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The Perceived Urgency of Tactile Patterns

by Timothy L. White

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Timothy L. White
Human Research and Engineering Directorate, ARL

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14. ABSTRACT
The purpose of this research was to examine the effects of stimulus intensity and inter-stimulus interval (ISI) on the perceived urgency and on the detection and identification of tactile patterns. A tactile system that includes an adjustable belt developed by Engineering Acoustics Inc. (EAI) was used to provide tactile stimuli. This adjustable belt, which consists of eight EAI C2 tactors positioned at 45-degree intervals, was worn around each participant's waist. Participants received tactile patterns at an intensity of either 12 dB or 23.5 dB with an ISI of either 0 ms (no interval) or 500 ms. Participants were asked to identify each tactile pattern that they received and rate how urgent they perceived the pattern to be on a scale of 1 to 10. Results show that participants were able to detect and identify tactile patterns with nearly 100% accuracy. Participants rated patterns that were provided at the 23.5 dB intensity with no ISI as the most urgent. Patterns provided at the 12 dB intensity with a 500 ms ISI were rated the least urgent.

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Contents

List of Figures

List of Tables

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1. Introduction

In recent years, there has been an increased interest in tactile displays because of the need to provide complex information to users who are subject to visual and auditory overload and because of the development of more sophisticated tactile display technology (Jones and Sarter, 2008). Much of the information that Soldiers are currently being provided with is presented visually and auditorily. As future technologies advance, Soldiers will be provided with even more information regarding combat situations. The multiple-resource theory suggests that offloading information from overtaxed sensory modalities to other modalities can reduce workload (Wickens, 2002). Tactile displays may be a viable solution to help mitigate the overload and performance degradation that can result from this abundance of information being provided to Soldiers. If designed and implemented properly, tactile displays may improve Soldiers' situational awareness and survivability on the battlefield.

A number of research efforts have already shown the potential of tactile display systems in military environments. Research efforts to employ tactile displays for orientation, navigation, and communication are ever increasing (van Erp and Self, 2008). Some researchers are interested in the use of tactile patterns to communicate more complex messages. For example, Brewster and Brown (2004) addressed some basic approaches to developing "Tactons" or tactile icons to communicate messages. In one study that compared conventional Army hand and arm signals to tactile patterns, Soldiers were able to receive, interpret, and accurately respond to the tactile patterns faster than with the hand and arm signals while negotiating an obstacle course (Pettitt et al., 2006). In another investigation, participants were able to identify and navigate using tactile patterns with almost perfect accuracy (Jones et al., 2006). In an extension of this work Krausman and White (2006) found that pattern detection and identification rates were degraded while participants negotiated obstacles. A noteworthy difference in the Pettitt et al. (2006) investigation and the other two mentioned investigations is the type of tactile system used. The Pettitt et al. (2006) investigation employed an acoustic transducer in which the intensity was higher than the pancake motors used in the other two investigations.

Parameters such as frequency, amplitude, and duration of tactile signals have been used to encode tactile patterns (Brewster and Brown, 2004). In military environments, some signals or messages may need to be encoded with some level of urgency. Research has shown significance in the perceived urgency of auditory signals by varying temporal parameters. In one study, inter-pulse intervals had a consistent effect on the perceived urgency of auditory signals, in that signals with shorter inter-pulse intervals and higher sound pressure levels were rated as more urgent (Haas and Edworthy, 1996). Similarly, varying inter-stimulus intervals (ISIs) in tactile patterns may also be a possible method of displaying urgency. The findings of another study that employed "Tactons" that were created from a combination of spatial location, rhythm, and roughness suggest that varying tactor intensity may also be a feasible alternative of displaying urgency (Brown et al., 2006).

2. Hypotheses

Because inter-sitmulus intervals have been successfully used to distinguish urgency in auditory signals, it was hypothesized that tactile patterns that have no ISI and a greater (23.5 dB) intensity would be rated the most urgent and patterns with a longer (500 ms) ISI and a lower (12 dB) intensity would be rated the least urgent. In one investigation, there were no significant differences found in detection and localization of tactile signals between two signals, one 20 dB and the other 23.5 dB above mean threshold tactor intensity (Krausman and White, 2008). Also, weak signals may go unnoticed (Gilson et al., 2007). Furthermore, it is not known how the varying intensity and ISIs will interact with each other. It was hypothesized that detection and identification rates would be degraded when the arithmetic distractor task was performed.

3. Objective

The objective of this laboratory study was to quantify the effects of ISI and stimulus intensity on perceived urgency and on the detection and identification of tactile patterns.

4. Method

4.1 Participants

Sixteen male Marines from the U.S. Marine Corps Detachment at Aberdeen Proving Ground, MD, volunteered to participate in this research. All participants were 19 years of age (19.5 years ±0.5). All participants had vision sufficient (corrected or uncorrected) for driving. Participants had normal hearing, as determined by an audiogram.

The voluntary, fully informed consent of the persons used in this research was obtained as required by 32 Code of Federal Regulations (CFR) 219 and Army Regulation (AR) 70-25 (1990). The investigators adhered to the policies for the protection of human subjects as prescribed in AR 70-25.

4.2 Apparatus

4.2.1 Tactile System

An Engineering Acoustics Inc. (EAI) C2 tactile system was used, which consists of an adjustable tactile belt display (figure 1) worn around the waist and a receiver unit. The adjustable belt display consists of eight EAI C2 tactors (acoustic transducers) that are approximately 1.2 inches in diameter. A belt display was used because, in a more realistic dismounted combat situation, it will allow stimuli to be easily perceptible and will be less likely to shift as opposed to other body locations during physically demanding tasks (Merlo et al., 2006). Previous research findings have proven the feasibility of an eight-tactor belt display (Cholewiak et al., 2004). Each of the eight tactors is positioned at 45-degree intervals in the adjustable belt. The tactors can be activated individually, sequentially, or in groups to provide a specific sensation or to create unique patterns of vibration. The tactor control unit is capable of receiving wired or wireless signals and converts them into recognizable patterns of vibration. The system, which provides the capability to vary signal frequency, gain, and duration, is powered by a 9.6 V nickel-metal hydride (Ni-MH) battery.

Figure 1. Tactile communications system.

4.2.2 Tactile Patterns

Four tactile patterns were provided via a tactile belt during this experiment. These patterns were developed based on the work of Jones et al. (2006) in which similar tactile patterns were used in a 4 × 4 back display. In figure 2, for each pattern, the numbers indicate the sequence in which tactors vibrated. The duration of the vibrations were 500 ms. Participants received these patterns with varying intensity and ISIs. All patterns were provided at a frequency of 250 Hz. The intensity of each pattern was presented at either an EAI gain setting of 2 (12 dB) or 4 (23.5 dB), and the ISI of each pattern was either 500 ms or 0 ms. Therefore, tactile patterns with an ISI of 500 ms had a total duration of 3.5 seconds (s), and tactile patterns with an inter-stimulus interval ISI of 0 ms had a total duration of 2.0 s (figure 3). The gain settings refer to the mean ratio of tactor output to the voltage input.

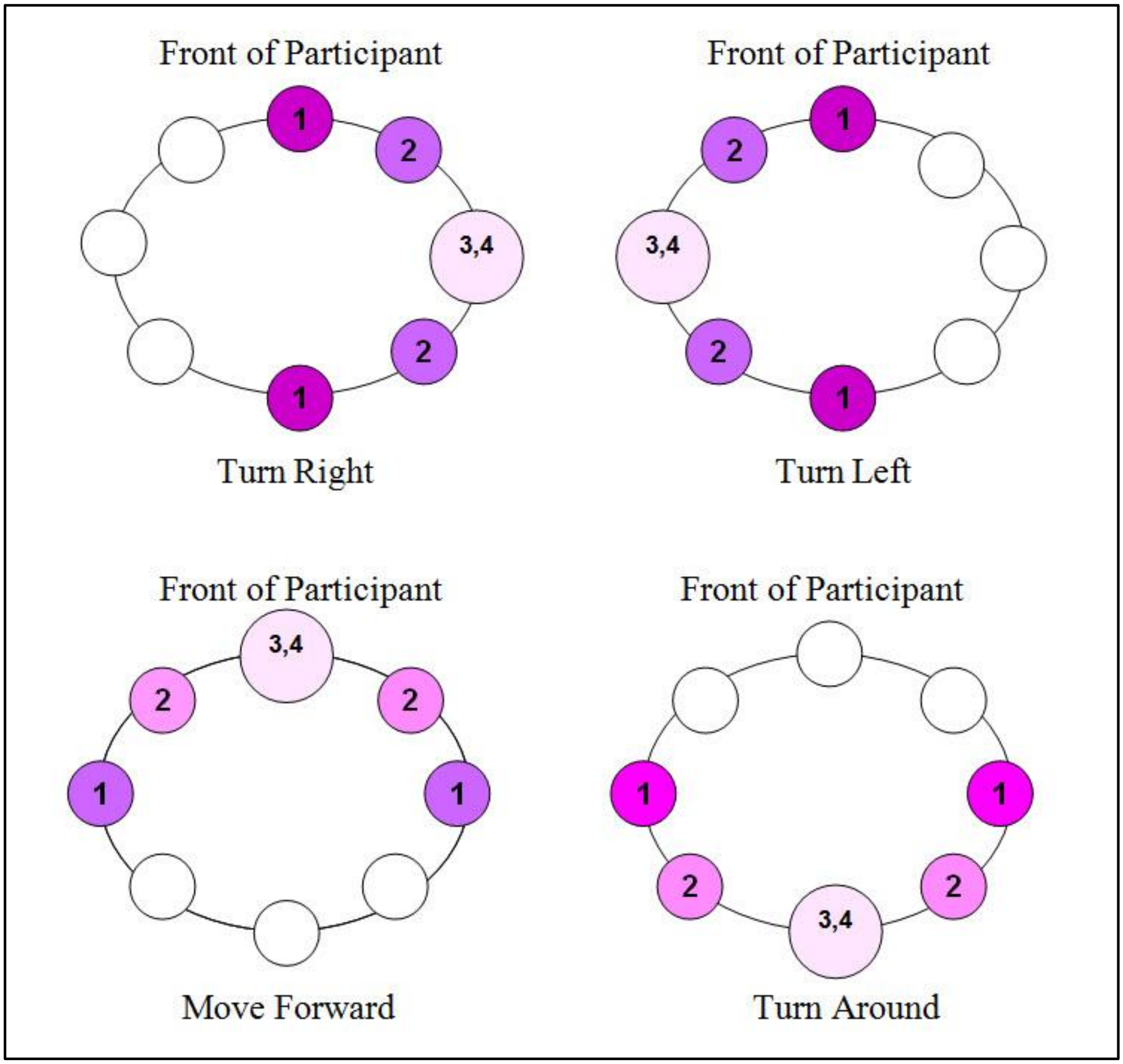

Figure 2. Tactile patterns.

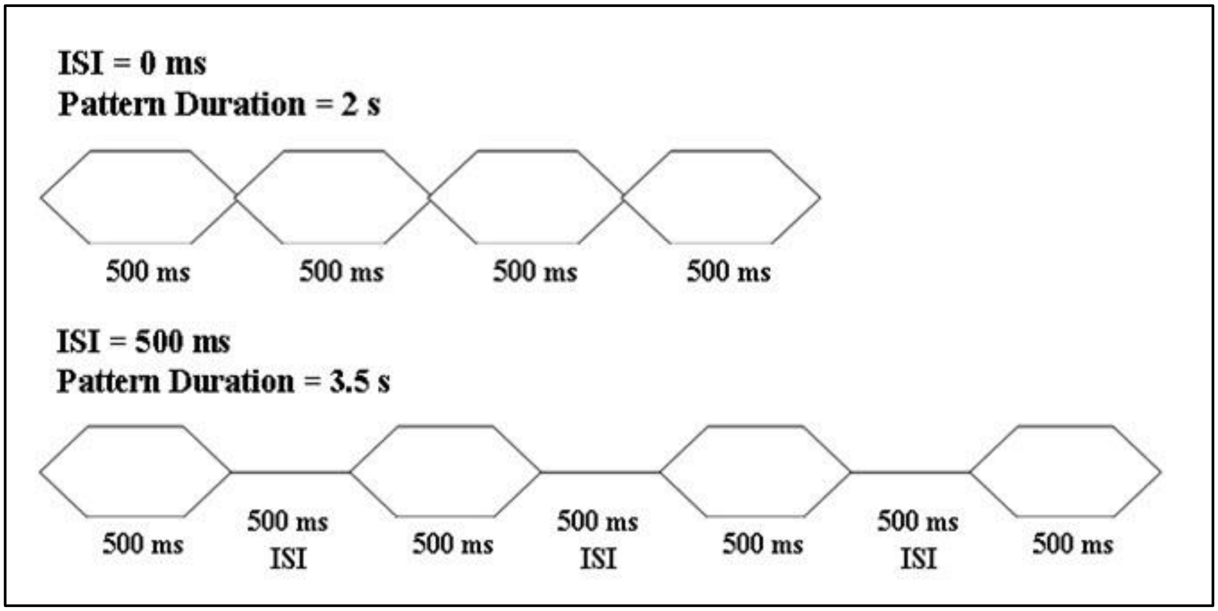

Figure 3. ISI and pattern durations.

The two intensity levels and the two ISI levels were combined to form four urgency combinations as shown in table 1. Each of the 4 patterns with each urgency combination was provided 4 times during each block for a total of 64 patterns per block. There was a three to six second interval between each pattern. The patterns and urgency combinations were counterbalanced using a Williams square.

Table 1. Urgency combinations.

Inter-Stimulus Interval	Intensity
0 ms	12 dB
0 ms	23.5 dB
500 ms	12 dB
500 ms	23.5 dB

4.2.3 Desktop Computer/Headphones

A standard Dell desktop computer was used to execute an application known as Synthetic Work Environment (SYNWORK) to present the arithmetic task. SYNWORK is a computer-based performance assessment tool that is capable of presenting up to four component subtasks (Elsmore, 1994). For this experiment, only the arithmetic subtask was presented (figure 4). In this task, participants were asked to add two randomly selected numbers. When the random numbers appeared on the screen, participants used a computer mouse to input the sum by clicking the “+” and “–” boxes below each digit of the default result. Upon completion of each problem, participants clicked the “Done” box to submit their answer to the current problem and to receive the next addition problem. The software recorded the number of correct problems, incorrect problems, and the average response time.

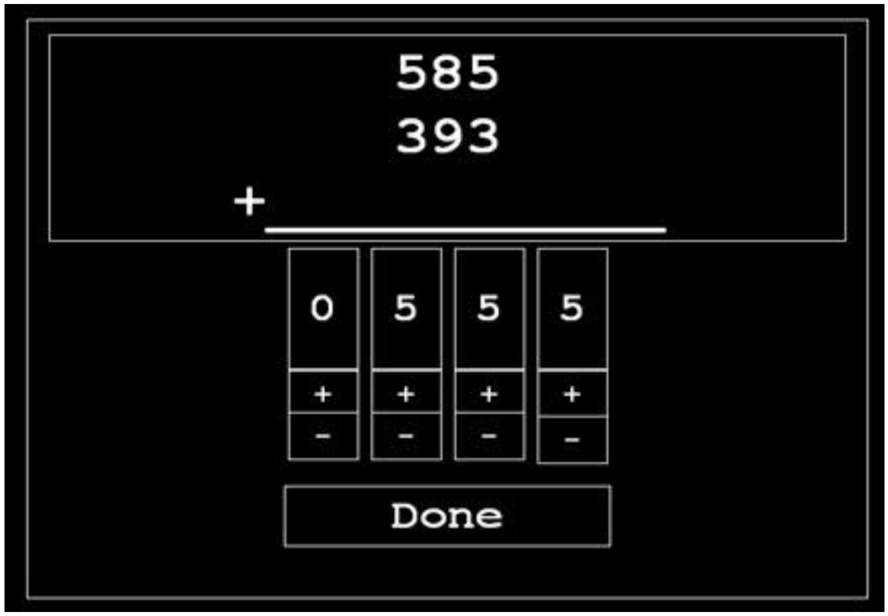

Figure 4. SYNWORK arithmetic task.

The desktop computer also generated a continuous tank noise that was provided to participants via Sony model MDR-7506 headphones. The continuous tank noise was used to mask the noise generated by the tactors to ensure that ratings of perceived urgency were based solely on the sense of touch and not the sense of hearing. The tank noise, recorded at the commander's position in an M1A2 tank, was 50 dBA SPL, measured under the earcup of the participant's headphones.

4.2.4 Questionnaire

Upon completion of each of the blocks, a post-block questionnaire was administered to gather each participant's comments, opinions, and perception of the difficulty to identify tactile patterns (appendix B).

4.3 Experimental Design

A 2 × 2 × 2 × 4 within-subjects design was used with four independent variables: ISI, intensity, arithmetic task, and pattern. The independent variables and their associated levels are shown in table 2. Each participant completed eight blocks during the study. Each block lasted 10 minutes (min) and consisted of 64 trials or 64 random tactile pattern presentations. The order of presentation of the experimental blocks was counterbalanced using Williams squares.

Table 2. Independent variables and levels.

Variable	**Levels**
Inter-Stimulus Interval	0 ms, 500 ms
Intensity	12 dB, 23.5 dB
Arithmetic Task	provided, not provided
Pattern	turn right, turn left, move forward, turn around

Four dependent variables measured: (1) ratings of perceived urgency of patterns, (2) the proportion of patterns detected, (3) the overall proportion of patterns correctly identified, and (4) ratings of difficulty of pattern identification. The proportion of patterns detected measured whether a pattern was perceived, regardless of whether it was identified correctly or not. For the overall proportion of patterns correctly identified, undetected patterns and incorrect identification were counted as errors.

4.4 Training

Each volunteer was briefed on the purpose of the investigation, the procedures to be followed during the study, and any risks involved in their participation. The investigator read the volunteer agreement affidavit aloud to the participant who followed along (appendix A) and addressed any questions the participant might have had regarding the study. If the volunteer agreed to take part in the investigation, he completed the information on the last page of the affidavit and signed it.

Next, each participant donned the tactile belt display (figure 5) and was seated in front of a desktop computer. They were then trained on both the tactile patterns and arithmetic task. For the tactile pattern training, participants were given a paper copy of the tactile patterns and received a brief explanation of each pattern. Participants were then provided each pattern several times to allow them to become familiar with how each tactile pattern felt. Next, the tactile patterns were provided in a random order, and the participant was asked to verbalize which pattern they received. The investigator informed participants if they made any identification errors. Once participants became 100% accurate in identifying tactile patterns, the investigator demonstrated the two ISI levels and the two intensity levels separately.

Figure 5. Participant donning tactile belt.

Upon completion of the tactile pattern training, the investigator demonstrated how to perform the arithmetic task. Next, the participants performed the arithmetic task for 2 min. Total training time lasted about 15 min for each participant.

4.5. Testing

During the experiment, each participant completed four blocks with the arithmetic task and four blocks without the arithmetic task. Participants were informed of whether or not the arithmetic task would be provided during each block. During each block, the participants verbally identified tactile patterns and indicated their perceived urgency level under various levels of stimulus intensity (12 dB and 23.5 dB) and ISI (0 ms and 500 ms). Ratings were based on a scale of 1 to 10, with 10 indicating extremely high urgency. Responses were recorded by the investigator. A typical response would be "Turn Right–7." When the arithmetic distractor task was provided, participants performed the arithmetic task in addition to the detection, identification, and perceived urgency task. Participants were not told that either task was more important. During all experimental trials, participants listened to continuous tank noise to mask the noise of the tactors. Upon completion of each block, participants completed a questionnaire about the block that they received (see appendix B). This questionnaire allowed participants to rate how well they were able to identify tactile patterns and perform the arithmetic task. A 5 min break was given after each block of the data collection. Total time to complete the experiment was approximately 2 h.

5. Results

Separate analyses of variance (ANOVA) were conducted on the percentage of patterns detected and correctly identified, ratings of perceived urgency, and ratings of pattern identification difficulty. Statistical significance was concluded when $p < 0.05$. Significant effects were examined post hoc with the least significance difference (LSD) test. Means and standard error of the means are presented in figures 6–12. Descriptive statistics (means and standard error of the means) are presented in appendix C.

5.1 Perceived Urgency

The analysis of the ratings of perceived urgency revealed an Inter-Stimulus Interval × Intensity interaction, $F(1, 15) = 23.128$, $p < 0.001$, with main effects of both ISI, $F(1, 15) = 19.418$, $p = 0.001$ and intensity, $F(1, 15) = 47.397$, $p < 0.001$. No other main effects or interactions were found.

The Inter-Stimulus Interval × Intensity interaction is shown in figure 6. Post hoc analyses revealed that when patterns were presented at both the 12 dB and 23.5 dB intensities, ratings of perceived urgency were higher when the ISI was 0 ms than at 500 ms. This interaction can be attributed to the main effects of ISI and intensity. Ratings of perceived urgency were significantly higher when the ISI of patterns was 0 ms than at 500 ms. In regard to intensity, ratings of perceived urgency were significantly lower when patterns were presented at 12 dB than at 23.5 dB.

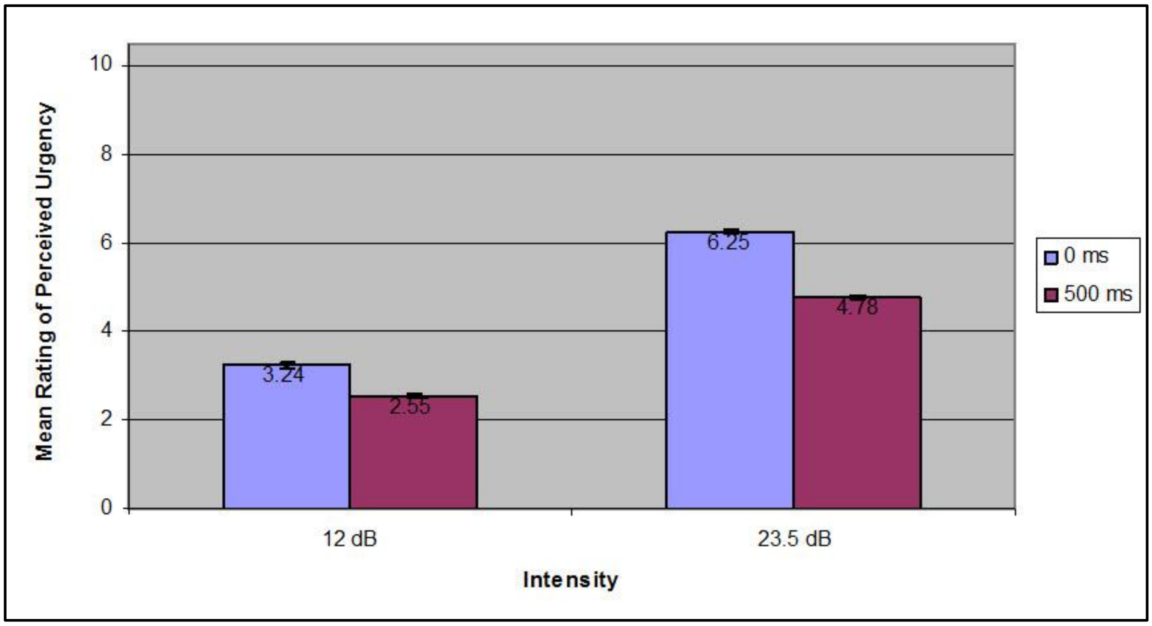

Figure 6. Inter-Stimulus Interval × Intensity interaction (rating of perceived urgency).

5.2 Percent Detected

The analysis of the percentage of patterns detected revealed an Inter-Stimulus Interval × Intensity interaction, $F(1, 15) = 4.623$, $p = 0.048$, with a main effect of intensity, $F(1, 15) = 7.816$, $p = .014$. A significant Inter-Stimulus Interval × Pattern interaction, $F(3, 45) = 3.824$, $p = 0.016$ was also indicated by the analysis. No other main effects or interactions were found.

The Inter-Stimulus Interval × Intensity interaction is shown in figure 7. Post hoc analyses revealed that when patterns were presented at an intensity of 23.5 dB, there was no significance in detection rates. However, when patterns were presented at an intensity of 12 dB, detection rates were higher when the ISI was 500 ms than at 0 ms. This interaction can be attributed to the main effect of intensity. A significantly greater percentage of patterns (1.32%) were detected when intensity was provided at 23.5 dB than at 12 dB. The Inter-Stimulus Interval × Pattern interaction is shown in figure 8. Post hoc analyses indicate that when the ISI was 500 ms, there was no significance in pattern detection rates. When the ISI was 0 ms, detection rates for “Move Forward” were significantly higher than “Turn Around.”

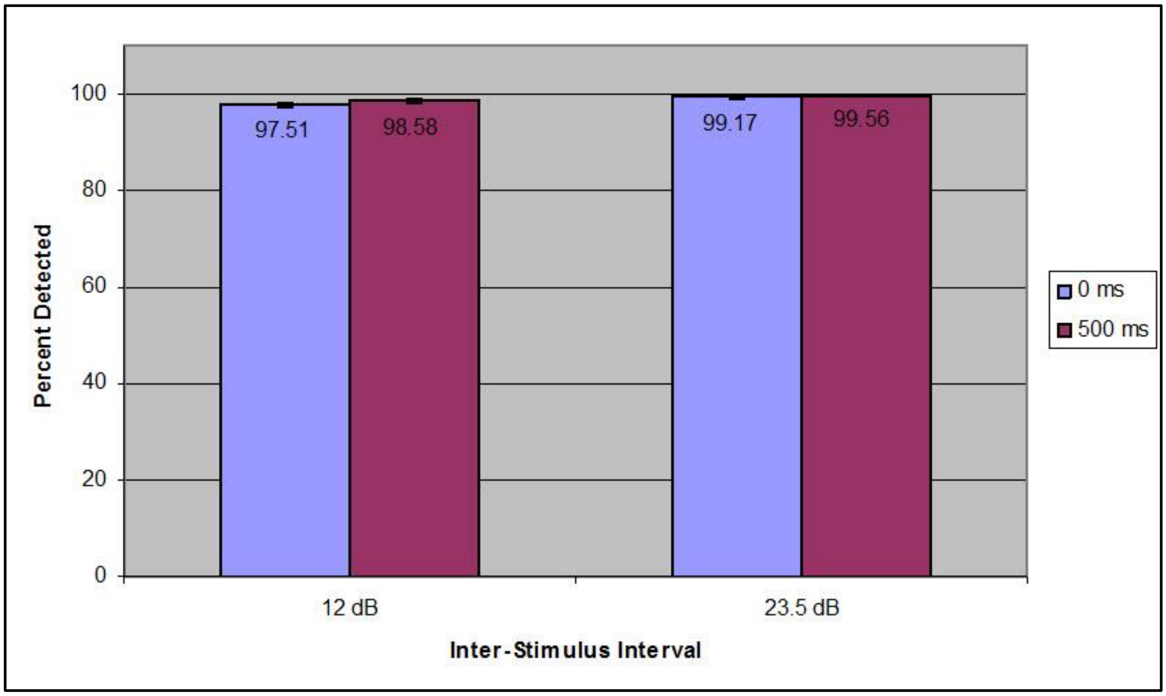

Figure 7. Inter-Stimulus Interval × Intensity interaction (percent detected).

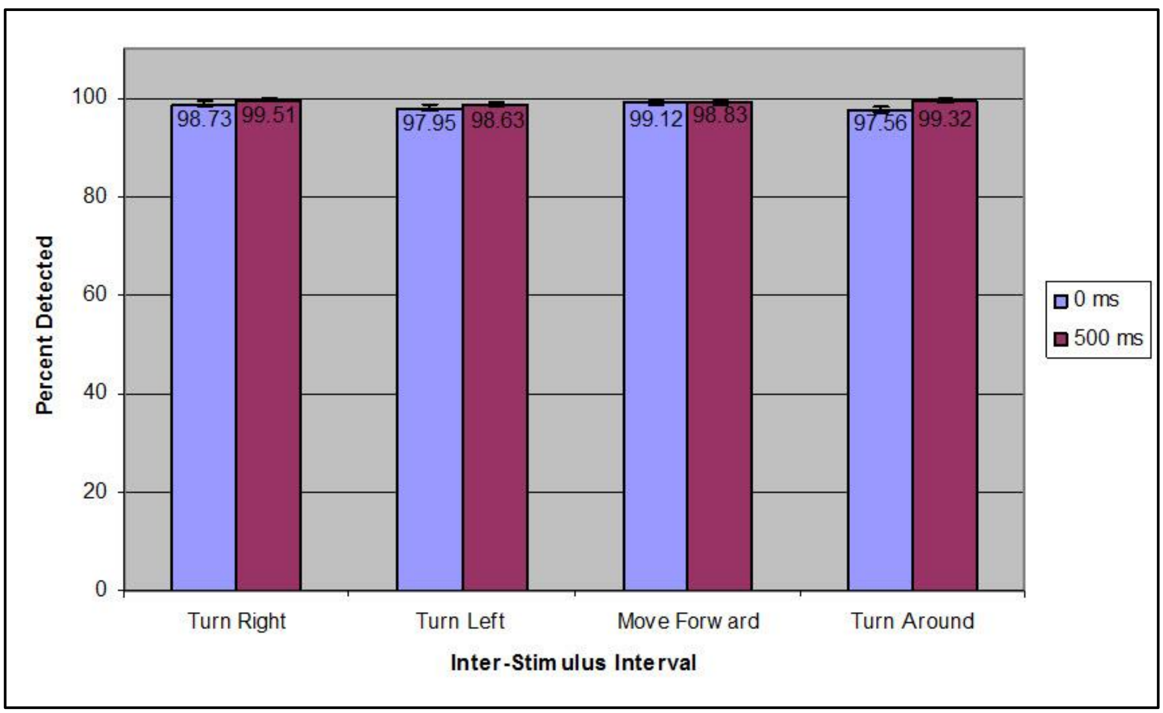

Figure 8. Inter-Stimulus Interval × Pattern interaction (percent detected).

5.3 Overall Percent Correct

The analysis of the overall percentage of correctly identified patterns revealed an Inter-Stimulus Interval × Intensity interaction, $F(1, 15) = 7.061$, $p = 0.018$, and a significant Intensity × Pattern × Arithmetic interaction, $F(3, 45) = 3.103$, $p = 0.036$. Results showed a main effect of intensity $F(1, 15) = 14.796$, $p = 0.002$. No other main effects or interactions were found.

The Inter-Stimulus Interval × Intensity interaction is shown in figure 9. Post hoc analyses revealed that when patterns were presented at an intensity of 23.5 dB, there was no significance in the overall percentage of correctly identified patterns. However, when patterns were presented at an intensity of 12 dB, identification rates were higher when the ISI was 500 ms than at 0 ms. This finding is similar to the Inter-Stimulus Interval × Intensity interaction for detection. The Intensity × Pattern × Arithmetic interaction is shown in figures 10 and 11. Post hoc analyses indicate that when intensity was provided at 12 dB, for "Turn Around," identification rates were significantly higher when the arithmetic was not provided than when the arithmetic was provided. However, identification rates for "Move Forward" were significantly lower when no arithmetic was provided than when it was provided. When intensity was provided at 23.5 dB, for "Turn Right," identification rates were significantly higher when arithmetic task was provided than when it was not provided. These interactions can be attributed to the main effect of intensity. A significantly lower percentage of patterns (2%) were correctly indentified when intensity was provided at 12 dB than at 23.5 dB.

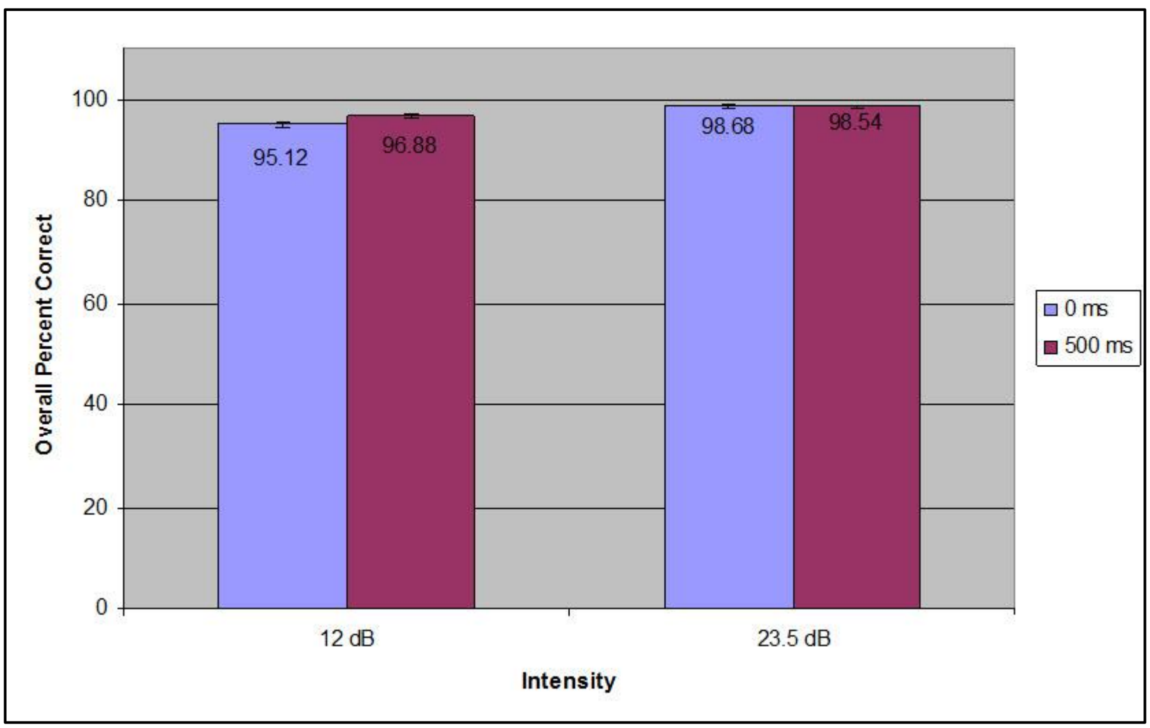

Figure 9. Inter-Stimulus Interval × Intensity interaction (overall percent correct).

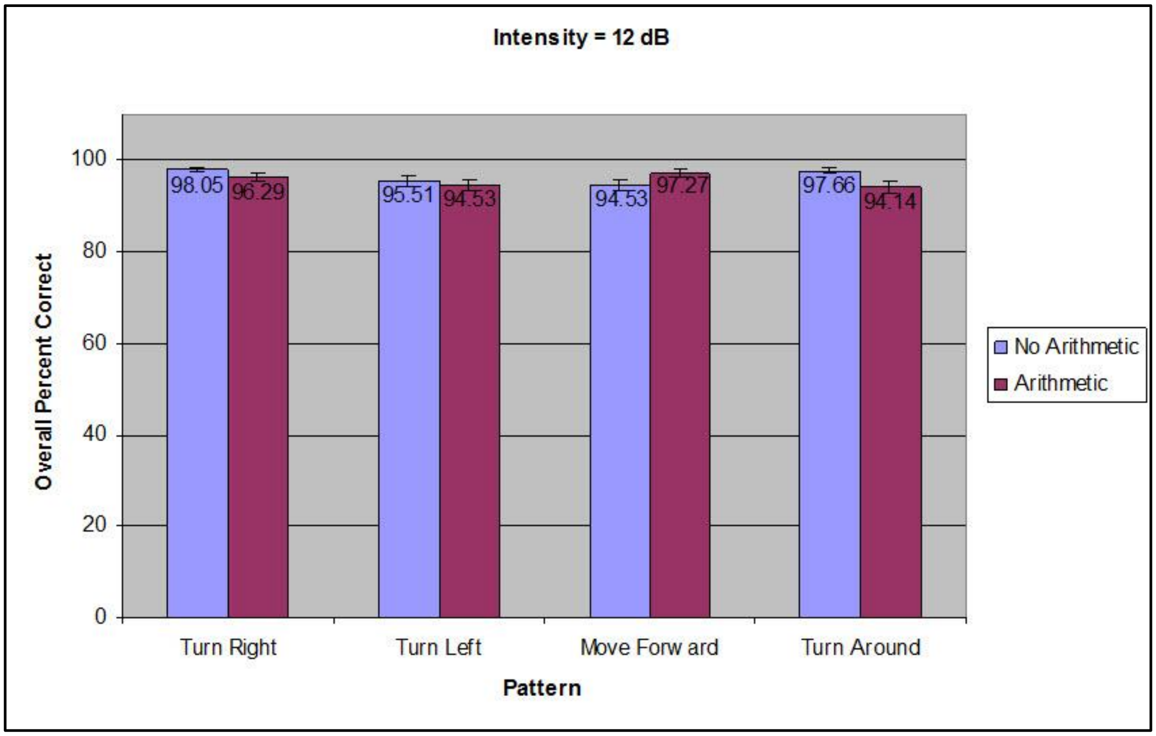

Figure 10. Intensity (12 dB) × Pattern × Arithmetic interaction (overall percent correct).

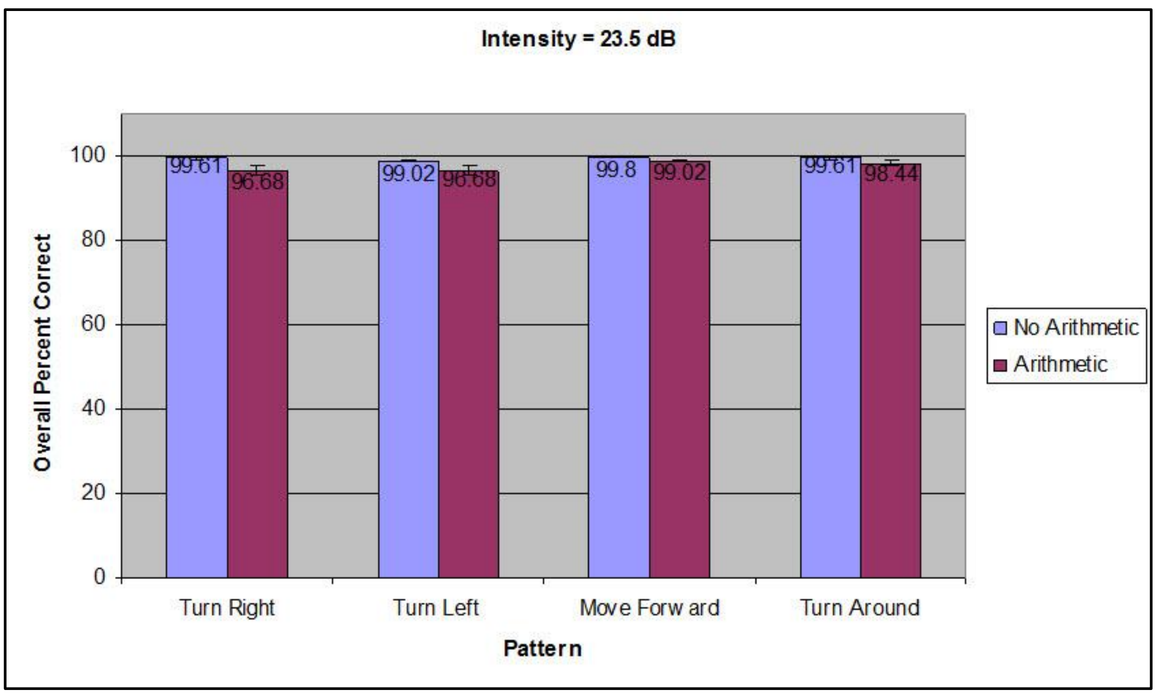

Figure 11. Intensity (23.5 dB) × Pattern × Arithmetic interaction (overall percent correct).

5.4 Identification Difficulty

Analysis of the ratings of the difficulty to identify patterns revealed a significant main effect of arithmetic, $F(1, 14) = 6.512$, $p = 0.023$. Ratings of difficulty were significantly higher when arithmetic was provided (figure 12).

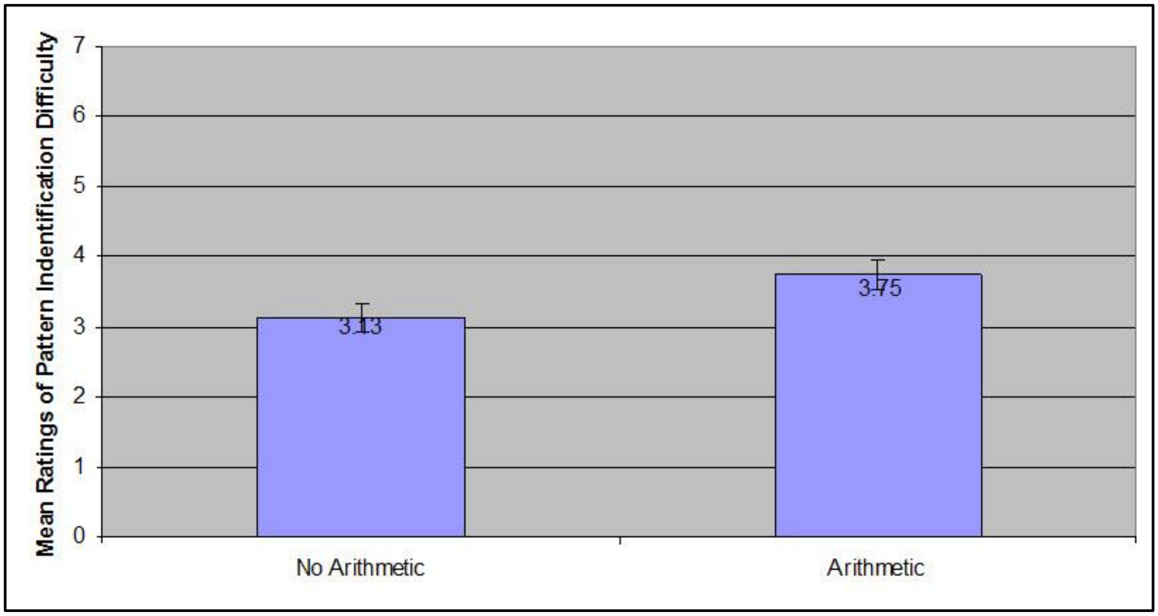

Figure 12. Mean rating of pattern identification difficulty by arithmetic.

6. Discussion

Although the use of tactile patterns has been successfully used to communicate messages, there may be a need to provide levels of priority or some sense of urgency to those patterns to enhance the information management of Soldiers. In an effort to maximize the benefits of tactile displays for Soldiers, it is essential that the manipulation of parameters such as frequency, intensity, duration, and ISI be explored. The objective of this study was to quantify the effects of ISI and stimulus intensity on perceived urgency and on the detection and identification of tactile patterns. Findings of this study will be discussed in light of the dependent variables and the hypotheses.

In regard to ratings of perceived urgency, intensity and ISI both had an effect on how participants rated the urgency of tactile patterns. Data from the Inter-Stimulus × Intensity interaction indicate that patterns provided at with no ISI at the strong 23.5 dB intensity were rated the most urgent, and patterns with the 500 ms ISI at the 12 dB intensity were rated the least urgent. These findings support our hypotheses regarding ratings of perceived urgency. Although patterns provided with the 500 ms ISI at the 12 dB intensity were rated the least urgent, these patterns provided for higher detection and identification rates than patterns provided with no ISI at the 12 dB intensity. Apparently these patterns were not as easily missed because they had a longer total duration, which made them more distinct than the patterns with no ISI. These findings are similar to those obtained for these parameters (intensity and ISI) in auditory display research. Auditory signals with shorter inter-pulse intervals and higher sound intensity pressure levels yielded greater perceived urgency (Haas and Edworthy, 1996; Haas and Casili, 1995).

It is important that users of tactile display systems are able to detect tactile stimuli regardless of the type of environment in which the stimuli is provided. In this investigation, detection rates were better when tactile patterns were provided at the strong 23.5 dB intensity than at the weaker 12 dB intensity. Data from the Inter-Stimulus Interval × Intensity interaction indicate that when tactile patterns were provided at the greater 23.5 dB intensity, ISI had no effect on detection rates. However, tactile patterns were more difficult to detect when they were provided at the weak 12 dB intensity with no ISI. It appears that patterns with no ISI or shorter total duration time were more easily missed when they were provided at the weaker intensity. The Inter-Stimulus Interval × Pattern interaction indicates that when no ISI was provided, it was more difficult to detect the "Turn Around" pattern than the "Move Forward" pattern. This finding may be explained by the shorter total duration time of patterns provided with no ISI and the difference in sensitivity thresholds for the belly and the back. For the "Move Forward" pattern, the sequence in which the tactors vibrate begins on the sides of the body and sweep toward the belly, and for the "Turn Around" pattern, the sequence begins on the sides and sweep toward the back. All participants in this investigation were male, and for males, the sensitivity thresholds on the back are slightly higher than the belly (Weinstein, 1968). Although significant effects were found, detection results were very high (97% and above) in this investigation.

In addition to users being able to detect tactile stimuli, it is important that users are able to distinguish or identify tactile stimuli as well. Similar to the detection findings, identification rates were better when tactile patterns were provided at the strong 23.5 dB intensity than at the weaker 12 dB intensity. The analysis also revealed a similar Inter-Stimulus Interval × Intensity interaction. ISI had no effect on identification rates at the strong 23.5 dB, but identification rates were lower when tactile patterns were provided with no ISI at the weak 12 dB intensity. This finding can be explained in the same way as the Inter-Stimulus Interval × Intensity interaction for detection. Data from the Intensity × Pattern × Arithmetic interaction indicate that when patterns were provided at the strong 23.5 dB intensity, identification rates were better when arithmetic task was provided than when it was not provided for "Turn Right." When tactile patterns were provided at the weak 12 dB intensity, identification rates were better when the arithmetic was not provided than when the arithmetic was provided for "Turn Around." Although identification rates were not significantly better for all patterns when the arithmetic was not provided as opposed to when it was provided, these findings partially support the hypothesis that states that detection and identification rates would be degraded when the arithmetic task was provided. However, on the contrary, identification rates for "Move Forward" were worse when no arithmetic was provided than when it was provided. Providing an explanation for this finding is rather difficult because it is unclear why this occurred. Significant effects were found in identification rates. However, results were very high (95% and above) in this study

In regard to the hypothesis that states that detection and identification rates would be degraded when the arithmetic distractor task was provided, the arithmetic distractor task did not degrade detection and identification rates. However, questionnaire results indicate that participants felt that it was harder to identify tactile patterns when the arithmetic distractor task was provided.

7. Conclusions and Future Work

Results of the present study show that the manipulation of ISI and intensity are a feasible means of adding a sense of urgency to tactile patterns. Despite the significance among the detection and identification findings, these findings are not very meaningful from a practical perspective since the results were so high. Therefore, it is difficult to identify one urgency level as more favorable than the other in the investigation. Adding this level of complexity to tactile patterns or messages will enhance the information management of Soldiers by allowing them to prioritize the tasks within their overall mission. This laboratory investigation was the first step in empirically determining the ability of Soldiers to detect and identify tactile patterns with varying urgency levels. However, this research should be extended to the field so that it encompasses more demanding, operationally relevant tasks such as performing dismounted maneuvers or riding in a vehicle. Greater significant effects are expected in the field. Also, a more in depth look should be taken at the number of levels of urgency and the number of patterns that are perceivable in Army relevant environments.

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Appendix A. Volunteer Agreement Affidavit

Informed Consent Form
Army Research Laboratory, Human Research & Engineering Directorate
Aberdeen Proving Ground, MD 21005

Title of Project: The Effects of Stimulus Intensity and Inter-Stimulus Duration on Perceived Urgency and the Ability to Detect and Identify Tactile Patterns

Project Number: ARL-

Sponsor: Army Research Laboratory

Principal Investigator: Timothy L. White
Army Research Laboratory
Human Research & Engineering Directorate
RDRL-HRS-B, Bldg. 459
Aberdeen Proving Ground, MD 21009
(410) 278-5884; timothy.l.white1@us.army.mil

Associate Investigator: Andrea S. Krausman
Army Research Laboratory
Human Research & Engineering Directorate
RDRL-HRS-B, Bldg. 459
Aberdeen Proving Ground, MD 21009
(410) 278-5933; andrea.krausman@us.army.mil

You are being asked to join a research study. This consent form explains the research study and your part in it. Please read this form carefully before you decide to take part. You can take as much time as you need. Please ask the research staff any questions at any time about anything you do not understand. You are a volunteer. If you join the study, you can change your mind later. You can decide not to take part now or you can quit at any time later on.

This appendix appears in its original form, without editorial change.

Purpose of the Study

The purpose of this study is to assess the effects of urgency on the detection and identification of tactile patterns. You are being invited to participate because you are in good health and are not taking medications for any health reasons

Procedures to be Followed

You will be asked to (1) to detect and identify tactile patterns and rate their urgency and (2) to perform an arithmetic task. Tactile patterns will be provided with a belt that will be worn around your waist on the outside of your shirt, and the arithmetic task will be presented on a computer screen. Before the testing period, you will be trained on the tactile patterns and the arithmetic task.

There will be a total of eight blocks in this experiment. Each block will last 10 minutes. In four of the blocks, you will only identify tactile patterns and provide an urgency rating of those patterns. In the other four blocks, you will perform an arithmetic task in addition to the pattern identification and urgency rating task. You will rate the urgency of the tactile patterns you receive on a scale of 1 to 10, with 10 indicating an extremely urgent pattern. Random tactile patterns will be presented with varying intensity and inter-stimulus intervals during each block. When tactile patterns are received, you will be asked to verbalize the tactile pattern received and rate its urgency (for example: "Turn Right – 7"). There will be 64 trials per block for a total of 512 trials to complete the experiment.

After each block, you will be asked to complete a questionnaire to rate how well you were able to identify tactile patterns and perform the arithmetic task (if provided). You will be given the opportunity to rest for 5 minutes after each block. The investigator will record any comments that you may have during this investigation.

Discomforts and Risks

The risks to you in this experiment are considered minimal. They are not unlike those to which you might be exposed when reading a standard computer screen. These risks might include headaches and eye strain associated with observing the visual display.

Benefits

There are no personal benefits for you for taking part in this study. However, your participation will provide valuable information about Soldier performance that will assist in the design of future Army systems.

Duration

It will take approximately 2 hours for you to take part in this study.

Confidentiality

Your participation in this research is confidential. The data will be stored and secured at Aberdeen Proving Ground, in a locked file cabinet. The data, without any identifying information, will be transferred to a password-protected computer for data analysis. After the data is put in the computer file, the paper copies of the data will be shredded. This consent form will be sent to Army Research Laboratory's Institution Review Board, where it will be retained for a minimum of three years.

If the results of the experiment are published or presented to anyone, no personally identifiable information will be shared. Publication of the results of this study in a journal or technical report, or presentation at a meeting, will not reveal personally identifiable information. The research staff will protect your data from disclosure to people not connected with the study. However, complete confidentiality cannot be guaranteed because officials of the U. S. Army Human Research Protections Office and the Army Research Laboratory's Institutional Review Board are permitted by law to inspect the records obtained in this study to insure compliance with laws and regulations covering experiments using human subjects.

We would like your permission to take pictures during the experimental session. The pictures will be printed in technical reports and shown during presentations when we describe the results of the study. To protect your identity, we will pixelate the image to obscure your face. You can still be in the study if you prefer not to be photographed. Please indicate below if you will agree to allow us to take pictures of you.

I give consent to be photographed during this study: ____Yes ____No
please initial:____

Contact Information for Additional Questions

You have the right to obtain answers to any questions you might have about this research both while you take part in the study and after you leave the research site. Please contact anyone listed at the top of the first page of this consent form for more information about this study. You may also contact the Chairperson of the Human Research & Engineering Directorate, Institution Review Board, at (410) 278-5992 with questions, complaints, or concerns about this research, or if you feel this study has harmed you. The chairperson can also answer questions about your rights as a research participant. You may also call the chairperson's number if you cannot reach the research team or wish to talk to someone else.

Voluntary Participation

Your decision to be in this research is voluntary. You can stop at any time. You do not have to answer any questions you do not want to answer. Refusal to take part in or withdrawing from this study will involve no penalty or loss of benefits you would receive by staying in it.

Military personnel cannot be punished under the Uniform Code of Military Justice for choosing not to take part in or withdrawing from this study, and cannot receive administrative sanctions for choosing not to participate.

Civilian employees or contractors cannot receive administrative sanctions for choosing not to participate in or withdrawing from this study.

You must be 18 years of age or older to take part in this research study. If you agree to take part in this research study based on the information outlined above, please sign your name and the date below.

You will be given a copy of this consent form for your records.

This consent form is approved from to .

Do not sign after the expiration date of

______________________________________ ____________________

Participant Signature Date

____ ____________________

Person Obtaining Consent Date

Appendix B. Post-Block Questionnaire

Post-Block Questionnaire

Participant #: ___ Block ___ Arithmetic Yes or No

Answer each question below by placing an "X" in the bracket that best describes your experience in the experimental block you *just* completed.

Please answer the following question.

1. How difficult or easy was it to identify the tactile patterns and their urgency levels.

Extremely Difficult	←	→	*Neither Difficult Nor Easy*	←	→	*Extremely Easy*
[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

Comment: ____

If you received the arithmetic task in your last block, please answer the following question.

2. How difficult or easy was it to perform the arithmetic task.

Extremely Difficult	←	→	*Neither Difficult Nor Easy*	←	→	*Extremely Easy*
[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

Comment: ____

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Appendix C. Descriptive Statistics (Means and Standard Error of the Means [SEM])

Percent Detected

Intensity

Intensity	Mean	SEM
12 dB	98.05	0.274
23.5 dB	99.37	0.164

Inter-Stimulus Interval (ISI) x Intensity

ISI	Intensity	Mean	SEM
0 ms	12 dB	97.51	0.448
	23.5 dB	99.17	0.287
500 ms	12 dB	98.58	0.314
	23.5 dB	99.56	0.161

Inter-Stimulus Interval x Pattern

ISI	Pattern	Mean	SEM
0 ms	Turn Right	98.73	0.502
	Turn Left	97.95	0.613
	Move Forward	99.12	0.348
	Turn Around	97.56	0.623
500 ms	Turn Right	99.51	0.257
	Turn Left	98.63	0.406
	Move Forward	98.83	0.384
	Turn Around	99.32	0.350

Overall Percent Correct

Intensity

Intensity	Mean	SEM
12 dB	96.00	0.389
23.5 dB	98.61	0.229

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Inter-Stimulus Interval x Intensity

ISI	Intensity	Mean	SEM
0 ms	12 dB	95.12	0.627
	23.5 dB	98.68	0.323
500 ms	12 dB	96.88	0.458
	23.5 dB	98.54	0.325

Intensity x Pattern x Arithmetic

Intensity	Pattern	Arithmetic	Mean	SEM
12 dB	Turn Right	No	98.05	0.595
	Turn Left	No	95.51	1.158
	Move Forward	No	94.53	1.357
	Turn Around	No	97.66	0.704
	Turn Right	Yes	96.29	1.041
	Turn Left	Yes	94.53	1.385
	Move Forward	Yes	97.27	0.887
	Turn Around	Yes	94.14	1.344
23.5 dB	Turn Right	No	99.61	0.275
	Turn Left	No	99.02	0.430
	Move Forward	No	99.80	0.195
	Turn Around	No	99.61	0.275
	Turn Right	Yes	96.68	1.051
	Turn Left	Yes	96.68	1.014
	Move Forward	Yes	99.02	0.430
	Turn Around	Yes	98.44	0.772

Ratings of Perceived Urgency

Inter-Stimulus Interval

ISI	Mean	SEM
0 ms	4.74	0.044
500 ms	3.66	0.034

Intensity

Intensity	Mean	SEM
12 dB	2.90	0.029
23.5 dB	5.51	0.039

Inter-Stimulus Interval x Intensity

ISI	Intensity	Mean	SEM
0 ms	12 dB	3.24	0.047
	23.5 dB	6.25	0.056
500 ms	12 dB	2.55	0.034
	23.5 dB	4.78	0.048

Ratings of Identification Difficulty

Arithmetic

Arithmetic	Mean	SEM
No	3.13	0.196
Yes	3.75	0.193

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