Mortar System Prototype: Phase II. (ARL-TR-4111). Aberdeen Proving Ground, MD: U.S Army Research Laboratory.

The abstract for this report is limited and cannot be published in this document.

Ortega, S.V., Garrett, L., and Harper, W.H. (2007). Soldier Performance with the M240E6 Lightweight Machine Gun. (ARL-TR-4144). Aberdeen Proving Ground, MD: U.S Army Research Laboratory.

The abstract for this report is limited and cannot be published in this document.

Ortega, S.V., Harper, W.H., and Panozzo, P.R. (2007). Training and Qualification Assessment of Soldiers with the MK19 Grenade Machine Gun While the Soldiers Were Using a Standard and Mixed Belt of 40-mm Ammunition. (ARL-TR-4076). Aberdeen Proving Ground, MD: U.S Army Research Laboratory.

The abstract for this report is limited and cannot be published in this document.

Wilson, R. Faughn, J., and Harper, B. (2007). Evaluation of Crew's Ability to Ingress and Egress Selected U.S. Army Wheeled and Tracked Vehicles While Carrying a Personal Defense Weapon. *Customer report: prepared for PM Individual Weapons*.

The abstract for this report is limited and cannot be published in this document.

Woods, R.J., Statkus, M.J., and **Salvi, L.** (2006). *Human Science/Modeling and Analysis Data Project: Urban Canyon Street Flight and Blufor in Defense Data Collection Effort.* (Natick/TR-00/009L). U.S. Army Natick Soldier Research, Development and Engineering Center.

The abstract for this report is limited and cannot be published in this document.

Thrust Area 6: Medical Human Factors

Research Area 6.1: Education/Training Attrition (POC: Dr. Rice)

Protocols:

ARL/HRED Protocol 20098-05042, Identifying Personal Factors Related to Soldier Performance and Retention Among 68W Health Care Specialists at Ft. Sam Houston, TX

The mission of the Army Medical Department Center and School is to train competent health care professionals and paraprofessionals. Attrition (failing the program and cycling into a new military occupational specialty) is a constant concern and reducing attrition is an invariable goal, especially for those programs that are especially academically demanding and/or in high demand. The objectives of this research were to 1) determine the cognitive and personal risk factors that influence 68W academic performance and 2) develop a model to predict 68W academic performance. The resulting model was used to develop a survey tool for use by AMEDDC&S students and instructors to identify individual and class characteristics that put students 'at risk' for academic attrition, thus enabling them to develop targeted intervention programs early in the program.

ARL/HRED Protocol 20098-0531, Personal Factors Related to Student Performance and Retention Among 91W Health Care Specialists at Ft. Sam Houston, Texas: Self and "Battle-Buddy" Reports on Factors Affecting Academic Performance

Across the Army, academically demanding Advanced Individual Training (AIT) programs are experiencing high rates of academic attrition. Many students have to repeat courses or recycle into alternate Military Occupational Specialty (MOS) training. The 68W MOS-Health Care Specialist is one MOS that is experiencing high attrition and recycling. In response to the Commander of the AMEDDC&S, this study was initiated as one portion of a larger initiative (and series of studies) examining academic attrition in the 68W MOS. The unique aspect of this study is the obtaining of information through both questionnaires and interviews of 1) the trainee who is unsuccessful in passing the course (this means they have failed in at least two attempts to pass the course), 2) the trainee who is very successful in the course (average grade of at least a "B" or above), and 3) trainees who are either the "battle buddy" or friend of the unsuccessful and successful trainees (#1 and #2). By obtaining information from each of these individuals, those factors specific to the trainee who has failed 68W MOS training may be isolated. The objective is to obtain information from the individual trainee and from one of their peers who is familiar with their study habits, personal abilities, etc.

ARL/HRED Protocol 20050708 ASVAB Scores and Test Performance as Predictors of the 68W Health Care Specialist Student Performance

The objective of the proposed research project is two-fold: (1) to determine the amount of variance in course success (first-time and after recycling) that is explained by ASVAB scores and scores on major tests alone; and (2) to create multiple performance models based on different ASVAB ST (and other AAC) scores to determine how attrition might change with a change in the prerequisite AAC score. Once we understand how much variance in 91W success is explained by a student's AAC scores and how changing the minimum AAC score or adding new AAC requirements may impact 91W attrition, these data may be used to direct the research efforts aimed at decreasing 91W attrition rates.

ARL/HRED Protocol 20098-06046, Evaluation of the Effectiveness of a New Technology Intervention: A Pilot Study on Improving 91W Recycle Pass Rates.

Military Occupational Specialty Training (MOS) occurs during Advanced Individual Training (AIT) or Individual Entry Training programs. Across the Army, academically demanding AIT programs are experiencing high rates of attrition, i.e. recycles and reassignments. The 68W, Health Care Specialist, MOS AIT is one such program. It is also a critical shortage area, meaning the US Army does not have enough Soldiers entering and completing 91W training to fulfill this critical mission. The purpose of this study was to examine the effect of neurocognitive training on the performance of Soldiers recycling into the 68D program. The objective was to examine the impact of two neurocognitive interventions (interactive metronome vs. videogame use) on 1) Soldier performance during AIT (grade point average, pass/fail status) and 2) pre/post test measures (Minnesota Dexterity Test, the Barkley and Murphy ADHD Symptom Questionnaire, and the Woodcock-Johnson III standardized academic-cognitive test).

ARL/HRED Protocol 20098-08004, Usability Testing of an Academic Feedback Tool for Students and Faculty: Effectiveness, Ease-of-Use, and Feasibility of the Personal Academic Strategies for Success (PASS) and Academic Class Composite (AC^2T) Programs.

The PASS program is a self-evaluation tool developed from models of 68W academic attrition. After the students complete a questionnaire, the PASS program provides Soldiers with personalized feedback/strategies to better understand themselves and their behavior patterns, and ultimately improve academic achievement in the 68W Course. The Academic Class Composite Tool (AC2T) is a sub-set of the PASS, and provides cadre (commanders, supervisors, and instructors) with class-level composite information (strengths and areas for improvement) and feedback/strategies on how to better meet the needs a specific class of students. The purpose of this study was to conduct usability testing on the PASS and AC2T programs to determine how well the programs do what they are intended to do (effectiveness), how easy the programs are to navigate and to use (ease of use), and to establish whether the programs would be used if made available (feasibility).

ARL/HRED Protocol 20098-09010, An Investigation of Audio-Photic Stimulation to Enhance Cognitive Resiliency.

The Future Force will confront an increasingly complex operational environment that will challenge individual Soldiers and their leaders in unprecedented ways. To address these challenges, in 2008 the US Army published a unique Human Dimension concept. The human dimension encompasses the moral, physical, and cognitive components of the Soldier and leader performance essential for the Future Force full spectrum operations. While conventional combat remains a possibility, the most likely future clashes will be against opponents with radically different perspectives. Sustained high operations tempo (OPTEMPO) for the transformed military, will encompass complex challenges. One important aspect of sustained operations is the identification of techniques, processes, and technologies that will enhance Soldier resilience and resistance to performance decrements while performing in future operations with complex physical terrain, complex human terrain, and complex informational terrain. The focus of this project is on cognitive resiliency during sustained operations. One important aspect of sustained operations is the identification of techniques, processes and technologies that will enhance Soldier resilience and resistance to performance decrements. Research efforts have explored a number of ergogenic aids, including that are mechanical, pharmacological, physiological, nutritional, and psychological aids. This project will examine a neurocognitive 'brain training' technology with students attending the AMEDDC&S to determine its' impact on cognitive (automated neuropsychological assessment metric) and academic performance (grades, pass/fail status), self-reported sleep, mood (Profile of Mood States), self-reported stress. The ultimate goal being to help Soldiers not just endure, but perform extremely well, during sustained operations.

<u>Refereed Journal Articles:</u>

DeVilbiss, C. , **Rice, V.J**, Laws, L., and **Alfred, P**. (in press). If You Want to Know Why Students Fail, Just Ask Them: Self and Peer Assessments of Factors Affecting Academic Performance. *The United States Army Medical Department Journal.,*

One method to discover potential reasons why individuals fail academic training is to ask them. However, self-report information can be difficult to trust, especially if students are perceived as having something to lose if they are honest. The purpose of this study was to identify potential reasons students fail (or do well) in their training as reported by four groups: those who failed their program (F) (n=28) and a peer (F-P) (n=28) and those who passed with a grade of B or above (P) (n=101) and one of their peers (P-P) (32). Statistical analysis included Chi2 statistics and t-tests with a $p < .05$. Only findings considered 'external' to student are included here, including class structure and schedule, instructors and teaching, support systems, and sleep. Few differences were found between peer reports and self-reports by students who passed or students who failed their program. On the positive side, both P and F students indicated they could get individual attention even with large classes, having good support systems, and bonding well with their unit. On the negative side, P and F students reported having difficulty staying focused during long class hours, and F students felt teaching methods made it difficult to succeed and struggled with the fast pace of the course ($p < .05$). More than half of all students reported sleeping between five and six hours per night, but those who failed more often reported sleeping only three to four hours per night ($p<.05$). These findings highlight areas of organizational strength, as well as areas of difficulty for students, which will permit administrators to set goals and perhaps tailor their programs to reduce attrition.

Rice, V.J., Vu, T., Butler, J., Marra, D., Merullo, D., and Banderet, L. (2009). Fear of failure among students attending military health care specialist training. *Work: A Journal of Prevention, Assessment, and Rehabilitation, 34(4).*

During scholastic or physical performance testing, individuals who fear failure tend to focus on their fears instead of the task and often perform poorly. This study examined the relationship between fear-of-failure (FoF) and performance among 200 students (male = 140, female = 60) attending Health Care Specialist Advanced Individual Training (AIT) at Ft. Sam Houston. Performance measures included grade point average, pass/fail status, Army Physical Fitness Test scores, and number of musculoskeletal injuries. Pearson Product Moment Correlations revealed that Soldiers who scored higher on a FoF scale also had higher final grades ($r = .16$, $p = .02$, $r^2 = .026$). No significant correlations were found between FoF and other performance measures. While the variation in GPA accounted for by FoF was small (2.6%), this finding demonstrates a positive relationship that differs from previous studies. This finding may be explained by the concepts of failure avoidance and success orientation (self confidence and motivation), as well as the unique military setting. Suggestions for designing military educational interventions during AIT and throughout one's military career are offered.

Rice, V.J., Mays, M.Z., and Gable, C. (2009). Self-reported health status of students in-processing into military medical advanced individual training. *Work: A Journal of Prevention, Assessment, and Rehabilitation, 34(4).*

Musculoskeletal injuries during Army advanced individual training (AIT) are high. This technical report focuses on the self-reported health status among soldiers arriving in two medical training Battalions at Ft. Sam Houston. The results reveal that 43% of arriving soldiers have musculoskeletal symptoms and 35% have symptoms that interfere with their ability to accomplish the normal daily activities required during their student status. The most common sites of symptoms were knee (17 and 18%), foot/toe (16 and 13%), ankle (9 and 10%), and lower leg (9 and 12%) for the 232nd and 187th Medical Battalions respectively. Risk factors for those with symptoms that interfere with their abilities to do their jobs include gender, past history of injury, and self-reported stress levels. Other risk factors for medical specialties other than combat medic include being older (over 24 yrs of age) and active duty status. This information can be used to help screen for "porcelain soldiers", that is, soldiers who are considered to be "at risk of breaking" during AIT. This will enable their supervisors to tailor their physical training, as much as possible, so they can achieve fitness without additional injury.

Rice, V.J., Connolly, V.L., Pritchard, A., Bergeron, A., and Mays, M.Z. (2008). Effectiveness of a Screening Tool to Detect Injuries among Army Combat Medic Soldiers. *Work: A Journal of Prevention, Assessment, and Rehabilitation, 29 (3)* 177-188.

The purpose of this project was to evaluate the effectiveness of an initial screening and referral process in reducing the impact of musculosketetal injuries among soldiers attending Health Care Specialist training. Musculoskeletal injury among Army Health Care Specialist students have been reported to be approximately 24% for men and 24-30% for women. The highest student visit rate to the troop medical clinic for musculoskeletal injuries, for men and women, occurs during the first week of training. Anecdotal reports indicate that many students arrive for training with existing injuries or symptoms. This project was designed to assess whether formalized early screening, referral, and intervention could 1) identify arriving Combat Medic students that arrive at training needing musculoskeletal injury-related medical attention, 2) reduce the number of students receiving limited duty status during their 10-week training, 3) decrease the total number of limited duty days for students, and 4) decrease the number of students who cannot graduate due to musculoskeletal injury. Students (N = 291) from one company were divided into three groups of 97 students. Three methods were used to screen and refer combat medic students for medical intervention: 1) traditional (T), 2) by health care providers (HCP), or 3) by Drill Sergeants (DS). Screening by HCP and DSs involved using a new screening tool to identify and consequently refer students with symptoms to a troop medical clinic (TMC) for early evaluation and intervention. Using the screening tool, HCPs identified 92% of students with injuries, while DSs accurately identified 80%. The screening did not reduce the number of students receiving limited duty status, total limited duty days, or the number of students that could not graduate due to musculoskeletal injury ("holdovers") ($p > 0.05$). The screening tool demonstrated good sensitivity and specificity whether conducted by HCPs or DSs. It failed to demonstrate efficacy in reducing the impact of musculoskeletal injuries among Combat Medic soldiers, as measured by limited duty days and holdovers.

Refereed Conference Presentations/Proceedings:

Alfred, P. (Chair), **Boykin, G**. (co-Chair), Caldwell, L., **Rice, V.** (speaker/presenter), Miller, N., Matsangas, P., Lieberman, H., and Wesensten, N. (accepted). Discussion Panel: Sleep Across Military Environments. Proceedings of the 2010 Human Factors & Ergonomics Society Annual Meeting, San Francisco, CA.

This focus of this discussion panel is on the effect of sleep on human performance in different military environments or contexts. Panelists will discuss a wide range of topics including how to address fatigue among Air Force pilots, the impact of sleep on performance in Army Advanced Individual Training, the effects of adjusting Army and Navy recruits' sleep schedules during training, the existing gaps in addressing sleep needs on naval vessels, the impact of sleep loss and other stressors on dismounted warfighter performance, and the effects of chronic inadequate sleep on cognitive readiness. It is important to understand both the differences in the effects of sleep in these environments, as well as the commonalities that can be applied to multiple environments and operators. Our panelists include some of the foremost sleep experts of today, as well as others who examine sleep in their human performance research. Participation in this panel will include discussing their latest research, offering practical applications, and engaging the audience in discussions of cross-disciplinary applications, including areas for collaboration across military and civilian services and environments. Finally, panelists and audience members will and share ideas about directions for future sleep-related research.

Rice, V.J., Butler, J., and Marra, D. (in press). Self-reported Sleep and Soldier Performance. Proceedings of the Applied Human Factors and Ergonomics Conference, Miami, FL.

Cognitive performance can be impaired by lack of sleep. Healthcare Specialist (68W) Advanced Individual Training (AIT) is rigorous and students must learn and process a great deal of information in a short time. The purpose of this study was to explore the relationships between self-reported sleep (SRS) and the academic and physical performance of students attending 68W AIT, as well as exploring the relationship between SRS and personal variables that may impact performance. Soldiers (n=579) attending 68W AIT completed a questionnaire two weeks after beginning training. The questionnaire addressed hours of sleep, demographics, personal characteristics and coping skills potentially related to performance. Final grades and physical training scores were recorded. SRS was less for those who were older and who currently smoked. Those who were more motivated and willing to complete training, or with higher self-efficacy scores had higher SRS. SRS followed an inverted U-shape, according to stress levels, with SRS being lowest among those with extremely high and extremely low stress. SRS was related to initial and mid-course physical fitness scores ($p < 0.05$), but not to the physical fitness test conducted at the end of the course or to final grade point average or pass/fail status ($p > .05$). The results reveal relationships between SRS and constructs related to Soldier performance. Possible future research and program considerations are provided.

Alfred, P., **Rice, V**., **Boykin, G**., and Laws, L. (in press). Auditory Discrimination and Academic Performance. Proceedings of the Applied Human Factors and Ergonomics Conference, Miami, FL.

Auditory discrimination, or the ability to attend to and differentiate between similarly sounding words in the presence of background noise, may influence why an individual fails or passes a course. The purpose of this study was to explore the relationship between auditory discrimination, key demographic variables, and academic performance among 68D Operating Room Specialist trainees. Scores on the Woodcock Johnson III Test of Auditory Attention were compared between 68D students considered academically at-risk and students performing well in the course. Volunteers consisted of 48 trainees from the 68D course, 25 high-risk students who failed the course, and 23 low-risk students with an A/B average. On average, high-risk students scored at an 8th-grade level, while low-risk students scored at an 11th-grade level. We also found that Caucasian females scored at a 7th-grade level, while Caucasian males scored at an 11th-grade level. We were able to predict auditory discrimination by using three pieces of information—Caucasian race, female gender, and high risk status. Implications of these findings on classroom design, potential interventions, and future research are discussed.

Rice, V.J. (2009). You've seen Macroergo and Neuroergo, now there is "EduErgo": Collaborating to Use Ergonomics in Education Investigation, Evaluation and Design. Human Factors & Ergonomics Society Annual Meeting, San Antonio, TX.

Ergonomics involves evaluating a product or process (what exists), comparing it with related scientific literature (what works), and using the information to re-design the product or process. The new design seeks to match known information about human capabilities and limitations with the product or process requirements in order to improve the ease-of-use, efficiency, productivity, or safety. Ergonomics is applied in a variety of settings including aeronautics, health care, training, construction and other industries. Within education settings, ergonomics is typically applied on a micro level, such as the design of chairs, workstations, or classrooms. This paper describes the application of macroergonomics to the evaluation and design of educational programs, with the goal of improving student performance and reducing attrition due to academic failure. Examples focus on medical technician programs.

Alfred, P. (Chair), Miller, N. (co-Chair), **Rice, V.J**. (speaker/presenter), **DeVilbiss, C.** (speaker/presenter), Bazley, C., Jacobs, K., and Vause, N. (2009). Discussion Panel: Human Factors Applications in Academic Settings. Proceedings of the Human Factors & Ergonomics Society Annual Meeting, San Antonio, TX.

Members of this panel will discuss their work in applying Human Factors/Ergonomics in a unique field of application: Academia. Each panel member will give a short presentation describing how they have applied Human Factors/Ergonomics within academia to include: ensuring an adequate auditory environment, safety and injury prevention, office ergonomics, reducing attrition, examining backpack weight and laptop computer use of students, and "brain training" to reduce the effects of stress and improve academic performance. Each panelist will also talk about the role they envision for Human Factors/Ergonomics professionals within academic settings, from kindergarten through university level programs.

Alfred, P. (Chair), Miller, N. (co-Chair), **Rice, V.J.** (speaker/presenter), **DeVilbiss, C.** (speaker/presenter), Bazley, C., Jacobs, K., and Vause, N. (2009). Discussion Panel: Human Factors Applications in Academic Settings. Proceedings of the Human Factors & Ergonomics Society Annual Meeting, San Antonio, TX.

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Alfred, P. and **Rice, V.J**. (2008). Cognitive Characteristics of Academically 'At Risk' Students Attending Operating Room Specialist Training. Presented at the Human Systems Integration Symposium.

Reducing attrition from military medical training programs is especially important during war, when there is high demand for, but a shortage of, trained personnel. In an effort to reduce academic attrition during medical Advanced Individual Training, the Army Research Laboratory – Army Medical Department Field Element is conducting a series of studies to determine reasons for attrition and to test interventions to reduce attrition. This paper examines one potential reason for academic attrition— cognitive ability. Portions of the Woodcock Johnson III were used to examine cognitive abilities among 25 Operating Room Specialist trainees who failed their training and were waiting to recycle into the program in a second attempt to pass. Cognitive ability is presented in terms of grade equivalency (GE) scores across different factors of cognitive ability, and areas of academic achievement. Individual GEs ranged from kindergarten to graduate school levels, demonstrating personal limitations in both cognitive functioning and academic achievement. Looking at overall means, all scores were at or above the 10th grade level with the exception of auditory attention (8.5 GE). Results from this study indicate that auditory attention may be a precursor of academic failure. This paper presents recommendations for helping individuals with auditory attention difficulties in a classroom environment, along with a more general discussion of how cognitive information can be used to understand the individuals attending the training and design the training based on their needs. Finally, it is recommended that similar tests be conducted with students who have passed or are passing their training to determine whether there is, indeed, a significant difference between the groups in auditory attention.

Rice, V.J. and Butler, J. (2007). Revisiting an Old Question with a New Technology: Gender Differences on a Neuro-Cognitive Temporal Tracking Task. Human Factors & Ergonomics Society Annual Meeting, Baltimore, MD, pp 581-586.

Gender differences exist, but the strength and importance of those differences is debatable. This study examined differences in performance among men (n = 64) and women (n = 56) on 14 neuro-cognitive temporal tasks. No adult norms exist for these tasks. Therefore, the goals were to 1) record and compare scores achieved by men and women, and 2) investigate differences in terms of performance (grade point average and physical fitness score) during Army Health Care Specialist Advanced Individual Training (AIT). Descriptive statistics and T-Tests identified and compared scores by gender, while IM scores and performance relationships were explored with Pearson Correlations (PC) and regression analysis. Men's temporal responses were closer to the reference beat than women's on 11.9% of tasks ($p<0.05$). There were no significant relationships between temporal responses and physical fitness performance scores and only two correlations between temporal responses and grade point average (right hand tapping, *task average* and *Super Right On* (percent within ±15ms of the target beat (PC = 0.189, $p = 0.04$; and PC = 0.20, $p = 0.03$). No relationship between temporal abilities and either physical or academic achievement during AIT was found, however this research does uphold findings of differences between men and women in temporal abilities.

Banderet, L.E., Merullo, D.J., **Rice, V.J**., Butler, J., and Marra, D. (2006). Personal thoughts and success/failure in a military, medical training program. *International Military Testing Association Annual Meeting*, Oct 2006, Kingston, Canada.

Several theoretical frameworks describing personal adjustment and development, success, abnormal behavior, and psychocybernetics describe the role of personal thoughts in affecting these diverse phenomena. Personal thoughts are often covert ideas (or images) that an individual processes cognitively and often, the individually indoctrinates him/herself with those thoughts. A questionnaire known as Banderet's Personal Thoughts Questionnaire (BPTQ) was developed to determine if such personal thoughts were associated with classroom academic performance (course grades) and success/failure in a military medical training program. Volunteers were ~520 students enrolled in the 91W Health Care Specialist Program (formerly Combat Medic course) at the U.S. Army Medical Center and School at Ft. Sam Houston, Texas. The BPTQ has 17 items rated with a Likert Scale with discrete anchor points. The questionnaire was prepared as a paper and pencil form that could be optically scanned and scored with a computer. Questionnaire data were collected during the first two weeks of training. Following data collection, a statistical factor analysis was performed to determine its factor structure, i.e., Negative Thoughts, Positive Thoughts, Fit of Military Occupational Specialty (MOS), and Perceived Capabilities. Independent linear regressions of each individual's factor score with course grade yielded statistically significant correlations (all $p < 0.01$) that accounted for 1-6% of the variance. The factors that were the most substantial predictors of course grade from our questionnaire were Negative Thoughts (6%), MOS (4%), and Perceived Capabilities (2%). Combined with other predictors, this information will enable identification of students at risk for having academic difficulty, so that interventions can be suggested.

Rice, V.J., Butler, J. and Marra, D. (2006). Predicting performance: Self-Esteem among soldiers attending health care specialist training. *Proceedings of the Human Factors& Ergonomics Society 50th Annual Meeting*. Santa Monica, CA: Human Factors Society.

Reducing failure and recycling in demanding military Advanced Individual Training (AIT) programs will reduce costs: time and morale for the Soldier and financial costs for the organization. This study is one in a series, examining factors internal and external to the Soldier that can influence performance during AIT. The purpose of this research was to document self-esteem among 252 Soldiers attending Health Care Specialist Training using the Rosenberg Self-esteem Survey and to examine the relationship between self-esteem, general demographics, self-reported health, motivation, self-efficacy and grade point average (GPA). Self-esteem fell into a relatively predictable bell curve. No relationship was found between self-esteem and gender, marital status, age, race, military component or high school GPA or science grades ($p>0.05$). Self-esteem was correlated with self-reported health status, endurance, strength, self efficacy and motivation ($p< 0.05$). No relationship was found between self-esteem and GPA.

Sharp, M. A., Pietila, D., and **Rice, V. J**. (2006). Manual materials handling in multiple person teams. In Karwowski (Ed.) *International Encyclopedia of Ergonomics and Human Factors 2nd Ed*, Taylor & Francis, London.

No Abstract

<u>Technical Reports:</u>

DeVilbiss, C. and **Rice, V.J.B.** (2007). Survey Results for the Development of the Academic Class Composite Tool for the Academic Instructors and Supervisors. Technical Memorandum No. ARL-MR-0677, US Army Research Laboratory Field Element, Ft. Sam Houston, TX 78234-6125.

This report presents results from a survey of 113 Academic Instructors to validate the design definition developed in the initial report: "*The 'Academic Class Composite Tool' for the Academic Instructors and Supervisors: Definition and Development*. That report summarized the process used in the design and definition of the *Academic Class Composite Tool* (AC^2T), one of two specialized tools for the 91W Advanced Individual Training (AIT) program. While the main tool, i.e., the *Personal Academic Strategies for Success (PASS),* is being developed for use by individual Soldiers upon arrival for their AIT course, the AC^2T is designed for use by the academic instructors, drill sergeants, and supervisors. That report documented the first level design specifications for the Academic Class Composite Tool and collected initial data to verify user input. A Flow Diagram of the work is contained in this technical report. This report fulfills the next step in the path forward by replicating the survey that was administered to the drill sergeants with the academic instructor population.

Rice, V.J.B., Butler, J., and Marra, D. (2007). Neuro-Cognitive Assessment, Symptoms of Attention Deficit and Hyperactivity Disorder, and Soldier Performance during 68W Advanced Individual Training. Technical Report No. ARL-TR-4292, US Army Research Laboratory Field Element, Ft. Sam Houston, TX 78234-6125.

This study is one in a series of studies examining factors that impact Soldier performance during Advanced Initial Training (AIT). This study examines the relationships between 1) Soldier performance using the Interactive Metronome® (IM), a new interactive-computer technology used to assess neuro-cognitive function in terms of auditory and visual input with psycho-motor timing and rhythm output, 2) symptoms of attention deficit and hyperactivity disorder (SoAD/HD), and 3) academic and physical performance during 68W AIT. Pearson Product Correlations and backward stepwise regressions were used to analyze the data. Participants included 122 Soldiers attending 68W AIT. Results revealed a negative correlation between SoAD/HD and grade point average (GPA) ($p = 0.03$). Results also revealed correlations between overall ($p = 0.03$) and inattentive type ($p = 0.00$) SoAD/HD and IM performance without auditory cues hypoanticipatory scores (the individual is late in their response) ($p < 0.05$). In addition, the IM assessment with auditory cues was predictive of AIT performance including GPA, all components of the Army Physical Fitness Test, and of both the total number of new musculoskeletal injury (MSI) profiles and total profile days for MSIs. Although the R-square was small in each case ($R^2 \leq 0.13$), these results demonstrate relationships between neuro-cognitive performance as measured by the IM, SoAD/HD, and physical and cognitive performance during AIT. Additional research is recommended on SoAD/HD among Soldiers, training with the IM to reduce attrition and improve cognitive performance among Soldiers at risk for reduced performance during AIT, and use of IM training to improve physical performance and reduce MSI injuries.

DeVilbiss, C., **Rice, V.J.B**, and Laws, L. (in press) Personal Factors Related to Student Performance and Retention Among 68W Healthcare Specialists: Self and Peer Assessments of Factors Affecting Academic Performance Technical Report No. ARL-MR-(in press), US Army Research Laboratory Field Element, Ft. Sam Houston, TX 78234-6125.

Across the Army, academically demanding Advanced Individual Training (AIT) programs are experiencing high rates of academic attrition as many trainees must repeat courses or recycle into alternate Military Occupational Specialty (MOS) training. This study is one portion of a larger initiative that included a series of studies examining academic attrition in one specific specialty, the 68W (previously 91W) MOS, Health Care Specialist. The two primary objectives of this study were (1) Identify factors that influence academic attrition by interviewing trainees who have failed the 68W MOS and one of their peers and (2) Compare and contrast responses from trainees who have failed 68W MOS training with those who are passing, along with their respective peers, i.e., Battle Buddies. The questionnaires provide a good insight into the similarities and differences among the trainees who passed and the trainees who failed the course. As seen in the following summary, the trainees accept personal responsibility for their academic performance (96% and 98%, passing and failing trainees, respectively) and have supportive family and friends (87% and 79%, passing and failing, respectively). In addition, all trainees also report having difficulty in staying focused in class (50% and 43%, passing and failing, respectively), experiencing the same pattern of depression (23.8% and 21.4%), and report 68W MOS was not what they expected from recruiter description (57% each). By contrast, failing trainees were more likely to report they were affected by stress (54% vs. 39%) and report that teaching methods made it difficult for them to succeed (54% vs. 25%). With few exceptions, the peer evaluations did not differ significantly from the corresponding trainee responses. In the few instances where there was a difference, the Battle Buddy tended to report a more positive response than did the corresponding trainee. For example, the battle buddies reported that the passing trainees had less trouble staying awake in class than was reported by the passing trainees themselves.

Rice, V.J., Alfred, P., Boykin, G., McMillan, K.K., Nawrocik, M.E., Hodges, W.E. (in progress). Ease of Use Evaluation of the Personal Academic Strategies for Success (PASS) and Academic Class Composite Tool (AC^2T) User-Interface Prototype. Technical Report No. ARL-MR-(in progress), US Army Research Laboratory Field Element, Ft Sam Houston, TX 78234-6125.

No Abstract

Rice, V.J., Alfred, P., Boykin, G., McMillan, K.K., Nawrocik, M.E. (in progress). Feasibility of Personal Academic Strategies for Success (PASS) and Academic Class Composite Tool (AC^2T). Technical Report No. ARL-MR-(in progress), US Army Research Laboratory Field Element, Ft Sam Houston, TX 78234-6125.
No Abstract

Rice, V.J., Alfred, P., Boykin, G., Nawrocik, M.E., McMillan, K.K. (in progress). Effectiveness of Personal Academic Strategies for Success (PASS) on Attrition Rate and Grade Point Average in 68W Health Care Specialist Training. Technical Report No. ARL-MR-(in progress), US Army Research Laboratory Field Element, Ft Sam Houston, TX 78234-6125.

No Abstract

Books:

Marek, T., Karwowski, W. and **Rice, V**. editors (in press). Advances in Neuroergonomics and Human Factors of Special Populations.

No Abstract

Book Chapters:

Sharp, M.A., Pietila, D. and **Rice, V.J**. (2006). Manual materials handling in multiple-person teams. In Karwowski (Ed.) International Encyclopedia of Ergonomics and Human Factors, 2nd Ed, Taylor&Francis, Ltd, Boca Raton, FL. Chapter 160, pp 786-789.

No Abstract

Research Area 6.2: Intervention

MRMC Protocol: C.2009.117d, Describing Clinical Characteristics and Indentifying Leading and Lagging Marker for Functional Outcomes: A Retrospective Record Review of a Traumatic Brain Injury Population.

Traumatic Brain Injury (TBI) is considered the signature wound of the current conflicts in Iraq and Afghanistan. While TBI is of concern in the civilian population as well, little is known about the population of service members who are evaluated and treated for TBI, and even less is known about the adequacy of treatment interventions for this unique patient population. This research proposes to use a retrospective patient record review to define and describe the population of service members with a TBI who have been evaluated and treated at the Brooke Army Medical Center (BAMC) Traumatic Brain Injury (TBI) Clinic and to initiate the identification of early indicators of clinical and functional outcomes. This effort will also include developing a patient monitoring and data record keeping system to enable and streamline scientifically-based outcome studies on the efficacy of multidimensional rehabilitation regimens, which can be used as a template for other TBI treatment centers. It is anticipated that this research will result in a series of descriptive papers and presentations on the characteristics of service members with a TBI and the leading and lagging indicators of clinical and functional outcomes. It is further expected that the database system developed during this research will enhance continued clinical research on rehabilitation and reintegration techniques and serve as a template for other TBI treatment centers. This study addresses research gaps examining the diagnostic utility of symptoms, mechanism of injury, personal characteristics, and differential diagnosis of TBI /post concussive disorder to include neuropsychological assessments and clinical management of service members with such an injury.

MRMC Protocol C.2008.083. The Investigation of Emerging Technologies For Use in Screening for Traumatic Brain Injury

Rapid Equipping Force requested the assistance of Medical Research and Materiel Command (MRMC) in determining the value of balance as a reliable and valid screening tool to detect the presence of Traumatic Brain Injury (TBI) in Service Members exposed to blast and other deployment related trauma. This request was blended with the Army Research Laboratory – Army Medical Department Field Elements (ARL-AMEDD Field Element) study examining three technologies for the same purpose: the Brain Acoustic Monitor (BAM), Voice Analysis (VA), and the Automated Neuropsychological Assessment Metric (ANAM). The purpose of this study is to examine the effectiveness of emerging and existing technologies for assisting in the assessment of TBI in a 4 (group) x 3 (time) mixed factorial, repeated measure design. Groups include: +TBI – PTSD, -TBI + PTSD, +TBI +PTSD, -TBI –PTSD. Time includes initial and 2 follow-ups at 1 week intervals.

Building Soldier Resiliency Through a 'Second Life'

The proposed research will be conducted with the USC Institute for Creative Technologies. The ICT-ARL HRED team envisions performing a series of studies which will implement various interventions and products over the internet (through *Second Life*). The first proposed study will examine the usability by military service members and veterans of the portals and sites recently created within the Military Veterans Center in *Second Life*, to include ease-of-use, acceptability, feasibility (whether volunteers would use the program on their own, if given the opportunity), and content (do volunteers using the program value current content and/or do they have alternate suggestions for content). The second study is expected to incorporate a training program conducted over the internet through Second Life based on a Mindfulness-Based Stress Reduction Curriculum, such as the one offered with the UCSD Center for Mindfulness. The study will examine the effectiveness (reduction of stress-related symptoms) of the intervention. The focus on mindfulness-based stress reduction gives a basis from which to start, but the implications are far greater than this single effectiveness study. This method of delivering information and interacting with Soldiers could ultimately be extended to a multitude of interventions. Examples include providing counseling or advise (with a real-time counselor), permitting those in theater to discuss methods of handling precarious situations, or delivering any number of education and training initiatives.

BAMB IRB C.2008.158e. Validating the Use of Rubber Mannequin IV Arms as a Teaching Modality in Training Peripheral Intravenous Cannulation Skills to Army Practical Nursing Students

Mr. Boykin is serving as a co-investigator on this protocol written by authors in the Department of Nursing Science. This research focuses on comparing current instruction on initiating and discontinuing intravenous infusions using human versus mannequin arms in a simulated clinical environment.

<u>Refereed Journal Articles:</u>

Cooper, D.B., Mercado-Couch, J.M., Critchfield, M.S., Kennedy, J**., DeVilbiss, C.A**., Bowles, A.O., Cullen, M., and Gaylord, K.M., (in press). Factors predicting cognitive dysfunction following explosion injuries in OIF/OEF service members: Traumatic severity, mild traumatic brain injury (mTBI), medication effects, and psychiatric co-morbidity. *Neurorehabilitation*.

OBJECTIVE: To examine the relationship between mTBI, psychiatric conditions, pain medications, and injury severity on cognitive functioning in service members admitted to a burn unit. We hypothesize that psychiatric co-morbidity and pain medications will have a stronger relationship with cognitive dysfunction than mTBI diagnosis in this population. **METHOD:** Retrospective review of clinical evaluations (n = 194) completed between September 2005 – October 2007 on service members with burn injuries secondary to explosive munitions. Evaluations were completed during the acute stage of recovery (mean = 7.87 weeks). mTBI diagnosis (n = 50) was made through a clinical interview using ACRM criteria. Exclusion criteria included duration of posttraumatic amnesia > 24 hours (n = 10); and inability to complete neurocognitive measures due to severe bimanual burns and/or amputations (n = 17). Cognitive functioning was evaluated using the Repeatable Battery for the Assessment of Neuropsychological Status (RBANS). **RESULTS:** Subjects who sustained mTBI demonstrated significantly greater difficulty on the RBANS visuospatial and attention/processing speed indices. A hierarchical linear regression, using mTBI diagnosis, psychiatric diagnosis, time since injury, presence of pain medications, and measures of trauma severity as predictive factors, found that mTBI diagnosis and pain medications had significant, but small unique effects on cognitive functioning. Contrary to our hypothesis, psychiatric co-morbidity was not shown to have a significant effect on this population of acutely injured service members. **CONCLUSIONS:** While the relationship between severe TBI and cognitive functioning is well established, the relationship between mTBI and its effects on cognitive and behavioral abilities is less clear. The current study demonstrates that mTBI and analgesic medications have a small effect neurocognitive functioning in this population. Continued examination of this relationship is warranted.

Bowles, AO, Cooper, DB, **DeVillbis, C.**, and **Rice, V**. (2009) Clinical characteristics of OIF/OEF Service Members with mild and moderate traumatic brain injuries. *Journal of Neurotrauma, 26*(8): A-24.

OBJECTIVE: To examine psychiatric and post-concussive symptoms in a selected sample of active duty service members presenting for outpatient treatment in a traumatic brain injury (TBI) clinic at a military medical center. We hypothesized that psychiatric factors, particularly post-traumatic stress disorder (PTSD), would be prevalent and would have a considerable clinical impact on post-concussive symptom reporting. **METHODS:** Subjects were drawn from a larger pool of Service Members (N=427) on their initial presentation to a traumatic brain injury clinic at a military medical center between August 2007 and April 2009 who completed clinical outcome instruments as part of their routine care. Twenty-eight subjects were excluded because they did not complete all measures. Additional subjects were excluded on the basis of TBI severity (N=8; severe and penetrating TBI) and non-traumatic etiology (N=7; anoxic and subarachnoid hemorrhage), resulting in our final sample (N=384) for analysis. Clinical instruments included measures of combat stress (Posttraumatic Stress Disorder Checklist – Military Version), headache (Headache Impact Test – 6), and post-concussive symptoms

(Neurobehavioral Functioning Inventory). Subjects were divided into three groups: TBI negative (N=71), mild TBI (N=296), and complicated mild/moderate TBI (N=17) for analysis. **RESULTS:** Combat stress symptoms were significantly greater (F=1.68, p<0.001) in subjects with mild TBI (mean=41.4; sd=16.8) than in service members who did not sustain a concussion (mean=32.6; sd=15.5). In addition, nearly 44% of subjects with mTBI met criteria for PTSD. Post-concussive symptom reporting was significantly greater among subjects with mild traumatic brain injury on measures of headache ($Z_{0.05(2)}$ =-4.68, p<0.001), somatic functioning ($Z_{0.05(2)}$ =-4.05, p<0.001), and cognitive complaints ($Z_{0.05(2)}$ =-4.08, p<0.001). **CONCLUSION:** This study examines clinical characteristics of service members receiving outpatient TBI treatment in a military medical center during the current conflicts in Iraq and Afghanistan. Preliminary data suggests that co-occurrence of combat stress is common in a mild TBI population presenting for treatment. Further examination of this relationship is necessary in order to develop optimal treatment programs for returning service members with traumatic brain injury.

Refereed Conference Presentations/Proceedings:

Boykin, G., **Rice, V.J**., and **Alfred, P**. (in press). Past Videogame Experience and Neurocognitive Timing Performance. Proceedings of the Applied Human Factors and Ergonomics Conference, Miami, FL.

The Interactive Metronome (IM®) is a neurocognitive testing and training device that targets perceptual-motor timing, with visual and auditory cuing and feedback. As such, it might be expected that individuals with prior video gaming experience (VGE) would perform better on an initial IM®. Both IM® tasks and video gaming require information processing, interaction of tactile, kinesthetic, visual, and auditory processes, elicitation of motor responses, and the ability to attend (and respond) over time. The purpose of this research was to examine the relationship between self-reported videogame experience (VGE) and IM® Long Form assessment Task Average (TA) scores. Volunteers (*n*=25), mean age (20.96) attending Military Occupational Specialty (MOS) 68D Advanced Individual Training (AIT) (surgical technologist program) completed a VGE questionnaire, in which they reported the number of years they have played videogames (SRY), the hours per week they play videogames (SRH), and their level of proficiency on a 1-10 scale (SRP). Pearson product moment correlations between IM® Long Form assessment scores indicated a moderate positive relationship between right sided tasks (*r*(23)=.402, *p*=.046) and SRH of video game activity, i.e. Those who played more hours had lower IM® right-side scores. No relationship was found between SRY or SRP and IM® scores. While these results should be interpreted carefully due to the small sample size, they suggest that VGE does not improve timing, as measured by the IM®. Therefore, therapist, coaches, and teachers should not exclude those individuals who have a great deal of VGE from intervention programs aimed at improving timing.

Cooper, D.B., Mercado-Couch, J.M., Critchfield, M.S., Kennedy, J., **DeVilbiss, C.A.**, Bowles, A.O., Cullen, M., and Gaylord, K.M., Factors predicting cognitive dysfunction following explosion injuries in OIF/OEF service members: Traumatic severity, mild traumatic brain injury (mTBI), medication effects, and psychiatric co-morbidity., 11th Annual George E. Omer, Jr. Research and Alumni Lectureship, 2009. (Received the Thompson Award for Outstanding Research (non-orthopedic division).

No Abstract

Bowles, AO, Cooper, DB, DeVillbis, C., and Rice, V. (Sept 2009). Clinical characteristics of OIF/OEF Service Members with Mild and Moderate Traumatic Brain Injury. Poster presentation at the National Neurotrauma Society Symposium.

No Abstract

Rice, V.J. (2008). Ergonomics & Rehabilitation: Similarities, Differences, and the Interface. Presented in a Panel Discussion at the Human Factors & Ergonomics Society Annual Meeting, NY, NY. Partial content available in the Human Factors & Ergonomics Society Annual Meeting Proceedings.

The process of rehabilitation, accommodation and return-to-work entails an assessment of a patient's ability to engage in work activities, an analysis of job demands and the matching of these elements to determine whether the individual and the job are compatible. The process involves numerous stakeholders, whereby ergonomists may analyze the demands of the job, clinicians may assess the individual's abilities and the matching is conducted as a joint effort. The success of the joint effort depends on the communication between several professional disciplines. To improve the communication we need tools that advance the decision making. The process of 'ergonomics for one' requires tools and methodologies of sufficient resolution to address the individual's needs. From the ergonomist's perspective, do we have tools that support clinical decision making regarding the ability of an individual patient to return to work? Similarly, does the ergonomist have tools to assist in adapting the job to the individual's abilities? The session is aimed for practitioners involved in industrial ergonomics as well as rehabilitation. The panel will examine several attempts to address these questions conceptually or practically, limiting the scope of the discussion to rehabilitation and accommodations of physical impairments. The goal of the session is to identify areas and directions that need further research and development.

Technical Reports:

Rice, V.J., Lindsay, G., Overby, C., Jeter, A., **Boykin, G.L., DeVilbiss, C., Alfred, P.E., and Bateman, R.** Brain Acoustic Monitor: Human Factors Feedback. (in press). Technical Report No. ARL-TR-XXXX. U.S. Army Research Laboratory, Human Research and Engineering Directorate, Aberdeen Proving Ground, MD 21005-5425.

The technology that is the subject of this Human Factors Assessment, i.e., the Brain Acoustic Monitor, is one of four technologies evaluated under the protocol "The Investigation of Emerging Technologies for Use in Screening for Traumatic Brain Injury". This document contains lessons learned and suggestions for improving the device, based on use during the research. A human factors assessment for each of the other three technologies, i.e., the balance platform; a voice analysis system; and the Automated Neuropsychological Assessment Metric (ANAM), are documented in separate reports.

Boynton, A.C., **Rice, V.J**., **DeVilbiss, C.A**., and **Faughn, J.A.** (2007). An evaluation of the issue and wearing of the personnel armor system for ground troops (PASGT) and advanced combat helmet (ACH). Technical Report No. ARL-TR-4225. U.S. Army Research Laboratory, Human Research and Engineering Directorate, Aberdeen Proving Ground, MD 21005-5425.

No Abstract

Other Publications:

Alfred, P.E. (2007). Applied Human Systems Integration: Developing a Methodology for the DOTMLPF Assessment of the Army's Land Warrior System. Unpublished master's thesis. Naval Postgraduate School, Monterey, CA.

The U.S. Armed Forces, through the Department of Defense (DoD) Directive 5000.1 and DoD Instruction 5000.2, requires optimizing total system performance and minimizing the cost of ownership through a "total system approach" to acquisition management (Defense Acquisition University, 2004). Human systems integration, an emerging inter-disciplinary field, seeks to achieve optimal system performance by taking a human-centered perspective and approach to the system design and development process. DOTMLPF is a problem solving and assessment framework that includes Doctrine, Organization, Training, Leadership and Education, Materiel, Personnel, and Facilities and in some respects, is similar to HSI. This thesis examined the link between HSI and DOTMLPF as well as the relationships within the DOTMLPF areas and the HSI domains. In addition, since a methodology did not yet exist for collecting DOTMLPF and HSI data, a survey methodology was identified, selected, developed, implemented, and applied to a real world case study--the DOTMLPF Assessment of the Army's Land Warrior (LW) System. Finally, this thesis uses the Land Warrior DOTMLPF survey effort and results from the Basis of Issue section of the survey as a case study to illustrate the utility of survey methodology for future DOTMLPF and HSI assessments, and to identify statistical techniques to analyze such data.

Savage-Knepshield, P., **Rice, V.J**., Butler, J., and **DeVilbiss, C**. (2006). Saving Soldiers: Combat Challenges in Iraq Spur Medical Innovations. Human Factors & Ergonomics Society Bulletin, 49(8), pp. 1-3.

No Abstract

Additional Publications by Soldier Performance Research Thrusts 1, 2, 3; and Research Area 4.2

CY2010/FY2011

Harrison, A., and Etienne-Cummings, R., (2010). High Dynamic Range Image Display Quality Assessment: An Ideal Observer," the IEEE International Conference on Digital Image Processing, Spring 2010, (under review).

Kalb, J.T. (2010), "Measurement and characterization of army impulsive noise sources", POMA and Program of 159th ASA/NOISE-CON meeting, Baltimore, MD Apr 2010.

Kalb, J.T. (2010). "A hearing protector model for predicting impulsive noise hazard", POMA and Program of 159th ASA/NOISE-CON meeting, Baltimore, MD Apr 2010.

Merritt, J., **CuQlock-Knopp, V.G.,** Kregel, M., **Wallace, S.,** & **Vaughan, B**. *Binocular Depth Acuity*. In Identifying Experts in the Detection of Improvised Explosive Devices (IED2), United States Army Research Institute for the Behavioral and Social Sciences Technical Report. (In Press).

Price, G. R. (2010). "Susceptibility to intense impulse noise: evidence from the Albuquerque dataset", POMA and Program of 159th ASA/NOISE-CON meeting, Baltimore, MD Apr 2010.

CY2009/FY2010

Abouchacra, K., **Letowski, T**. Koehnke,. J. and Besing, J. (2009). Clinical application of the Synchronized Sentence Set (S3). Proceedings of the 16th International Congress on Sound and Vibration, Krakow, Poland, compact disk, paper 352, 1-8.

Amrein, B., and **Letowski T,** (2009). The Environment for Auditory Research. Proceedings of the Acoustics Week in Canada (Canadian Acoustical Association) 2009 Conference, Ontario, Canada, **37**-3, 152-153.

Binseel, M., Kalb, J., and **Price, G. R.** (2009). Using the Auditory Hazard Analysis Algorithm for Humans (AHAAH) software, beta release W93e. Aberdeen Proving Ground, MD: U.S. Army Research Laboratory. (ARL-TR-4987)

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Fedele, P. D, and **Dorney, A. L.** (2009). Analysis of fatigue influence on the performance of networked Joint Biological Point Detection Systems' operators. Aberdeen Proving Ground, MD: U.S. Army Research Laboratory. (ARL-TN-368, limited distribution).

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McBride, M., **Weatherless, R., Mermagen, T., and Letowski, T.** (2009). Effects of hearing protection on speech communication. Proceedings of the 16th International Congress on Sound and Vibration, Krakow, Poland, compact disk, paper 48, 1-8

Melzer, J., Brozoski, F., **Letowski, T.**, Harding, T., and Rash, C. (2009). Guidelines for HMD design. In C. E. Rash, M. B. Russo, T. R. Letowski, and E. T. Schmeisser (Eds.), Helmet-mounted displays: Sensation, perception and cognition issues (pp. 805-848). Ft. Rucker, AL: U. S. Army Aeromedical Research Laboratory.

Mullins, L. (2009). Effects of viewpoint offset for use in the development of advances indirect view sensor systems. Aberdeen Proving Ground, MD: U.S. Army Research Laboratory. (ARL-TR-4775).

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CY2008/FY2009

Mullins, L. (2008). Development of indirect view sensor systems: Effects of viewpoint offset on human performance. Proceedings of the Army Science Conference, issue, pages

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POSTERS AND PRESENTATIONS

CY2009/FY2010

Presentations

Henry, P. (2009, May). Perception of Auditory Motion. United States Army Aeromedical Research Laboratory (USAARL) Seminar. Ft. Rucker, AL.,

Henry, P. (2009, March). Auditory Research at the U.S. Army Research Laboratory. Presented as part of a panel, "Essential Information for Research Audiologists", LTC Marjorie Grantham, moderator. Joint Defense/Veterans Audiology Conference 2009, Mesa, Arizona.

Myles, K. (2009). Head Tactile Communication. U.S. Army Research Laboratory Tactile Workshop, February 10-11, Aberdeen Proving Ground, MD.

Posters

Weatherless, R., Grantham, M., Kehring, K., Fedele, P. (2010) Interaction Between Simulated Hearing Loss and Navigation Task Performance, 3rd International Conference on Applied Human Factors and Ergonomics AHFE 2010 Poster Session, July 2010.

CuQlock-Knopp, V. G., Wallace, S., Karsh, R., Merritt, J., and Kregel, M. (2009, March). Video-based criterion measure. Poster presented at the Joint IED Defeat Organization (JIEDDO) Semi-annual Cross Briefs, University of Maryland, College Park. MD.

Hairston, D., Letowski, T., and McDowell, K. (2009, June-July). Examining cross-modal influence of the auditory brainstem response. Poster presented at the 10th International Multisensory Research Forum. New York, NY.

Norin, J., Emanuel, D., and **Letowski, T.** (2009, April). The effect of level-dependent hearing protection devices on speech communication in low level noise. Poster presented at the AAA AudiologyNOW 2009 Meeting, Dallas, TX.

Toll, L., Emanuel, D., **Letowski, T.,** and Pallett, S. (2009, April). Effect of static force on bone conduction test reliability. Poster presented at the AAA AudiologyNOW 2009 Meeting, Dallas, TX.

Vaughan, B., Kregel, M., Merritt, J**., CuQlock-Knopp, V. G.,** and **Wallace, S.** (2009, March). Binocular depth accuity. Poster presented at the Joint IED Defeat Organization (JIEDDO) Semi-annual Cross Briefs, University of Maryland, College Park. MD.

Other

CuQlock-Knopp, G., Davison, A., Karsh, R., Raglin, A., **Schweitzer, K., Vaughan, B.,** & **Wallace, S.** (2009). Improving Your Visual IED Detection. JIEEDO Tactical Pocket Reference Card.

CuQlock-Knopp, G., Davison, A., Karsh, R., Raglin, A., Schweitzer, K., **Vaughan, B.,** & **Wallace, S.** (2009). Identifying experts in the IED Detection. JIEEDO Tactical Pocket Reference Card.

2008

CuQlock-Knopp, G., Bender, E., Merritt, J., and **Smoot, J.,** (2008). The recognition of scene features in fused imagery versus unfused visible/near-infrared or long-wave infrared imagery. Military Sensing Symposia Specialty Group on Passive Sensors. Las Vegas (NV): February 4-7.

Grantham, M.A.M., and Letowski, T., (2008). The role of the audiologist on the battlefield. National Black Association for Speech, Language, and Hearing (NBALSH) conference, Crystal City, (VA): April 17.

Grantham, M.A.M. (2008). Mentoring. Military Audiology Short Course, Portland (OR): February 19.

Henry, P. (2008). Environment for Auditory Research (EAR): A new research facility at the Army Research Laboratory. Military Audiology Short Course, Portland (OR): February 18.

Jokel,C.; **Kalb, J.T.** (2008). The AHAAH model and hearing protection. Moab Conference/Workshop on the Effects of High Intensity Continuous and Impulse/Blast Noise on Humans. Moab (UT):

Kalb,J.T. (2008). Propagation of continuous and impulse noise. Moab Conference/ Workshop on the Effects of High Intensity Continuous and Impulse/Blast Noise on Humans. Moab (UT):

Monaco, W. (2008). Eye disease and treatment. In-Service Presented at Delaware Hospital for the Chronically Ill, May.

Monaco, W. (2008). Visual assessment and ocular disease management. Presentation to the Physician Assistant Program, Arcadia University, August.

Scharine, A. A., and **Mermagen, T.** (2008). Characterization of the Environment for Auditory Research (EAR) at the U.S. Army Research Laboratory. The 15th International Congress on Sound and Vibration, Daejeon, Korea: July 6-10.

Solberg, J., Stanard, T., **CuQlock-Knopp, G**., Ashworth, A., and Raglin, A. (2008). Evaluating visual detection of IEDs, 76th Military Operations Research Symposium. New London (CT): June 10-12.

2007

Binseel, M., Cave, K., and **Letowski, T.** (2007). Effectiveness of an improved Combat Arms Earplug. The 32nd Annual Conference of the National Hearing Conservation Association, Savannah (GA) February 15-17.

Cave, K. (2007) Army audiology: Update from operations in Iraq. The American Academy of Audiology 2007 Meeting. Denver (CO): April 18-21.

Mohananchettia, A., Cevher, V., **CuQlock-Knopp, G**., Chellappa, R., and Merritt, J. (2007). Hyperstereo algorithms for the perception of terrain drop-offs. SPIE Helmet- and Head-Mounted Displays X: Technologies and Applications Conference. Orlando (FL), April 10.

Scharine, A. A., MacDonald, J., Binseel, M. S., Mermagen, T., and Walsh, S. (2007). The effects of ear coverage and reflected sound on the localization of sound. The 153rd Meeting of the Acoustical Society of America. Salt Lake City (UT): June 4-8.

Tang, H., and **Letowski, T.** (2007). High-frequency hearing threshold measurements using insert earphones and warble signals. The 2007 Industrial Engineering Research Conference. Nashville (TN): May 19-23.

2006

Binseel, M., Cave, K. and Letowski, T. (2006). An evaluation of the acoustic properties of an improved combat arms earplug. The 4th Joint Meeting of the Acoustical Society of America and the Acoustical Society of Japan, Honolulu (HI), November 28 – December 2.

Cave, K. (2006). Combat Arms Earplug (CAE). The James Madison University 7th Annual Innovations in Clinical Communication Sciences Conference. Harrisonburg (VA): October 14.

Kalb, J. T., Bullock. C.D., Pucket, T. (2006) Design guidance from weapons noise criteria changes in MIL-STD-1474D. Joint Army Navy NASA Air Force Interagency Propulsion Committee. San Diego (CA): December 4-8.

MacDonald, J., Henry, P., Letowski, T. (2006). Spatial audio through a bone conduction interface. Podium presentation at the American Auditory Society Annual Meeting, Scottsdale, AZ: March 5-7.

MacDonald, J. A., and Tran, P. K. (2006). A sound localization algorithm for use in unmanned vehicles. American Association for Artificial Intelligence (AAAI) 2006 Fall Symposium on Aurally Informed Performance: Integrating Machine Listening and Auditory Presentation in Robotic Systems. Arlington (VA); October 13-15.

McBride, M., Letowski, T., and Tran, P. (2006). Comparison of bone conduction hearing thresholds in quiet and noise environments. The 4th Annual Meeting of the Society for Human Performance in Extreme Environments. San Francisco (CA), October 15-16.

Merritt, J. O., **CuQlock-Knopp, V. G.,** Paicopolis, P., **Smoot, J.,** Kregel, M., and Corona, B. (2006). Binocular depth acuity research to support he Modular Multi-Spectral Stereoscopic Night Vision Goggle. SPIE Helmet- and Head-Mounted Displays XI: Technologies and Applications Conference. Orlando (FL), April 17.

Scharine, A., Mermagen, T., and Letowski, T. (2006). Learning to identify acoustic environments from reflected sounds. The 47th Annual Meeting of the Psychonomic Society. Houston (TX): November 16-19. (Poster)

2005

Abouchacra, K., and **Letowski, T.** (2005). Localization of speech in non-directional and directional noise. The 17th American Academy of Audiology Convention Washington (DC): March 30 – April 2. (Poster)

Babeu, L. (2005). DPOAE and level-dependent hearing protection after small arms fire. The 30th Annual Conference of the National Hearing Conservation Association (NHCA). Tuscon (AZ): February 19-21.

Babeu, L. (2005). Sound recognition and level-dependent hearing protection in open field. Military Audiology Association Conference. Washington (DC): April 4-6.

Fluitt, K., Letowski, T., and Mermagen, T. (2005). Auditory and visual performance in an open field. The 149th meeting of the Acoustical Society of America. Vancouver, BC: May 16-20. (Poster)

MacDonald, J. A. (2005). An algorithm for the accurate localization of sounds. NATO Symposium on New Directions for Enhancing Auditory Effectiveness (HFM-123), Amersfoort, Netherlands: April 11-13.

McBride, M., **Letowski, T.,** and **Tran, P.** (2005). A search for an optimum vibrator location for bone conduction communication. The 2005 Institute of Industrial Engineers Annual Conference. Atlanta (GA): May 14-18.

Merritt, J. O., **CuQlock-Knopp, V. G.,** Kregel, M., **Smoot, J.,** and **Monaco, W.** (2005). Perception of terrain drop-offs as a function of L-R viewpoint separation in stereoscopic video. SPIE Helmet- and Head-Mounted Displays X: Technologies and Applications Conference. Orlando (FL), March 29.

Price, G. R. (2005). Auditory hazard assessment algorithm for humans, . Military Audiology Association Conference. Washington (DC): April 4-6.

Scharine, A. (2005). The acoustical effect of helmet design on auditory localization ability and sound attenuation. The 149th Meeting of the Acoustical Society of America. Vancouver (CA): May 16-20.

Scharine A. A., Henry P, and **Binseel M.** (2005). An evaluation of the communication assemblies and hearing protection systems under consideration for use in the Future Force Warrior ensemble. The ASNE Human System Integration Symposium on "Enhancing Combat Effectiveness through Warfighter Performance". Arlington (VA): June 20-22.

2004

Scharine A. (2004). The effect of hearing protection type on localization ability. The 3rd Auditory Perception, Cognition, Action and Memory (APCAM) Meeting. Minneapolis (MN), November 18-20.

CuQlock-Knopp G (2004). One of three opening speakers at the USDA-ARL-FDA Food & Nutrition Summer Institute, "From Science to Action Part II. Preparing the Nation for Health and Security." North Carolina Central University, Durham, N.C., June.

Babeu L, Binseel M, Garrett L, and **Letowski T.** (2004). Observation of the DPOAE after exposure to small arms. Military Audiology Short Course. Park City (UT): April 4-7.

Babeu L. (2004). Application of the Tanstheorectical Stages of Change to hearing conservation. Military Audiology Short Course. Park City (UT): April 4-7.

Babeu L. (2004). The effects of non-linear hearing protection on distortion product otoacoustic emissions (DPOEs). American Statistical Association (Chesapeake Chapter) Meeting. Aberdeen (MD): March 23.

Henry P and **Letowski T.** (2004). Auditory localization across distance. The American Auditory Society Annual Meeting, Scottsdale (AZ): March 7-9.

Babeu L and **Binseel M.** (2004). Sound localization with passive level-dependent earplugs. The 29th Annual Conference of the National Hearing Conservation Association (NHCA). Seattle (WA): February 19-21.

Price, G. R. (2004) Predicting human performance as a function of changes in hearing. Invited talk to Acoustic, Optical, and Multi-Sensory Device Workshop, San Antonio (TX): January 14-15.

Price GR. (2004). Using AHAAH to calculate risk from intense sounds. Acoustic, Optical, and Multi-Sensory Device Workshop. San Antonio (TX): January 14-15.

2003

Henry P and Letowski T. (2003). Auditory localization for various loudspeaker-to-listener distances. The 2nd Auditory Perception, Cognition, Action, and Memory (APCAM) Meeting, Vancouver (BC), November 4-6.

Scharine A. (2003). Level Dependent Modeling of the Perception of Sounds that Vary in Intensity and Frequency. The 2nd Auditory Perception, Cognition, Action and Memory (APCAM) Meeting. Vancouver (BC), November 4-6.

MacDonald JA. (2003). An ideal observer approach to temporal masking. The 2nd Annual Auditory Perception, Cognition, Action, and Memory (APCAM) Meeting, Vancouver (BC): November 4-6.

Henry P. (2003). Factors affecting auditory localization accuracy in the horizontal plane. The 4th Annual Innovations in Clinical Communication Sciences Conference, James Madison University. Harrisonburg (VA): October 18. Invited talk.

CuQlock-Knopp G (2003). "Ideas for National Ergonomics Month (NEM) Based Upon Experiences of the HFES Diversity Committee," at the Annual Human Factors & Ergonomics Society Meeting in Denver, October.

Babeu L, Binseel M, Mermagen T, and **Letowski T**. (2003). Sound localization with the Combat Arms Earplug. The 6th Annual Force Health Protection Conference. Albuquerque (NM): August 11-17.

Myles K, Karsh R, CuQlock-Knopp G, and **Kalb J**. (2003). Action-Based Target Acquisition Methods for Use in Urban Environments. The 71st Military Operations Research Society (MORS) Conference. Quantico (VA): June 10-13.

2002

Maddux J, Halprin M, Schnerider S, Thompson M, Schulz T, Dobie R, **Vause N**, and Dennis K. (2002). Is Hearing Loss a Significant Health Condition? OSHA's Controversy! The 2002 OSHA Annual Conference. Atlanta (GA): November 21-24.

Scharine A. (2002). The contribution of integral processing of frequency and intensity to auditory scene analysis. The 1st Auditory Perception, Cognition, Action, and Memory (APCAM) Meeting. Kansas City (MO), November 20-22**.**

2001

Vause N and LaRue A. (2001). Creating our own casualties - Auditory effects of anti-tank weapons fire without hearing protection - A clinical case study. International Military Noise Conference. Edgewood (MD): April 24-25.

Vause N, Froman F, Todd J, and Dooley M. (2001). Emerging communication technologies and double hearing protection. International Military Noise Conference. Edgewood (MD): April 24-25.

Price R and **Kalb J.** (2001). New perspectives on protecting hearing from intense impulse noise. International Military Noise Conference. Edgewood (MD): April 24-25.

Kalb J and **Price R.** (2001). Firing weapons from enclosures: Predicting the hearing hazard. International Military Noise Conference. Edgewood (MD): April 24-25.

Kalb J. (2001). Firing weapons from enclosures: Predicting the wave form. International Military Noise Conference. Edgewood (MD): April 24-25.

Vause N and **Letowski T.** (2001). Dou you hear what I hear? Army auditory engineering research. The AAA 2001 Meeting. San Diego (CA): April 17-22.

2000

Shilling R, Storms R, and **Letowski T.** (2000). Applications of spatial audio displays within attack rotary wing aircraft. The 22nd Army Science Conference. Baltimore (MD), December 12-13. Poster.

Vause N, Abouchacra K, Letowski T, and Resta E. (2000). Spatial-audio (3-D) displays improve speech communication in the command and control (C2V) vehicle. The 22nd Army Science Conference. Baltimore (MD), December 12-13. Poster.

Abouchacra K and Letowski T. (2000). Speech recognition performance with non-spatialized and spatialized sound presented through helmets. The 14th Science Meeting of the National Council for Scientific Research (NCSR). Beirut (Lebanon): November 23-25.

Ghirardelli T, Vaughan B, and **Karsh R.** (2000). Cuing for attention to military targets in naturalistic scenes. The 41st Annual Meeting of the Psychonomics Society. New Orleans (LA): November.

Vause N, Resta E, **Mermagen T**, and **Letowski T**. (2000). Pitch and loudness perception abilities of musicians and non-musicians. Toronto 2000 Conference [Society for Music Perception and Cognition]: Toronto (Canada): November 1.

Vause N, Ferguson G, Mermagen T, and **Letowski T.** (2000). Do you hear what I hear? This land is mine land. The UXO/Countermine Forum, Anaheim (CA): May 2-4. Poster.

Shilling R and **Letowski T.** (2000). Using spatial audio displays to enhance virtual environments and cockpit performance. NATO Conference "What is Essential for Virtual Reality to Meet Military Human Performance Goals", The Hague (The Netherlands), April 8-9,

Ferguson L, Vause N, Mermagen T, and **Letowski T.** (2000). Audio interface issues in hand-held mine detectors. Detection and Remediation Technologies for Mines and Mine-like Targets V Conference [International Society for Optical Engineering (SPIE)], Orlando (FL), April 4-6.

Shilling R, **Letowski T**, and Storms R. (2000). Spatial auditory displays for use within Attack Rotary Wing Aircraft. ICAD 2000 Meeting [International Committee on Auditory Displays], Atlanta (GA), April 2-5.

Chapters

Rash, C. E, Russo, M. B., **Letowski, T. R.**, and Schmeisser, E. T. (Eds.) (2009). Helmet-mounted displays: Sensation, perception and cognition issues. Ft. Rucker, AL: U. S. Army Aeromedical Research Laboratory.

Ghirardelli, T. G., and **Scharine, A. A.** (2009). Auditory-visual interactions. In C. E. Rash, M. B. Russo, T. R. Letowski, and E. T. Schmeisser (Eds.), Helmet-mounted displays: Sensation, perception and cognition issues (pp. 599-618). Ft. Rucker, AL: U. S. Army Aeromedical Research Laboratory.

Maronrooge, S., Emanuel, D., and **Letowski, T.** (2009). Basic anatomy of the hearing system. In C. E. Rash, M. B. Russo, T. R. Letowski, and E. T. Schmeisser (Eds.), Helmet-mounted displays: Sensation, perception and cognition issues (pp. 279-306). Ft. Rucker, AL: U. S. Army Aeromedical Research Laboratory.

Melzer, J., Brozoski, F., **Letowski, T.,** Harding, T., and Rash, C. (2009). Guidelines for HMD design. In C. E. Rash, M. B. Russo, T. R. Letowski, and E. T. Schmeisser (Eds.), Helmet-mounted displays: Sensation, perception and cognition issues (pp. 805-848). Ft. Rucker, AL: U. S. Army Aeromedical Research Laboratory.

Myles, K. P. and **Binseel, M. S.** (2009). Exploring the tactile modality for HMDs. In C. E. Rash, M. B. Russo, T. R. Letowski, and E. T. Schmeisser (Eds.), Helmet-mounted displays: Sensation, perception and cognition issues (pp. 849-876). Ft. Rucker, AL: U. S. Army Aeromedical Research Laboratory.

Scharine, A. A., and **Letowski, T. R.** (2009). Auditory conflicts and illusions. In C. E. Rash, M. B. Russo, T. R. Letowski, and E. T. Schmeisser (Eds.), Helmet-mounted displays: Sensation, perception and cognition issues (pp. 579-598). Ft. Rucker, AL: U. S. Army Aeromedical Research Laboratory.

Scharine, A. A., Letowski, T. R., and **Cave, K.** (2009). Auditory perception and cognitive performance. In C. E. Rash, M. B. Russo, T. R. Letowski, and E. T. Schmeisser (Eds.), Helmet-mounted displays: Sensation, perception and cognition issues (pp. 391-490). Ft. Rucker, AL: U. S. Army Aeromedical Research Laboratory.

Tran, P, Amrein, B. E., and **Letowski, T. R.** (2009). Audio helmet-mounted displays. In C. E. Rash, M. B. Russo, T. R. Letowski, and E. T. Schmeisser (Eds.), Helmet-mounted displays: Sensation, perception and cognition issues (pp. 175-236). Ft. Rucker, AL: U. S. Army Aeromedical Research Laboratory.

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2010

Crowell, H.P., Milner, C.E., Hamill, J., and Davis, I.S. (2010). Reducing Impact Loading During Running With the Use of Real-Time Visual Feedback. *Journal of Orthopaedic & Sports Physical Therapy*, 40(4), 206-213.

Cruz-Neira, C., Springer, J.P., Reiners, D., Supported by Human Research Engineering Directorate Dismounted Warrior Branch. (2010). Let Them Move: Incorporating Physical Walking into a Virtual Environment. *Proceedings of the Engineering of Virtual Reality*. San Jose, CA.

Harper, W.H., Ortega, S.V., and Wiley, PW. (In Review). *Shooting Performance Characterization of 5.56 mm Subcompact Weapons*. Aberdeen Proving Ground, MD: U.S Army Research Laboratory.

2009

Harper, W., and Wiley, P. (2009). Determining thumb control location for vertical foregrips of assault rifles. Proceedings of the 14th Annual International Conference on Industrial Engineering. Anaheim, CA.

LaFiandra, M. (2009). The Working Back: A Systems View [Review of the book The working back: a Systems View]. Ergonomics in Design 17 (3), 30.

Statkus, M.J., **Salvi, L.,** and Peloquin, A. (2009). *Dismounted Warrior Performance Data: Moving Targets in Close Combat Data Collection Effort.* (NATICK/TR-09/016L). U.S. Army Natick Soldier Research, Development and Engineering Center.

Subramanian, A., Mital, A., Ware, B., **LaFiandra, M.,** Kattel, B., and Fernandez, J., ed. (2009). The 14th Annual International Conference on Industrial Engineering - Theory, Applications and Practice.

Wiley, P.W., Scribner, D.R., and Harper, W.H. (2009). Evaluation of wearable information systems during route reconnaissance and assault missions using commercial games. *Proceedings of the 14th Annual International Conference on Industrial Engineering*. Anaheim, CA.

2008

Faughn, J.A. (2008). *United States Patent No. 7,415,929.* Washington, DC: U.S. Patent and Trademark Office.

Garrett, A.W., Zaky, A., and **Salvi, L.** (2008). *Documentation of the Close Combat Reflexive Firing Experiment in Support of the Soldier Focused Area Collaborative Team, Critical Research Area*. (AMSAA TR-2008-34). Army Materiel Systems Analysis Agency.

Harper, W., LaFiandra, M. and Wiley, P. (2008). The effect of weapon mass and center of mass on shooting performance with an assault rifle. *Proceedings of the 13th Annual International Conference on Industrial Engineering.* Las Vegas, NV.

LaFiandra, M. (2008) Methods, Models & Technology for Lifting Biomechanics. In *Handbook For Digital Human Modeling: Research for Applied Ergonomics and Human Factors Engineering*. V. Duffy (Eds.).

LaFiandra, M., Harper, W., and Wiley, P. (2008).The effect of weapon mass and center of mass on aiming movement. *Proceedings of the 13th Annual International Conference on Industrial Engineering.* Las Vegas, NV.

LaFiandra, M.E. (2008). *A Tool for Calculating the Center of Mass and Moment of Inertia of Small Arms Weapons.* (ARL-TR-4517). Aberdeen Proving Ground, MD: U.S Army Research Laboratory.

Ortega, S.V., Garrett, L., and Burcham, P. (2008). *Soldier Performance With the M240 Lightweight Machine Gun - Phase II.* (ARL-TR-4561). Aberdeen Proving Ground, MD: U.S Army Research Laboratory.

Pohl, M.B., **Crowell, H.P.,** and Davis, I.S. (2008). What Strategies Do Runners Utilize to Reduce Tibial Acceleration Following A Gait Retraining Protocol? *Medicine & Science in Sports & Exercise*, 40, S19.

2007

Boynton, A.C., Rice, V.J., DeVilbiss, C.A., and **Faughn, J.A.** (2007). An Evaluation of the Issue and Wearing of the Personnel Armor System for Ground Troops (PASGT) and Advanced Combat Helmets (ACH). (ARL-TR-4225). Aberdeen Proving Ground, MD: U.S Army Research Laboratory.

Boynton, A.C., and **Faughn, J.A.** (2007). Quantification of Correct Wear of Properly Fitted Advanced Combat Helmets (ACH) and Personnel Armor System for Ground Troops (PASGT) Helmets. (ARL-TR-4020). Aberdeen Proving Ground, MD: U.S Army Research Laboratory.

Jarboe, N., and **Faughn, J.A.** (2007). A Human Factors Assessment of Female Soldier's Ability to Pull Hand Grenade Fuze Safety pins and to Throw Inert M67 Hang Grenades. (ARL-TR-4311). Aberdeen Proving Ground, MD: U.S Army Research Laboratory.

LaFiandra, M., Harman, E., Cornelius, N., Frykman, P., Gutekunst, D., and Nelson, G. (2007). The Effects of the Personal Armor System for Ground Troops (PASGT) and the Advanced Combat Helmet (ACH) With and Without PVS-14 Night Vision Goggles (NVG) on Neck Biomechanics During Dismounted Soldier Movements. (T07-09). United States Army Research Institute of Environmental Medicine Technical report.

Ortega, S.V., Garrett, L., and Harper, W.H. (2007). Soldier Performance with the M240E6 Lightweight Machine Gun. (ARL-TR-4114). Aberdeen Proving Ground, MD: U.S Army Research Laboratory.

Ortega, S.V., Harper, W.H., and Panozzo, P.R. (2007). Training and Qualification Assessment of Soldiers with the MK19 Grenade Machine Gun While the Soldiers Were Using a Standard and Mixed Belt of 40-mm Ammunition. (ARL-TR-4076). Aberdeen Proving Ground, MD: U.S Army Research Laboratory.

Ortega, S.V., Garrett, L., and Burcham, P.M. (2007). Mobility, Portability, and Human Factors Investigation of an Improved 81-mm Lightweight Mortar System Prototype: Phase II. (ARL-TR-4111). Aberdeen Proving Ground, MD: U.S Army Research Laboratory.

Wilson, R. Faughn, J., and Harper, B. (2007). Evaluation of Crew's Ability to Ingress and Egress Selected U.S. Army Wheeled and Tracked Vehicles While Carrying a Personal Defense Weapon. Customer report: prepared for PM Individual Weapons.

2006

Boynton, A.C., and Crowell, H.P. (2006). *A Human Factors Evaluation of Exoskeleton Boot Interface Sole Thickness.* (ARL-TR-3812). Aberdeen Proving Ground, MD: U.S Army Research Laboratory.

Crowell, H.P., and Davis, I.S. (2006). Between day reliability of accelerometry. *Medicine & Science in Sports & Exercise*. 38(5) Supplement: S256.

Crowell, H.P., Faughn, J.A., Tran, P.K., and **Wiley, P.W.** (2006). *Improvements in the omni-directional treadmill: Summary report and recommendations for future development.* (ARL-TR-3958). Aberdeen Proving Ground, MD: U.S Army Research Laboratory.

Crowell, H.P., and Davis, I.S. (2006). Reducing lower extremity loads through gait retraining using real-time feedback methods. *Proceedings of the 30th Annual Meeting of the American Society of Biomechanics.* Virginia Tech, Wake Forest.

Garrett, L., Harper, W.H., Ortega, S.V., and White, T.L. (2006). *Joint Service General Purpose Mask (JSGPM) Human Systems Integration (HIS) Evaluation: Comfort and Vision Correction Insert Stability Evaluation.* (ARL-TR-3900). Aberdeen Proving Ground, MD: U.S Army Research Laboratory.

Garrett, L., Jarboe, N., Patton, D.J., and Mullins, L.L. (2006). The Effects of Encapsulation on Dismounted Warrior Performance. (ARL-TR-3789). Aberdeen Proving Ground, MD: U.S Army Research Laboratory.

Woods, R.J., Statkus, M.J., and **Salvi, L.** (2006). *Human Science/Modeling and Analysis Data Project: Urban Canyon Street Flight and Blufor in Defense Data Collection Effort*. (Natick/TR-00/009L). U.S. Army Natick Soldier Research, Development and Engineering Center.

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Appendix B. Awards and Honors

This appendix appears in its original form without editorial change.

Human Robot Interaction

Funding:

- 2010 Director's Research Initiative (Yr2): RoboLeader: Dynamic Re-tasking for Persistence Surveillance in an Urban Environment Using Robot-to-Robot Control (**Jessie Chen, Michael Barnes,** and Zhihua Qu)
- 2009 Director's Research Initiative (Yr 2): Extreme Scalability: Designing Interfaces and Algorithms for Soldier-Robotic Swarm Interaction (**Ellen Haas**, MaryAnn Fields, **Susan Hill, & Chris Stachowiak**)
- 2009 Director's Research Initiative (Yr1): RoboLeader: A Surrogate for Enhancing the Human Control of a Team of Robots (**Jessie Chen, Michael Barnes,** and Zhihua Qu)
- 2009 Robotics Directors Strategic Initiative (**Troy Kelley and Eric Avery**)
- 2008 Robotics Strategic Technology Initiative (**Troy Kelley and Keryl Cosenzo**)
- 2008 Director's Research Initiative (Yr 1): Extreme Scalability: Designing Interfaces and Algorithms for Soldier-Robotic Swarm Interaction (**Ellen Haas,** MaryAnn Fields, **Susan Hill, & Chris Stachowiak**)
- 2003 Directors Research Initiative: A fully autonomous system capable of learning appropriate battlefield behaviors (**Troy Kelley**)
- 2002 Director's Research Initiative: Dynamic Visualization of Co-evolving Adversaries in Small-Scale Contingencies (**Michael Barnes** and David Hillis)

Honoraries:

- 2009 3rd Place Best Paper Award AUVSI Conference, Robotics Collaboration Army Technology Objective Capstone Soldier Experiment - Unmanned System Mobility (Jillyn Alban, **Keryl Cosenzo**, Tony Johnson, Shawn Hutchins, Jason Metcalfe, and Erin Capstick)
- 2007 Best Paper Award (Runner Up) ACM/IEEE Conference on Human-Robot Interaction (**Susan G. Hill** and Barry Bodt)

Human System Integration

Funding:

- 2010 Program Execute Office Integration $100K Soldier Workload Analysis of Infantry Platoon with Increment 1 Assets **(Mitchell)**
- 2010 Army Test and Evaluation Center $75K Soldier Workload Analysis for Joint Light Tactical Vehicle **(Mitchell)**
- 2009 PM PEO GCS - PM FCS $70K Soldier Workload Analysis Infantry Squad **(Mitchell)**
- 2009 Joint Warfighter Test & Technology $70K Soldier Workload Coordination **(Mitchell)**
- 2009 PM Abrams Modernization $105K Abrams Crew Workload Analysis **(Mitchell)**
- 2008 PM PEO GCS - PM FCS $10K Soldier Workload Analysis Common Controller **(Mitchell)**

- 2008 Combined Test Organization $70K **(Mitchell)**
- 2008 LOG FACT grant - "Modular Simulation Component to Predict Combat Damage Impacts" – $275,000 **(Samms)**
- 2007 JIEDDO $76K RECCE Crew Soldier Workload Analysis **(Mitchell)**
- 2006 BAE $55K Manned Ground Vehicle (MGV) Common Crew Modeling **(Mitchell)**

Honorary:

- 2009 Army Small Business Innovative Research (SBIR) achievement award for SBIR topic A02-052 - ATLAS: A Generalized Maintenance Modeling and Simulation Tool Suite **(Grazaitis)**
- 2008 Human Factors and Ergonomics Society Systems Development Technical Group David Meister Best Paper Award for paper, "United We Stand: Using Multiple Tools to Solve a Multi-dimensional Problem" **(Mitchell)**
- 2008 MANPRINT Practitioner of the Year, Special Achievement Award - Awarded for early, rapid and detailed engineering assessments of the MRAP seat and restraint systems to directly address concerns expressed by Soldiers and Marines in the field. **(Kozycki)**
- 2008 MANPRINT Technology Research and Development or Studies Practitioner of the Year **(Lockett)**
- 2004 Army Material Command (AMC) Systems Analysis Awards - Small Group Category **(Mitchell, Samms &** Henthorn**)**
- 2004 AMC Nominee for the Dr. Wilbur B. Payne Memorial Award for Excellence in Analysis - Small Group Category **(Mitchell, Samms &** Henthorn**)**

Patents:

- Co-developed with **Mr. Jim Faughn**, ARL\HRED, an improved emergency egress/seatbelt extraction tool known as the "Lighted Aircrew Survival Egress Knife" (LASEK). Invention disclosure was submitted to the Invention Evaluation Committee (IEC) and was accepted and received docket number ARL 09-38. Disclosure is now in process for US Patent Application.

Social/Cognitive Network Science

Funding:

- 2008- 2011 US/UK International Technology Alliance in Network and Information Sciences, US Government Technical Area 4 Lead - $90,000/yr. (**Giammanco**)
- 2009 – 2010 Congressional Program, Conglomerating Networked Telemetry to Raise Understanding of Collaborative Teams (CONSTRUCT), Collaborative Alliance Manager - $27,000 (**May**)
- 2010 – 2011 Congressional Program, Conglomerating Networked Telemetry to Raise Understanding of Collaborative Teams (CONSTRUCT) Training Program, Collaborative Alliance Manager - $56,000 (**May**)
- 2009 – Present DARPA Deep Green - Human Centered System Design and Assessment (**Hansberger**)
- 2008 DARPA COMPOEX (Conflict Modeling, Planning, and Outcomes experimentation Program) - Human Centered System Design and Assessment (**Hansberger**)

- 2008 – 2010 Joint Forces Command Virtual Collaboration Environment for Whole of Society Crisis Response - Socio-technical system design and social network analysis. (**Hansberger**)
- Max Planck Society awarded fellowship (6th Schloessmann Seminar on the Cognitive Neuroscience of Human Ontogeny) (**Buchler**)

Honorary:

- Finalist and second place award in the "Federal Virtual World Challenge" for the design of the Virtual Collaboration Environment for Crisis Response – 2010 (**Hansberger**)
- US Army Combined Arms Center, Battle Command Battle Lab, Ft. Leavenworth, KS, Certificate of Appreciation in support of Omni Fusion 2009 (**Giammanco**)

Neuroscience

Funding:

- 2010 Army Research Laboratory Director's Strategic Initiative - $500,000 (**McDowell,** Dai, **Ries, Kerick**)
- 2010 ICB Award - $100,000 (**McDowell, Larkin**)
- 2010 – 2012 Science & Mathematics for Research Transformation (SMART) Fellowship – $150,000 (**Rawal**)
- 2009 Army Research Laboratory Director's Strategic Initiative - $500,000 (**McDowell,** Schmeisser, Edelstein, **Larkin, Maxwell)**
- 2009 Army Research Office Infrastructure Award - $170,000 (Schmeisser, **McDowell**)
- 2009 - 2011 Office of Naval Research, "Advanced Control for Improving Vehicle Mobility and Safety" - $730,000 (**Oie**)
- 2009 – Current: Oak Ridge Associated Universities Partnership Postdoctoral Fellowship - $120,000 (**Capó**)
- 2009 - 2010 Oak Ridge Associated Universities Partnership Postdoctoral Fellowship - $150,000 (**Lance**)
- 2008 – Current: Authored successful funding requests to increase the Army Research Laboratory's in-house neuroscience mission funding by ~$2,000,000-$4,000,000 per year
- 2008 Army Research Laboratory Strategic Technology Initiative – $500,000 (**Kerick, Oie, Davis,** Schmeisser, **McDowell, Maxwell**)
- 2008 – 2009 Oak Ridge Associated Universities Partnership Postdoctoral Fellowship - $150,000 (**Hairston**)
- 2007 Army Research Laboratory Strategic Technology Initiative – $650,000 (**Kerick,** Schmeisser, Edelstein, Nasrabadi, **McDowell, Oie, Davis**)
- 2007 - 2012 Science & Mathematics for Research Transformation (SMART) Fellowship – $375,000 (**Yu**)
- 2007 - 2011 Science & Mathematics for Research Transformation (SMART) Fellowship – $300,000 (**Whitaker**)
- 2007 – 2009 Science & Mathematics for Research Transformation (SMART) Fellowship – $150,000 (**Vettel**)
- 2007 - 2008 Oak Ridge Associated Universities Partnership Postdoctoral Fellowship

- $50,000 (**Judkins**)

- 2003 National Research Council Postdoctoral Fellowship - $85,000 (**Kerick**)

Honorary:

- 2009 Army Research and Development Achievement Awards (Nunez, **Davis,** Paul, Alban, **McDowell**)
- 2009 Army Research and Development Achievement Awards (Schoenherr, Jaster, **Davis,** Theisen)
- 2009 Department of the Army Official Commendations (**Davis, Haas, Hairston, Kerick, Larkin, Maxwell, McDowell, Oie, Ries, Smith, Vettel**)
- 2009 Army Modeling and Simulation Award (Paul, **Davis, Larkin**)
- 2008 Department of the Army Certificate of Achievement (**Davis**)
- 2007 Army Research and Development Achievement Awards (**McDowell,** Nunez, **Perala, Sterling**)
- 2006 U.S. Tank Automotive, Research, Development, and Engineering Center Outstanding Service Award (**McDowell**)
- 2004 Army Research and Development Achievement Awards (**Kerick, Wiley, Scribner, Kelly**)

Soldier Performance

Funding:

- 2000: Medical Surveillance of Musculoskeletal Injuries among Active Duty Personnel at Fort Sam Houston. Received: $92,010. **V.J. Rice** and M.Z. Mays.
- 2000: Early Intervention Initiative. Received: $128,904. **V.J. Rice** and M.Z. Mays.
- 2001: Identifying the Physical Demands of Military Occupational Specialties. Received: $214K. (**V.J. Rice** and M.S. Lopez)
- 2004 - 2005 National Research Council Post-doctoral Associateship awarded to **Daniel Cassenti**
- FY05 DRI: Cognitive Task Demands of the Future Force: Development and Validation of a Physiological Metric
- FY 2005: Investigation of Adult Symptoms of Attention Deficit and Hyperactivity Disorder among 91-W Soldiers attending Advanced Individual Training at Ft. Sam Houston: $145K from Medical Research and Materiel Command, Occupational Performance Division (**Rice**).
- FY06 DRI: Cognitive Task Demands on the Future Force: Psychophysiological Correlates of Prioritization and Strategy.
- 2005 – 2008 ARL Director's Facilities Upgrade Award: Environment for Auditory Research - $2,700,000 (**Amrein, Letowski**)
- FY 2006-2007: The Relationship of Attention Deficit Disorder Symptoms and Timing Ability to Advanced Individual Training Performance of Healthcare Specialists, funded by The Telemedicine and Advanced Technology Research Center (TATRC) of the Medical Research and Material Command (MRMC). $195K, 1 ½ yr (**Rice**).
- FY 2009, 2008: The Investigation of Emerging Technologies and Field Expedient Methods For Screening Traumatic Brain Injury And Tracking Initial Recovery. 2009:

$741K, 2008: ~$670K (**Rice, Alfred, DeVilbiss, Bateman, Boykin).**

- 2009 – 2010 Oak Ridge Associated Universities Partnership Postdoctoral Fellowship - $150,000 (**Gaston**)
- 2010 – 2011 Oak Ridge Associated Universities Partnership Postdoctoral Fellowship - $150,000 (**Pollard**)
- 2010 – 2012 Science & Mathematics for Research Transformation (SMART) Fellowship – $150,000 (**Vella**)
- FY 2010, 2009, 2008, 2007, 2006 and 2005: Academic Attrition Among 91-W Soldier attending Advanced Individual Training at Ft. Sam Houston: $250K/year/6 years from the AMEDDC&S, $250K/year/2 years from the Army Research Laboratory – Human Research and Engineering Directorate (**Rice**).

Honorary:

- 2009 Department of the Army Official Commendations (**Cassenti, Cosenzo, Headley, LaFiandra, Rice, Vaughan, White**)
- 2009 Department of the Army Research and Development Award (**Myles & Kalb**) for Efficacy of a Head-Mounted Tactile Display for Soldier Performance [nominated]
- 2009 Department of the Army Research and Development Award (**Amrein & Letowski**) for Development of the Environment for Auditory Research. [nominated]
- Thompson Award for Outstanding Research (non-orthopedic division): Cooper, D.B., Mercado-Couch, J.M., Critchfield, M.S., Kennedy, J., DeVilbiss, C.A., Bowles, A.O., Cullen, M., and Gaylord, K.M., Factors predicting cognitive dysfunction following explosion injuries in OIF/OEF service members: Traumatic severity, mild traumatic brain injury (mTBI), medication effects, and psychiatric co-morbidity., 11th Annual George E. Omer, Jr. Research and Alumni Lectureship, 2009.
- AOTA Service Commendation, April 2007 for work as Chair, Work and Industry Ad Hoc Workgroup, 2006: **Valerie J. Berg Rice**
- **Raymond M. Bateman**, Ph.D. Superior Civilian Service Award, 2005.
- USA Medical Command Office of Equal Employment Opportunity Program Certificate of Recognition as AMEDDC&S nominee for MEDCOM Science, Technology, Engineering, Mathematics Role Model Award, 2006: **Valerie J. Berg Rice**
- Annual Dr. Wilbur B. Payne Memorial Award for Best Large Group research: "Vice Chief of Staff, Army Combat Helmet Study", 2005: **Boynton, A.C**., **Rice, V.J., DeVilbiss, C.A., and Faughn, J.A.** (2007). An evaluation of the issue and wearing of the personnel armor system for ground troops (PASGT) and advanced combat helmet (ACH). Technical Report No. ARL-TR-4225. U.S. Army Research Laboratory, Human Research and Engineering Directorate, Aberdeen Proving Ground, MD 21005-5425.

Appendix C. Additional Publications Authored by U.S. Army Research Laboratory Major Laboratory Program Groups

This appendix appears in its original form without editorial change.

Human Robot Interaction

Journal Articles and Book Chapters:

In Press

Prewett, M. S., Johnson, R., Saboe, K., Coovert, M., **Elliott, L**. (in press). Managing workload in human–robot interaction: A review of empirical studies. Computers in Human Behavior Saboe, K. N., Johnson, R. C., Prewett, M. S.,

2010

Barnes M.J. & Evans A.E. (2010). Soldier-Robot Teams in Future Battlefields: An Overview. In M.J. Barnes & F.G. Jentsch (eds.) *Human-Robot Interaction in Future Military Operations* (pp. 9-30) Farnham: Ashgate Publishing

2007

Chen, J. Y. C. & Thropp, J. E. (Nov. 2007). Review of Low Frame Rate Effects on Human Performance. *IEEE Transactions on Systems, Man, and Cybernetics--Part A: Systems and Humans,* vol. 37, no. 6, 1063-1076.

Chen, J. Y. C., **Haas, E. C**. & **Barnes, M. J**. (2007). Human Performance Issues and User Interface Design for Teleoperated Robots. *IEEE Transactions on Systems, Man, and Cybernetics--Part C: Applications and Reviews,* vol. 37, no. 6, 1231-1245.

2006

Oron-Gilad, T., **Chen, J. Y. C**, & Hancock, P. A. (2006). Remotely Operated Vehicles (ROVs) from the Top-Down and the Bottom-Up. In N. Cooke, H. L. Pringle, H. K. Pedersen, & O. Connor (Eds). *Human Factors of Remotely Operated Vehicles*. *Advances in Human Performance and Cognitive Engineering.* Oxford, UK: Elsevier.

Barnes, M.J., **Hunn, B.P** & **Pomranky, R**. (2006). Modeling and Operator simulations for early development of Army UAV systems: Methods and results In N. J. Cooke, H. Pringle, H. Pedersen, & O. Connor (Eds.), *Human Factors of Remotely Piloted Vehicles* (pp. 59-70). Amsterdam, NL: Elsevier.

Technical Reports:

2009

Childers, M.A., Bodt, B.A., **Hill, S.G**., Camden, R., Dean, R., Dodson, W., Sutton, L., and Sapronov, L. (2009). *Unmanned Ground Vehicle Tactical Behaviors Technology Assessment* (ARL-TR-4698). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory

2007

Sterling, B.S., **Perala, C. H**., & Blaske, S. F. (2007). Workload and stress of crews operating future manned vehicles (ARL Tech. Rep. ARL-TR-4023). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

Sterling, B.S. & **Perala, C. H**.(2007). Workload, stress, and situation awareness of Soldiers who are controlling unmanned vehicles in future urban operations (ARL Tech. Rep. ARL-TR 4071). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

Sterling, B.S. & **Perala, C. H.** (2007). Controlling unmanned systems in a simulated counter-insurgency environment (ARL Tech. Rep. ARL-TR-4145). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

2006

Chen, J. Y. C., **Haas, E. C., Pillalamarri, K**., & Jacobson, C. N. (July 2006). Human Robot Interface: Issues in Operator Performance, Interface Design, and Technologies (ARL Tech. Rep. ARL-TR-3834). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

Sterling, B.S., & Jacobson (2006). Examination of human factors in networked sensors in live and virtual environments (ARL Tech. Rep. ARL-TR-3734). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

Proceedings Papers:

2010

Cosenzo, K. & **Barnes, M**. (2010). Human Robot Interaction Research For Current and Future Military Applications: From the Laboratory to the Field. *Proceeding of the Unmanned Sytems Technology Conference XII (SPIE Defense, Security, & Sensing),* Orlando, FL.

2009

Coovert, M., **Elliott, L**. Human-Robot Interaction (HRI) (2009). In *Proceedings of the Human-Robot Interaction ,2009,* Santa Monica, CA. Presentation.

Coovert, M., **Elliott, L**. Cognitive and Task Demands for a Prototypical Robot Operator: Specifications from O*NET. In *Proceedings of the Human-Robot Interaction,2009,* Santa Monica, CA. Presentation.

Johnson, R., Prewett, M., Saboe, K., **Elliott, L.** Coovert, M. Autonomy and Automation Reliability in Human-Robot Interaction: A Qualitative Review. In *Proceedings of the Human-Robot Interaction,2009,* Santa Monica, CA. Presentation.

Prewett, M., Johnson, R., Saboe, K., **Elliott, L.**, Coovert, M. (2009). Workload in Human-Robot Interaction: A review of manipulations and outcomes. Proceedings of the 2009 Annual Meeting of the Human Factors and Ergonomics Society.

2008

Childers, M.A., Bodt, B.A., **Hill, S.G.,** and Camden, R. (2008). *The impact of multilevel path planning on unmanned ground vehicle tactical behavior.* 2008 Army Science Conference, Dec 1-4, 2008, Orlando, FL.

Cosenzo, K.A, **Pomranky, R**., Capstick, E. (2008). Impact of Advanced Display Features on Situation Awareness, Workload and Performance of Complex Military Tasks. *Proceedings of the Human Factors and Ergonomics Society's* 52nd Annual Meeting, New York, NY, CD-ROM.

2007

Childers, M.A., Bodt, B.A., **Hill, S.G.,** Dean, R.M., Dodson, W.F., and Sutton, L.G. (2007). Assessing the impact of bi-directional information flow in UGV operation: A pilot study. *Proceedings of PerMIS 2007*, Aug 2007, Gaithersburg, MD. (also published as ARL-TR-4411).

2006

Barnes, M. J., **Chen, J. Y. C**., Jentsch, F., & **Haas, E**. (2006). Soldier interactions with aerial and ground robotic systems in future military environments. In Proceedings of *NATO Conference on the Human Factors of Uninhabited Military Systems,* France, October 2006.

Barnes, M.J., Cosenzo, K., Jentsch, F., **Chen, J.** & McDermott, P. (2006) Understanding Human robot teaming using virtual media. *Proceeding of the NATO Conference on the Use of Virtual Media for Military Application*, West Point, NY

Marshall, H., Garrity, P., Compton, R., Roberts, T., Green, G., **Chen, J. Y. C.**, Bounker, P., Tierney, T., Mohammed, S. (2006). Development of a Virtual Dismounted Soldier Robotics Control Testbed to Improve Operator Control Agents. In Proceedings of the *NDIA Intelligent Vehicle Systems Symposium,* Traverse City, MI, June 13-15, 2006.

2005

Barnes, M., Cosenzo K., Mitchell, D. & Chen, J. (2005). Soldier-Robot Teams for Future Combat Environments. *Proceedings of the 11th Annual Human-Computer Interaction International Conference*, Las Vegas, NV.

Goodrich, M., Quigley, M. and **Cosenzo, K.** (2005) Task Switching and Multi-Robot Teams. *Proceedings of the Third International Multi-Robot Systems Workshop,* Washington, DC.

Human System Integration

Allender, L, Kelley, T., Archer, S., & **Lockett, J**. (2005). Human performance modeling in the army: A long and winding road. In Proceedings of Human Factors and Ergonomics Society 49th Annual Meeting. Human Factors and Ergonomics Society: Santa Monica, CA.

Archer, S., Gosakan, M., Shorter, P., & **Lockett III, J. F.** (2005). New capabilities of the army's maintenance manpower modeling tool. Journal of the International Test and Evaluation Association (ITEA) 26 (1), 19-26.

Branscome, T, A., Grynovicki, J.O. (2005). "An Investigation of Factors Affecting Multi-task Performance in an Immersive Environment"; ARL-TR-4025 Army Research Laboratory, APG, MD.

Cosenzo, K., Branscome, T., & Fatkin, L. (2004). "Cognitive Uncertainty and Work Shifts in a Real-World Multitask Environment" ARL-TR-3515 Army Research Laboratory, APG, MD.

Dixen, M., Patton, D., Fatkin. L., Grynovicki, J. (2006). "Cognitive &Affective Predictors of Simulation Performance" 25th U.S. Army Science Conference. (Nov 2006).

Grynovicki, J.O. (2005). "MANPRINT Follow-on Assessment of Persistent Surveillance System of Systems" Presentation at Eleventh Annual U.S. Army Conference on Applied Statistics, Naval Post Graduate School, Monterey, CA.

Grynovicki, J.O. (2004) FCS Warfighter System Interface Style Guide Review, ARL, APG, Md., Army Research Laboratory, Human Research and Engineering Directorate, White Paper

Grynovicki, J.O. (2002). Knowledge Based Engineering Assessment of C4ISR Digitized Battlefield Experiments. Invited Presentation at Program for Interface 2002, Interface Foundation of North America. Montreal., Canada, April 2002.

Grynovicki, J.O. & **Kysor, K.P.** (2002). A Knowledge-Based System Evaluation Methodology for the Army's Battle Command System. 70th (MORS) Symposium. June 2002 pp. 222-233.

Grynovicki, J.O., **Kysor, K.P.**, & Murphy, J. (2002). ARL-HRED Insight Feeder Report to TRAC-FLVN on the Human Dimension of Battle Command Issues Evaluated during the DCX (Phase I). ARL-TR2837. Army Research Laboratory, APG, MD.

Grynovicki, J.O., **Kysor, K.P.**, & **Breitenbach, J**., (April 04) CAPES Usability and Functionality Memorandum Report,ARL-HRED (e) Grynovicki, J.O., Kysor, K.P., Breitenbach, J Human Factors Assessment of the CAPES Reference Manual, (August 04), Army Research Laboratory Memorandum Report.

Grynovicki, J.O., Kysor, K.P., & Murphy, J, **Breitenbach, J.** (2004) Analysis Plan for ABCA U.S. Exercise 04 Focus Area "Human Behavior of Battle Command", ABCA Armies' Standardization Program Analysis Continuity Book:", Volume 1, TAB E.

Grynovicki, J.O., Murphy, J & **Kysor, K.P.** (2003). Decision Making During the Execution PhaseC4ISR Experiment 71th Military Operations Research Society (MORS) Symposium. pp. 281-282.

Grynovicki, J. O., et al., (2001). "A Methodology for Quantifying Critical Decision Events During the Execution Phase of Battle ." U. S. Army Conference on Applied Statistics, October 21, 2001

Hawley, J.K., Lockett, J.F. & Allender, L. (2005). Soldier-centered design tools: recent developments, challenges, and paths forward. Human Factors and Ergonomics Society Bulletin: Santa Monica, CA.

Johnson L A., **Grynovicki, J.O.**, et al, Capabilities and Limitation Report for the PSDS2, U.S. Army Test and Evaluation Command, OCT, 2005-OT-FS –08

Lizza, G., **Lockett, J.**, & Narkevicius, J. (2008). Human systems integration: synergy across the United States military. Insight, 11 (2), 28-30.

Lockett, J. and Powers, J. (2003). Human engineering methods and tools. In H. R. Booher (Ed.), Handbook of Human Systems Integration. John Wiley & Sons, Inc: NY.

Lockett, J., Kozycki, R., Gordon, C., & Bellandi, E. (2005). An integrated human figure modeling analysis approach for the army's future combat systems. Paper number 05MV-5. In Proceedings of the 2005 SAE World Congress, Detroit, MI, SAE: Warrendale, PA.

Lockett, J.F., Assmann, E., Green, R., Reed, M.P., Raschke, U. & Verriest, J. (2005). Digital human modeling research and development user needs panel. In Proceedings of the SAE Digital Human Modeling Conference, Iowa City, IA. Paper number 2005-01-2745. selected for SAE Transactions: Journal of Passenger Cars - Electronic & Electrical Systems, Vol. 114. SAE: Warrendale, PA.

Mansir, J., **Grynovicki J.O.,** et al.,, (2004), Abbreviated SEP for the PSDS2, U.S. Army Test and Evaluation Command, 2004-OT-FS

Mitchell, D.K., Samms, C.L., Henthorn, T., and Wojciechowski, J.Q. (2003). "Trade Study: 2- vs. 3-soldier crew for the Mounted Combat System (MCS) and other Future Combat System platforms". Aberdeen Proving Ground, MD: U.S. Army Research Laboratory. ARL-TR-3026.

Mitchell, D.K., Samms, C.L., Glumm, M.N., Krausman, A.S., Brelsford, M., & Garrett, L. (2004). Improved Performance Research Integration Tool (IMPRINT) Model Analyses in Support of the Situational Understanding as an Enabler for Unit of Action Maneuver Team

Soldiers Science and Technology Objective (STO) in support of Future Combat Systems (FCS) (ARL-TR-3405). Army Research Laboratory, APG, MD.

Mitchell, D.K., Samms, C.L., & Henthorn, T.J. (2004). Workload Analysis of Two- Versus Three- Soldier Crew for the Non-Line-of-Sight Cannon (NLOS-C) System, (ARL-TR-3406). Army Research Laboratory, APG, MD.

Mitchell, D.K., Samms, C.L., & Henthorn, T.J. (2003). Trade Study: A Two- Versus Three-Soldier Crew for the Mounted Combat System (MCS) and Other Future Combat System Platforms (ARL-TR-3026). Army Research Laboratory, APG, MD.

Murphy, J., **Kysor, K.P. & Grynovicki, J.O.** (2003). Use Of The Battle Command Proficiencies Concept on the Unit of Action Battle Command CEP BCBL Report March 03.

Murphy, J., **Grynovicki,J.O, & Kysor,K.P.** (2003). Case Study of a Prototype Set of Behaviorally Anchored Rating Scales for C2 Assessment Invited Presentation at Program for 8th International Command and Control Research and Technology Symposium (8th ICCRTS) June 03

Samms, C. & Mitchell, D.K. (2005). Impacting Design Through Human Performance Modeling - A Success Story. Proceedings of the Human Systems Integration Symposium 2005.

SleeveI, N., Lee, M., Groover, R., Strukel, S., Shephard, M., Hayes, M., Russell, G., **Grynovicki, J.O.**, Davis, D., Kronening, D., Wilmer, M., Initial Insights Memorandum (IIM) for the Army Transformation Experiment 2002 (ATEx02), TRADOC Analysis Center (TRAC) , Fort Leavenworth, KS, August 2002, TRAC-F-TR-02-023.

Weaver, M., Booher, H.R., **Holland, D., Lockett, J.**, Olson, S. & Wallace, D. (2003). Improving the consideration of human factors in system design. In Proceedings of the International Council on System Engineering (INCOSE) 2003 Symposium. INCOSE: Seattle, WA.

Wojciechowski, J.Q. (2006). Validation of a Task Network Human Performance Model of Driving. Masters Thesis. Blacksburg, VA: Virginia Polytechnic Institute and State University.

Wojciechowski, J.Q. (2004). “Validation of Improved Research Integration Tool (IMPRINT) Driver Model for Workload Analysis”. Aberdeen Proving Ground, MD: U.S. Army Research Laboratory. ARL-TR-3145.

Wojciechowski, J.Q. (2004). "A Human Performance Model of Driving Ground Vehicles". In D.A. Vencenzi, M. Mouloua, and P.A. Hancock (Eds.), Human Performance, Situation Awareness and Automation Current Research and Trends: Vol. II. (pp. 242-247). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Wojciechowski, J.Q. & Archer, S. (2002). "Human Performance Modeling: Art or Science?" In Chinni, M.J., ed. Military, Government and Aerospace Simulation. Simulation Series Vol. 34, No. 3, The Society for Modeling and Simulation International., pp. 59-64.

Wojciechowski, J.Q. & Knapp, B. G. (2000). "Command and Control (C2) Human Performance Modeling". In Chinni, M.J., ed. Military, Government and Aerospace Simulation. Simulation Series Vol. 32, No. 3, The Society for Computer Simulation International., 69-74.

Wojciechowski, J.Q., Knapp, B.G., Archer, S., Wojcik, T., & Dittman, S. (2000). "Modeling human command and control performance sensor to shooter" [CD-ROM]. Proceedings from the Human Performance, Situation Awareness, and Automation Conference. SA Technologies, Inc. [Producer and Distributor].

Wojciechowski, J.Q., Plott, B., & **Kilduff, P.W.** (2005). "Human Performance Model Development of a Battalion Tactical Operations Center". Aberdeen Proving Ground, MD: U.S. Army Research Laboratory. ARL-TR-2635. Aberdeen Proving Ground, MD: U.S. Army Research

Wojciechowski, J.Q., Wojcik, T., Archer, S. & Dittman, S. (2001). "Information-Driven Decision-Making Human Performance Modeling". In Chinni, M.J., ed. Military, Government and Aerospace Simulation. Simulation Series Vol. 33, No. 4, The Society for Modeling and Simulation International., 3-8.

Social/Cognitive Network Science

Journal Articles

2007

Krausman, A. & Nussbaum, M. (2007). Effects of wearing chemical protective clothing on text entry when using wearable input devices. International Journal of Industrial Ergonomics, 37, 525-530.

2006

Hansberger, J.T., Schunn, C.D., Holt, R.W. (2006). Strategy variability: How too much of a good thing can hurt performance. Memory & Cognition, 34 (8). 1652-1666.

Reviewed Technical Reports, Book Chapters, Conference Papers, Magazine Articles, and White Papers

In Press

White, T.L., Krausman, A.S., & Haas, E. (In Press). Tactile displays for Army operations. In P. Savage-Knepshield, J. Lockett, J. Martin, & L. Allender (Eds.), Designing Soldier Systems: Current Issues in Human Factors.

2009

Krausman, A. & **White, T**. (2009). Effects of Vehicle Vibration on Perception of Tactile Cues in Combat Vehicles. In Proceedings of the IJIE Conference. Anaheim, CA: IJIE.

2008

Krausman, A. & **White, T**. (2008). Detection and Localization of Tactile Signals in Moving Vehicles. Technical Report ARL-TR-4463, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD.

2007

Krausman, A., **Pettitt, R**., & **Elliott, L**. (2007). Effects of redundant alerts on platoon leader performance and decision making. Technical report ARL-TR-3999, US Army Research Laboratory: Aberdeen Proving Ground, MD.

Krausman, A. & **White, T**. (2007). Using the tactile modality as a communication medium for dismounted soldiers. In Proceedings of the Human Factors and Ergonomics Society Annual Meeting, Santa Monica California: Human Factors and Ergonomics Society.

Wickler, G., Tate, A., & **Hansberger, J.** (2007). Supporting collaborative operations within a coalition personnel recovery center. Proceedings of the Knowledge Systems for Coalition Operations 2007 Conference, Waltham, MA.

2006

Gonzalez, C., Martin, M., and **Hansberger, Jeffrey T.** (2006). Feedforward effects on predictions in a dynamic battle scenario. Proceedings of the Human Factors and Ergonomics Society, San Francisco, CA.

Hansberger, J.T. and Giammarese, W. (2006). Experimental methodologies for joint Command and Control (C2) capability development. Proceedings of the Defense Analysis Seminar XIII, Seoul, South Korea.

Krausman, A.S., & **White, T.L**. (2006). Tactile displays and detectability of vibrotactile patterns as combat assault maneuvers are being performed. ARL-TR-3998, US Army Research Laboratory: Aberdeen Proving Ground, MD.

Krausman, A., Elliott, L., & Pettitt, R. (2006). Effects of alerts on platoon leader decision making and performance. Proceedings of the 11th International Command and Control Research Technology Symposium. McLean, Virginia.

Merlo, J., Terrence, P.I., Stafford, S., Brill, C., Gilson, R., Hancock, P, **Redden, E**., **Elliot, L**., **Krausman, A**., & **White, T**. (2006). A comparison of vibrotactile displays under simulated operational conditions for dismounted and mounted soldiers. Proceedings of the 2006 Army Science Conference, Orlando, FL.

Merlo, J., Terrence, P.I., Stafford, S., Brill, C., Gilson, R., Hancock, P, **Redden, E**., **Elliot, L**., **Krausman, A**., & **White, T**. (2006). The effects of dynamic environments and physiological stress on tactical communications and signaling. Proceedings of the Human Performance in Extreme Environments 4th Annual Meeting, San Francisco, CA.

2005

Elliott, L., Redden, E. Krausman, A. & Carstens, C. (2005). Multi-modal displays to support Army Infantry Decision-making and Performance. Proceedings of the 7th International Naturalistic Decision Making Conference. Amsterdam, The Netherlands.

Krausman, A., **Elliott, L**., & **Pettitt, R**. (2005). Effects of visual, auditory, and tactile alerts on platoon leader decision making and performance. Proceedings of the 10th International Command and Control Research Technology Symposium. McLean, Virginia.

Krausman, A. & Nussbaum, M. (2005). Effect of wearing chemical protective clothing on task performance using wearable input devices. Proceedings of the Human Factors and Ergonomics Society 49th Annual Meeting. Santa Monica, CA.

Neuroscience

Journal Articles

In Press

Davis, J., Smyth, C., & McDowell, K. (in press). The Effects of Time Lag on Driving Performance and a Possible Mitigation. IEEE Transactions on Robotics.

Lance, B., Marsella, S. (in press). The Expressive Gaze Model: Using Gaze to Express Emotion. IEEE Computer Graphics and Applications.

2008

McDowell, K., Nunez, P., Hutchins, S. & Metcalfe, J.S. (2008). Secure mobility and the autonomous driver. IEEE Transactions on Robotics, 24, 688-697.

Davis, J., Animashaun, **A**., Schoenherr, E., & **McDowell, K.** (2008). Evaluation of Semi-Autonomous Convoy Driving. Journal of Field Robotics, 25. 880-897.

2007

Chen, J., **Haas E.C.,** and Barnes, M.J. (2007). Human performance issues and user interface design for teleoperated robots. IEEE Transactions on Systems, Man, and Cybernetics – Part C, Applications and Reviews, 37, 6, 1231-1245.

Reviewed Technical Reports, Book Chapters, Conference Papers, Magazine Articles, and White Papers

In Press

Davis, J., Schoenherr, E. (in press). Investigating the Performance of an Autonomous Driving Capability for Military Convoys. Proceedings of the 2010 International Conference on Applied Human Factors and Ergonomics, Miami, FL.

Haas, E.C., Fields, M.A., **Hill**, **S**., **Stachowiak, C.C**. (in press). Designing interfaces and algorithms for soldier-robotic swarm interaction (multimodal controls). U.S. Army Technical Report, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD.

2009

Davis, J., Smyth, C., & McDowell, K. (2009). Mitigating the effects of time lag on driving performance. In Proceedings of the 2009 Ground Vehicle Systems Engineering and Technology Symposium (GVSETS), Troy, MI.

Fields, M.A., **Haas, E.C., Hill**, **S**., **Stachowiak, C.,** and Barnes, L. (2009). Effective robot team control methodologies for battlefield applications. Proceedings of the 2009 Intelligent Robots and Systems Conference, St. Louis, Mo.

Haas, E.C., Stachowiak, C., **White, T**., **Pillalamarri, K., & Feng, T.** (2009). Tactile and Auditory Cues to Communicate Multiple Levels of Information. Proceedings of the 2009 International Forum for Multisensory Information, New York, N.Y.

Haas, E.C., and van Erp, J. (2009). Tactile displays for human robot interaction. In Barnes, M., Jentsch, F. (Eds), Human Robot Interactions in Future Military Operations.

Haas, E.C., Fields, M.A., **Hill**, **S**., **Stachowiak, C.C.** (2009). Designing interfaces and algorithms for soldier-robotic swarm interaction (multimodal displays). Technical Report ARL-TR-4800, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD.

2008

Hill, S.G., Metcalfe, J.S., & **McDowell, K.** (2008). Use of a steering shaping function to improve human performance in by-wire vehicles. ARL Technical Report (ARL-TR-4387), Aberdeen Proving Ground, MD.

Metcalfe, J.S., **Davis, J., Tauson, R**., & **McDowell, K.** (2008). Performance decrements associated with sensory-mismatch between visual display and vehicle motion. ARL Technical Report (ARL-TR-4461), Aberdeen Proving Ground, MD.

Mitchell, D.K. & **McDowell, K.** (2008). Using modeling as a lens to focus testing. In Proceedings of 2008 International Symposium on Collaborative Technologies and Systems, Irvine, CA.

Savick, D., Elliott, L. R., Zubal, O., **Stachowiak, C.** (2008) Effect of audio and tactile cues on Soldier decision making in complex simulation scenarios. Technical Report ARL-TR-4413, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD.

2007

Haas, E.C., Stachowiak, C.C. (2007). Multimodal displays to enhance human-robot interaction on the move. Proceedings of the Performance metrics for Intelligent systems (PerMIS) Workshop, Gaithersburg, MD, USA.

McDowell, K., Oie, K.S., Tierney, T. & Flascher, O.M. (Jan – Mar, 2007). Addressing human factors issues for future manned ground vehicles (MGVs). Army AL&T, 20-23. (Cover Article)

McDowell, K., Paul, V., & Alban, J. (2007). Reduced input throw and high-speed driving. In Proceedings of the North America Driving Simulation Conference 2007, Iowa City, IA.

Zywiol Jr., H., Gorsich, D., **McDowell, K**., & Hill, S. (Jan – Mar, 2007). Using motion-base simulation to guide future force systems design. Army AL&T, 24-27.

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Haas, E.C., Pillalamarri, R.S., Stachowiak, C.C. (2006). Audio cues to assist visual search in narrow field of view displays. Proceedings of the 26th Triennial Congress of the International Ergonomics Association, Maastricht, the Netherlands.

Soldier Performance

Allender, L.E., Cassenti, D.N., & **de Pontbriand, R**. (2005). Human temporal judgment in the humans-in-automation environment. In D.D. Schmorrow (Ed.) *Foundations of Augmented Cognition Volume II (*pp. 680-689). Mahwah, NJ: Erlbaum.

Cosenzo, K. A. (2004). Field Study of the Relationship between Cognitive Uncertainty and Decision-Making. Proceedings from the 72nd MORS Symposium, D-259, Monterey, CA.

Cosenzo, K.A., Fatkin, L.T., & **Branscome, T.A.** (2005). Cognitive uncertainty and work shifts in a real-world multi-task environment (ARL-TR-3515). Aberdeen Proving Ground, MD: U.S. ARL HRED.

Cosenzo, K.A., Kilduff, P. & **Swoboda, J.** (2005). Human Performance Moderators for the C3TRACE Modeling Environment. Proceedings from the 2005 Behavioral Representation in Modeling and Simulation Conference.

Kelley, T. D. (2003). Symbolic and Sub-symbolic Representations in Computational Models of Human Cognition: What can be learned from biology? Theory and Psychology, 13(6), December.

Kelley, T. D. & **Scribner, D. R.** (2003). Developing a Predictive Model of Dual Task Performance. ARL Technical Memorandum, (ARL-MR-0556). Aberdeen, MD.

Kelley, T. D., Patton, D. J., & **Allender, L.** (2001). Error rates in mental manipulation of spatial images. Perceptual and Motor skills, 92, 985-992.

Kelley, T. D. (2001). An Overview of Modeling and Integration of Neurological Dynamics with Symbolic Structures (MINDSS). In W.F. Waite (Ed.) Proceedings of 2000 Summer Computer Simulation Conference, Vancouver, Canada. Society for Computer Simulation, San Diego, CA. 730-735.

Kelley, T. D., Patton, D. J., & **Allender, L.** (2001). Predicting Situation Awareness Errors using Cognitive Modeling. In: M. J. Smith, G. Salvendy, D. Harris, R. J. Koubek. (Eds.) Proceedings of Human-Computer Interaction International 2001 Conference, New Orleans, LA (Vol. 1) Lawrence Erlbaum Associates, Mahwah, New Jersey.

Refereed Conference Proceedings:

Rice, V.J. (2009). Human Factors in Weapons Safety (panel Chair), Human Factors & Ergonomics Society Annual Meeting, San Antonio, TX.

Rice, V.J. and Duncan, J. (2007). Professionalism in Ergonomics: A panel discussion. Human Factors & Ergonomics Society Annual Meeting, Baltimore, MD.

Steinberg, A.G., & **Smith, P.E**. (2001, August). Social support as it relates to stress in Army units. Proceedings of the 110th Annual Convention of the American Psychological Association, San Francisco, CA.

Technical Reports:

Bateman, R., Mendez, L., and Foust, J . (in progress). Verification and Validation of the Army Medical Department, Center for AMEDD Strategic Studies Disease and Non Battle Injury Model. Technical Report No. Pending, US Army Research Laboratory Field Element, Ft. Sam Houston, TX 78234-6125.

Customer Reports:

Rice, V.J. (2007). Effectiveness of Nursing Provided Patient Education on

Patient Pulmonary Function.

Rice, V.J., Butler, J., Marra, D., Vu, T., **DeVilbiss, C.,** Headley, D., Patton, D., Banderet, L. (2007). FY07 Accomplishments and Achievements: Army Medical Department Center and School Advanced Individual Training Attrition.

Rice, V.J., Butler, J., and Marra, D. (2007). Neuro-Cognitive Assessment, Symptoms of Attention Deficit and Hyperactivity Disorder, and Soldier Performance during 68W Advanced Individual Training.

DeVilbiss, C., **Rice, V.J.** (2007). The Academic Class Composite Tool for Academic Instructors and Supervisors: Instructors Survey.

Rice, V.J., Butler, J., Marra, D., **DeVilbiss, C**., Bundy, **M., Headley, D., Dixon, M., Patton, D., Rose, P.**, Banderet, L. (2006). FY06 Accomplishments and Achievements: Army Medical Department Center and School Advanced Individual Training Attrition.

Rice, V.J., Butler, J., Marra, D., **DeVilbiss, C.**, Bundy, M., **Headley, D., Dixon, M., Patton, D., Rose, P.**, Banderet, L. (2006). A Prediction Model for the Personal Academic Strategies for Success (PASS) and Academic Class Composite (AC^2T) Tool.

Rice, V.J. and **DeVilbiss, C**. (2006). Supporting Soldiers in AIT at Ft. Sam Houston, Texas: The Academic Class Composite Tool for Academic Instructors and Supervisors, Definition and Development.

Rice, V.J. and Marra, D. (2006). 91V Respiratory Therapy: Relationship between the Test for Adult Basic Education and Grade Point Average.

Rice, V.J. and Bundy M.J. (2005). Injury Prevention Education: Development and Evaluation of an Education Program for Drill Sergeants. Report for the US Army Center for Health Promotion and Preventive Medicine on the methodology used for development and testing of materials with target audience.

Rice, V.J. and Bundy, M. (2005). Development and Assessment of Injury Prevention Education. Five one-hour education sessions designed for the US Army Drill Sergeant School, technical manual, power point slides and instructional verbiage.

Rice, V.J. and Laws, L. (2005). Executive Leadership: Strategies for Safety Excellence. Technical manual, power point slides and instructional verbiage.

Rice, V.J. (2005). The US Army Executive Leadership: Strategies for Safety Excellence Leadership Call Evaluation. Technical manual, power point slides and instructional verbiage. Data on testing with target audience included.

Rice, V.J. and Bundy, M. (2005). Safety Training of Non-supervisory Soldiers (SToNS). One-hour and 4-hour instructional program. Data on testing of materials with target audience included. Technical manual, power point slides and instructional verbiage.

Rice, V.J. and Bundy, M. (2005). Command Teams and Supervisors (CTAS): Safety Skill Building 1 8-hr day of instruction. Data on testing of materials with target audience included. Technical manual, power point slides and instructional verbiage.

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Appendix D. Additional Journal Articles/Dissertations While Unaffiliated With the U.S. Army Research Laboratory

This appendix appears in its original form without editorial change.

Human Robot Interaction

Research Area 1.1 - Team Characteristics

In Press

Evans, III, A.W. (In Press). An introduction to human-robot interaction in military applications. In M. Barnes & F. Jentsch (Eds.). *Human-Robot Interactions in Future Military Operations.* Ashgate Publishing: London.

Evans, III, A.W. & Jentsch, F. (In Press). The future of HRI: Alternate research trajectories and their influence on the future of unmanned systems. In M.Barnes & F. Jentsch (Eds.). *Human-Robot Interactions in Future Military Operations*. Ashgate Publishing: London.

Jentsch, F. & **Evans, III, A.W.** (In Press). Model world: Military HRI research conducted using a scale MOUT facility. In M. Barnes & F. Jentsch (Eds.). *Human-Robot Interactions in Future Military Operations*. Ashgate Publishing: London.

2009

Fincannon, T, **Evans, III, A.W.**, Phillips, E., Jentsch, F, & Keebler, J. (2009). Team size and communication modality in the prediction of team effectiveness with unmanned systems. *Proceedings of the 53rd Annual Meeting of the Human Factors and Ergonomics Society.* San Antonio, TX.

2008

Evans, A.W., III & Jentsch, F (2008). Tracking dynamic targets with moving unmanned vehicles. *5th Annual Workshop on the Human Factors of Unmanned Aerial Vehicles*. Apache Junction, Arizona, May 13-15.

2006

Evans, III, A. W., Hoeft, R.M., Jentsch, F., Rehfeld, S. A., & Curtis, M. T. (2006). Exploring human-robot interaction: Emerging methodologies and environments. In N. J. Cooke, H. Pringle, H. Pedersen, & O. Connor (Eds.), *Human Factors of Remotely Piloted Vehicles* (pp. 345-358). Amsterdam, NL: Elsevier.

Research Area 1.2 - Shared Control

2008

Drexler, J. M., & Reeves, L. M. (Eds.) Foundations of Augmented Cognition (4th Ed.) (pp. 183-189).

Fincannon, T., Keebler, J.R., Jentsch, F.G., **Evans, A.W. III,** (2008). Target Identification Support and Location Support Among Teams of Unmanned System Operators. *Proceedings of the 26th National Army Science Conference,* Orlando, FL.

Fincannon, T., Keebler, J.R., Jentsch, F.G., **Evans, A.W. III**, (2008). Target Identification Support and Location Support Among Teams of Unmanned System Operators. *Proceedings of the 26th National Army Science Conference,* Orlando, FL.

2007

Ososky, S., **Evans, A. W.**, III, Keebler, J. R., & Jentsch, F. (2007). Using Scale Simulation and Virtual Environments to Study Human-Robot Teams. In Schmorrow, D. D., Nicholson, D. M.,

Research Area 1.3 - Individual Differences

2009

Fincannon, T, **Evans, III, A.W**., Jentsch, F, & Keebler, J. (2009). Dimensions of spatial ability and their influence on performance with unmanned systems. *Handbook of Human Factors in Combat Identification,* Ashgate Publishing.

2008

Fincannon, T.D., **Evans, A. W.,** Jentsch, F., & Keebler, J.R.(2008). Interactive Effects of Backup Behavior and Spatial Abilities in the Prediction of Teammate Workload Using Multiple Unmanned Vehicles. *Proceedings of the Human Factors and Ergonomics Society 52nd annual meeting.* New York, NY.

Fincannon, T, **Evans, A.W.III**, Jentsch, F, & Keebler, J.R. (2008). Interactive effects of spatial ability and shared visual resources in the prediction aerial vehicle backup behavior using multiple unmanned vehicles. *5th Annual Workshop on the Human Factors of Unmanned Aerial Vehicles.* Apache Junction, Arizona, May 13-15.

Keebler, J.R., Fincannon, T., **Evans, A.W**., Jentsch, F., Curtis, M. (2008). Effects of Shape Memory on 1:35 Scale Model Vehicle Identification. *Unmanned Aerial Vehicle Workshop*. Arizona State University, Mesa, AZ

Schuster, D., Fincannon, T., Jentsch, F.G., Keebler, J.R., **Evans, A.W. III** (2008). The Role of Spatial Ability in the Relationship Between Video Game Experience and Route Effectiveness Among Unmanned Vehicle Operators. *Proceedings of the 26th National Army Science Conference,* Orlando, FL.

Social/Cognitive Network Science

In Press

Buchler, N.G., Faunce, P., Light, L.L., Reder, L.M., & Gottfredson, N. (in press) Effects of repetition on associative recognition in young and older adults: Item and associative strengthening. *Psychology and Aging.*

2009

Davis, S.M., Dennis, N.A., **Buchler, N.G.**, White L.E., Madden D.J., & Cabeza, R. (2009) Assessing the effects of age on long white matter tracts using diffusion tensor tractography. *Neuroimage, 46,* 530-541.

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Buchler, N.G., Hoyer W.J., & Cerella, J. (2008) Rules and more rules: The effects of multiple tasks, extensive training, and aging on task-switching performance. *Memory & Cognition, 36*, 735-748.

Buchler, N.G., Light L.L., & Reder L.M. (2008). Memory for items and associations: Distinct representations and processes in associative recognition, *Journal of Memory & Language, 59,* 183-199.

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Buchler, N.E.G., & Reder, L.M. (2007) Modeling age-related memory deficits: A two-parameter solution, *Psychology and Aging, 22,* 104-121.

Hoyer, W.J., Semenec , S., **Buchler, N.G.** (2007) Acute alcohol impairs controlled search across the visual field. *Journal of Studies of Alcohol and Drugs, 68,* 748-758.

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Verhaeghen, P., Palfai, T., Cerella, J., **Buchler, N.E.**, et al., (2000). Age-related dissociations in time accuracy functions for recognition memory: Utilizing semantic support versus building new representations. Aging, Neuropsychology and Cognition, 7(4), 260-272.

Neuroscience

In Press

Vucetic Z, Totoki K, Schoch H, **Whitaker KW**, Hill-Smith T, Lucki I & Reyes TM. (In Press) Early Life Protein Restriction Alters Dopamine Circuitry. Neuroscience.

2010

Aldous, D.J., **Ong, J.R.,** Zhou, W. (2010) Empires and Percolation: Stochastic Merging of Adjacent Regions. J. Phys. A: Math. Theor. 43 025001.

Lance, B., Marsella, S. (2010). Glances, Glares, and Glowering: How Should a Virtual Human Express Emotion Through Gaze? Journal of Autonomous Agents and Multiagent Systems (AAMAS). vol. 20, no. 1. pp 50-69. 2010.

2009

Clarke KH, **Whitaker KW** & Reyes TM. 2009. Diminished Metabolic Responses to Centrally-Administered Apelin-13 in Diet-Induced Obese Rats Fed a High-Fat Diet. J Neuroendocrinology. 21(2):83-89.

Vettel, J.M. (2009) Neural Integration of Multimodal Events. PhD Thesis, Brown University, Dept. of Cognitive and Linguistic Sciences.

2008

Lance, B. (2008). Procedural Animation of Emotionally Expressive Gaze Shifts in Virtual Embodied Characters. Ph.D. Dissertation. University of Southern California, Dept. of Computer Science. December 2008.

Nestor, A., **Vettel, J.M.,** & Tarr, M.J. (2008). Task-Specific Codes for Face Recognition: How they Shape the Neural Representation of Features for Detection and Individuation. PLoS ONE, 3(12), e3978 doi:10.1371/journal.,pone.0003978

Whitaker, K.W., & Reyes, T.M. (2008). Central blockade of melanocortin receptors attenuates the metabolic and locomotor responses to peripheral interleukin-1beta administration. Neuropharmacology. 54(3):509-20.

2007

Griffith, J. F., Wang, Y. J., Antonio, G. E., Choi, K.C., **Yu, A.,** Ahuja, A.,Leung, P. C. (2007). Modified Pfirrmann grading system for lumbar intervertebral disc degeneration. Spine, 32(24), E708-E712.

2006

Kiemel T, **Oie KS**, Jeka JJ (2006) The slow dynamics of postural sway are in the feedback loop. *J Neurophysiol,* 95(3), 1410-1418.

Michelon, P., **Vettel, J.M.,** & Zacks, J.M. (2006). Lateral somatotopic organization during imagined and prepared movements. Journal of Neurophysiology, 95, 811-822.

Tam, L. S., Griffith, J. F., **Yu, A. B.,** Li, T. K., & Li, E. K. (2006). Rapid improvement in rheumatoid arthritis patients on combination of methotrexate and infliximab: clinical and magnetic resonance imaging evaluation. Clinical Rheumatology, 26(6), 941-946.

Zacks, J.M., Speer, N.K., **Vettel, J.M.,** & Jacoby, L.J. (2006). Event understanding and memory in healthy aging and dementia of the Alzheimer type. Psychology and Aging, 21, 466-482.

Zacks, J.M., Swallow, K.M., **Vettel, J.M.,** & McAvoy, M.P. (2006). Visual motion and the neural correlates of event perception. Brain Research, 1076, 150-162.

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Metcalfe, J. S., **McDowell, K**., Chang, T. Y., Chen, L. C., Jeka, J. J., & Clark, J. E. (2005). Development of somatosensory-motor integration: An event-related analysis of infant posture in the first year of independent walking. Developmental Psychobiology, 46, 19-35.

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Montenegro, M., Veiga, H., Deslandes, A., Cagy, M., **McDowell, K.,** Pompeu, F. et al., (2005). Neuromodulatory effects of caffeine and bromazepam on visual event-related potential (P300). Arquivos de Neuro-Psiquiatria, 63, 410-415.

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Soldier Performance

Allen, G., Lueder, R. and **Rice, V.J.** (2008). Children and Wayfinding. In R. Lueder and V. Rice (Eds.), Ergonomics for Children: Designing Products and Places for Toddlers to Teens, pp 861-886. New York: Taylor & Francis.

Banderet, L., **Rice, V**., Allison, J., Creedon, J., and Sharp, M. (2004). Medical indicators of successful United States military-specialty training. Proceedings of the International Military Testing Association Annual Meeting, Brussels, Belgium, pp 190-198.

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Connolly, V.L.Pritchard, A.E., Bergeron, A.L., Mays, M.Z., and **Rice, V.J.B.** (2002). Measurement of the effectiveness of a screening tool to detect injuries and improve readiness among combat medic students. Technical Report No. Aegis T02-2 U.S. Army Medical Department Center and School, Ft. Sam Houston, TX. 78234-6125.

Davis, S.M., Dennis, N.A., **Buchler, N.G.**, White L.E., Madden D.J., & Cabeza, R. (2009) Assessing the effects of age on long white matter tracts using diffusion tensor tractography. *Neuroimage, 46,* 530-541.

Flint, J.D., Pastore, R.E. & **Gaston, J.R**. (2008). *Evaluation and modification of listener decision strategy in human gait perception.* Paper presented at the 155th meeting of the Acoustical Society of America: Paris, France

Garamszegi, L.Z., Calhim, S., Dochtermann, N., Hegyi, G., Hurd, P.L., Jorgensen, C., Kutsukake, N., Lajeunesse, M.J., **Pollard, K.A**., Schielzeth, H., Symonds, M.R.E., & Nakagawa, S. (2009). Changing philosophies and tools for statistical inferences in behavioral ecology. Behavioral Ecology, 20, 1363-1375.

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Hoyer, W.J., Semenec , S., **Buchler, N.G.** (2007) Acute alcohol impairs controlled search across the visual field. *Journal of Studies of Alcohol and Drugs, 68,* 748-758.

Kemnitz, C.P., Johnson, R.F., Merullo, D.J., & **Rice, V.J.** (2001). Relation of rifle stock length and weight to military rifle marksmanship performance by men and women. *Perceptual and Motor Skills,* 93, 479-485. (DTIC No. AD A396685)

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