ARMY RESEARCH LABORATORY

Rapid Wall-Breaching Kit, Ingress Hole Determination Experiment

by Daniel D. Turner, Christian B. Carstens, Elizabeth S. Redden, and Joseph B. Whalen

ARL-TR-3064 **October 2003**

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Weapons & Materials Research Directorate, ARL

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14. ABSTRACT

The Human Research and Engineering Directorate of the U.S. Army Research Laboratory conducted an experiment to determine what size breaching hole is necessary for a soldier with a “fighting load” to enter a building in a tactical and timely manner. The results from this experiment were used to determine requirements for wall breaching technology.

The experiment was conducted at McKenna Military Operations in Urban Terrain (MOUT) site Ft. Benning, Georgia. Soldiers from the Ranger Training Brigade and Headquarters Company 3/11th Infantry participated in the experiment. The soldiers were divided into infantry squads and participated in an exercise that involved crossing a danger area, entering a building through the three different size holes, and clearing the initial room. After participating in each mission, the soldiers were given a questionnaire to solicit information about their capabilities and limitations to enter the building. Each event was also timed to determine a mean time for entry with each hole.

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1. Introduction

1.1 Background

The U.S. Army is preparing to initiate a contract for a rapid wall-breaching kit (RWBK). In order to determine the technology required to breach holes in walls made of different construction, the Army must determine what size hole is necessary for a soldier with a "fighting load" to enter in a tactical and timely manner. During the military operations in urban terrain (MOUT) advanced concepts technology demonstration (ACTD), several different wall-breaching munitions were evaluated, and most were capable of blowing large holes in all types of construction. However, no experimentation was conducted during the MOUT ACTD to collect data about the timeliness of entering buildings through these holes of varying sizes, nor were any data collected about the tactical effectiveness of soldiers entering buildings through these holes.

The U.S. Army Research Laboratory's (ARL) Human Research and Engineering Directorate, Fort Benning, Georgia, Field Element suggested the baseline hole size of 30 inches by 50 inches during the MOUT ACTD. The height of the hole was based on the height of a 95th percentile crouching man. The width was based on the shoulder width of a 95th percentile man wearing fighting load equipment.

The Office of the Product Manager Close Combat Systems (PM-CCS) requested ARL to conduct an experiment. The purpose of the experiment was to determine the minimum size hole that would allow an infantry squad to safely and quickly pass through. There were three ingress holes to be evaluated, one baseline ingress hole (A, a 30- by 50-inch hole) and two potential candidate ingress holes (B, a 39-inch circular hole and C, a 26- by 44-inch hole).

1.2 Purpose

The purpose was to investigate the time required for a nine-man squad in full "fighting load" to enter through the three specified breaching hole sizes.

2. Method

2.1 Overview of Experiment

A total of 34 soldiers wearing the "fighting load" organized into 30 different 9-man infantry squads, traversed the course, and entered the building during combat conditions through the three specified breaching hole sizes. Because of the limited number of soldiers available for this

experiment, the 34 soldiers were organized into different positions and squads (i.e., soldier 1 could be the squad leader for the first squad and could be used as a rifleman in the second squad) for each of the 30 squads (see appendix A). This allowed for organizing limited numbers of soldiers into the 30 different 9-man squads. The assumption was that if the squads were comprised of different soldiers occupying different positions in the squads, then technically, each of the 30 squads was different.

This experiment was executed over four days with 12 men each day. Soldiers received familiarization training on MOUT tactics, techniques, and procedures (TTPs) for crossing a danger area (i.e., moving across a street from building to building), entering a building through an explosive breach, and clearing a room. They were briefed at the beginning of each day to ensure that they understood what was required of them during the day's events. They conducted trials of crossing a danger area and entering the building using squad TTPs, as outlined in Field Manual (FM) 90-10-1, FM 3-06.11, and Army Drill Number 6 (*1, 2, 3*). Control personnel ensured that all movement was conducted in a tactical manner throughout the experiment. The experiment was conducted during prevailing weather conditions at Fort Benning's McKenna MOUT site (see figure 1) during the period of 21 to 25 October 2002.

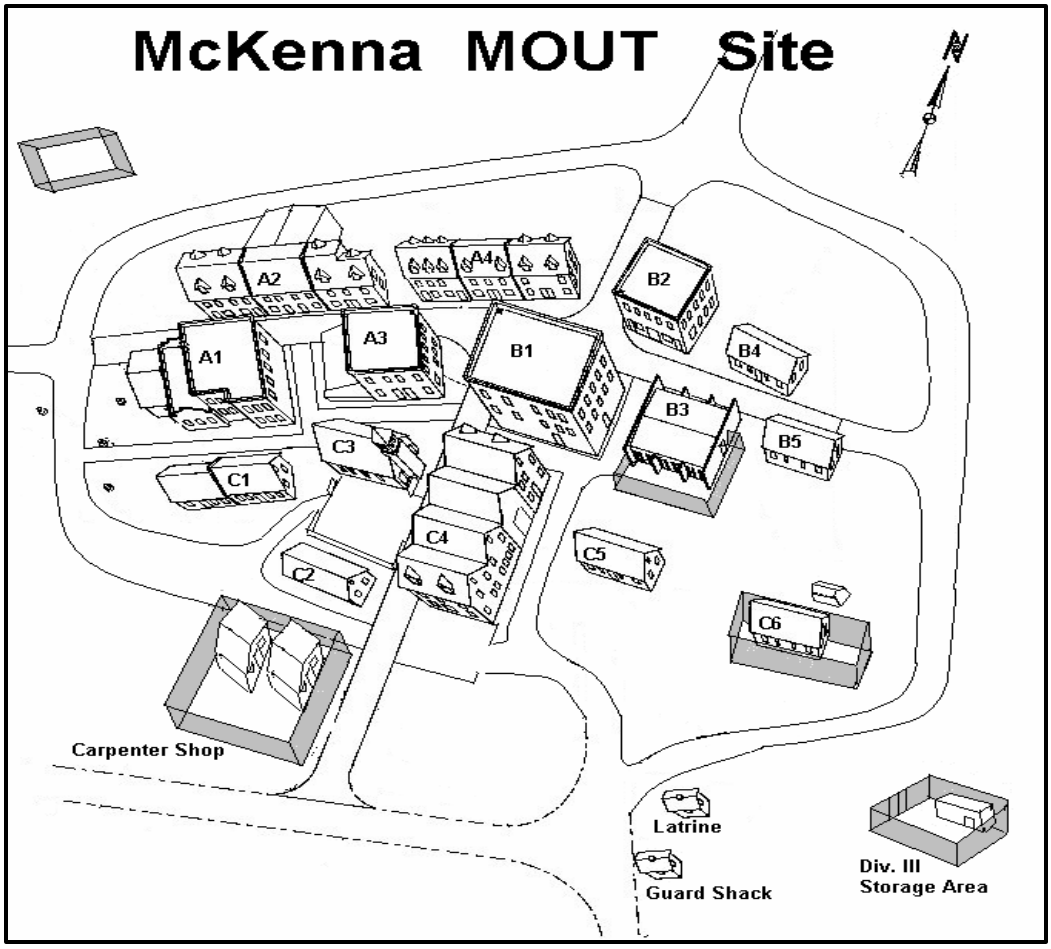

Figure 1. McKenna MOUT site.

2.2 Participants

Soldiers from the Ranger Training Brigade and the 3/11th Infantry Regiment participated in this experiment. Two noncommissioned officers (NCOs) from ARL's Fort Benning Field Element also participated in the experiment. The soldiers ranged in age from 19 to 42 years of age, with the mean age being 25.8 years. The soldiers ranged from 67 inches to 74 inches in height (24th to 96th percentile), with a mean of 70 inches. They ranged from 145 pounds to 215 pounds in weight (12th to 96th percentile), with a mean of 175.44 pounds. Their shoulder circumference ranged from 41.5 inches to 55.75 inches (2nd to 99th percentile), with a mean of 49.7 inches. Because the sample size was smaller than anticipated, some of the soldiers participated on two or more days of the experiment. Twenty-two soldiers participated for one day only, ten participated for two days, and two participated for three days.

The following ensured the voluntary nature of participation:

- Copies of the consent form were provided to all participating subjects before the experimentation began (results are on file for all participants).
- Subjects were given an opportunity to review the experiment objectives, could have any of their questions answered by the investigators, and were asked to sign a consent form indicating their informed voluntary consent to participate.
- All designated subjects chose to participate in all the experiment trials planned.

2.2.1 Pre-test Orientations and Volunteer Agreement

Each day, the soldiers were assembled and given an orientation about the purpose of the study and their participation. They were briefed about the objectives and procedures for the experiment, the equipment used, and the simulated holes they were required to use throughout the experiment. Any questions the soldiers had regarding the studies were answered. In addition, the volunteer agreement affidavit was explained, and its contents were read to the experiment soldiers. The soldiers were given the volunteer agreement affidavits to sign.

2.2.2 Medical Review and Screening

Before assignment to this experiment, the soldiers' units were asked to review the soldiers' medical records to ensure that none of the volunteers had medical profiles or histories that would jeopardize their safe participation in this investigation. After the soldiers arrived at the experiment site, the investigators asked them if any of them had a medical profile or history that would jeopardize them if they participated in the study. Soldiers were asked to complete the medical status form shown in appendix B. The results of this medical status form are on record at the Fort Benning Field Element.

2.3 Apparatus

2.3.1 Standard Fighting Load

All tasks planned for this experiment were a normal part of the infantryman's job. The soldiers completed this experiment while wearing their individual "fighting load." Tables 1 and 2 show the standard "fighting loads" and the individual loads by position in the squad. There are many different standard "fighting loads" within the Army. The load used for this report is the "fighting load" used in the MOUT ACTD and listed in that final report.

Table 1. Common clothing and equipment items worn or carried by all soldiers

Item Description
Underclothing and socks
Battle dress uniform
Belt with buckle
Boots
Hand grenades (two each inert)
Individual first aid kit
Assigned weapon by duty position
Personal armor system ground troop (PASGT) helmet
Pistol belt
Suspenders/load-bearing equipment
First aid packet
Canteen 1-quart (2)
Canteen 2-quart (1)
Ear plugs
Protective mask
Decontamination kit
Flashlight
One meal ready to eat (MRE)
Camouflage stick
Weapons cleaning kit
Bayonet
Soldier integrated multiple laser system (SIMLAS)
Goggle, protective
Elbow pads
Knee pads
Gloves (hatch resistant)
Kenwood radio
Shark headset
MOUT body armor
Flash bang (2)

Table 2. Fighting load by squad duty position

Squad Leader	Team Leader	Squad Automatic Weapon (SAW) Gunner	Grenadier	Rifleman
Compass	Compass			
M4 rifle with close combat optic (CCO) M68	M4 rifle with CCO M68	M249 SAW with bipod	M203 grenade launcher	M4 rifle with CCO M68
Ammunition pouches (2)	Ammunition pouches (2)	SAW soft pouch (6)	Grenadier vest	Ammunition pouches (2)
Magazine (7)	Magazine (7)		40-mm ammunition (24)	Magazine (7)
			Magazine (7)	
Ammunition (210)	Ammunition (210)	Ammunition (600)	Ammunition 5.56 (210)	Ammunition (210)
		Claymore (1)	Claymore (1)	Claymore (1)

2.3.2 Ingress Hole Descriptions

Each of the ingress holes used in this experiment was made from an 8-inch thick wall, with reinforcement bars (re-bar) simulated by wood dowels 1.125 inches long and 0.5 inch in diameter on 12-inch centers (see figures 2 through 4). The re-bar was positioned for the maximum number of re-bars in the opening. The bottom of the hole was 16 inches off the floor.

Figure 2. Hole A: 30- by 50-inch hole with 8- to 9-inch radius corners.

Figure 3. Hole B: 39-inch circular hole.

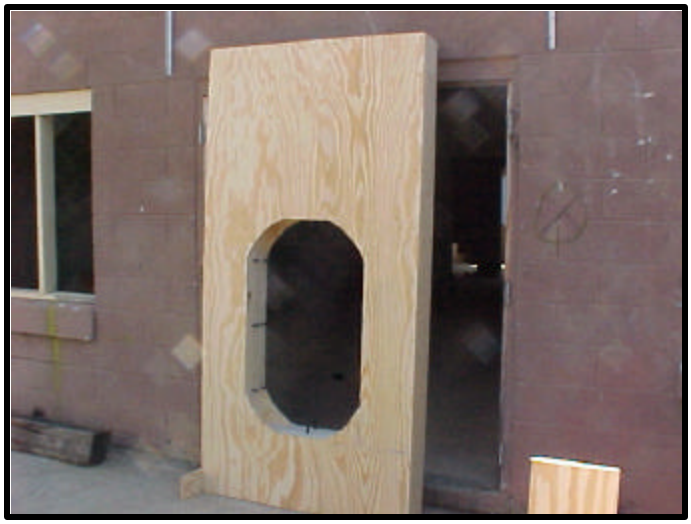

Figure 4. Hole C: 26- by 44-inch hole with 8- to 9-inch radius corners.

2.3.3 Questionnaires

Questionnaires were designed to elicit soldiers' opinions about their performance and experiences while entering the building through each of the candidate breaching holes. The questionnaires were designed to enable soldiers to rate the degree of difficulty or ease that each of the breaching holes offered for ingress into the building, using a seven-point scale ranging from "extremely easy" to "extremely hard." Questionnaires were administered to each soldier at the completion of each trial. Data collection questionnaires were designed to record times for the squad and individual fire teams to enter the specified breaching holes and for data collectors to record soldier comments.

2.3.4 Description of McKenna MOUT Site

The experiment was conducted at the McKenna MOUT site (see figure 1) in the two northwestern buildings of the site. Building A2 was the staging point for the squad to cross a danger area (the street) and enter a building (building A1).

2.4 Procedures

2.4.1 Training

The soldiers were in a military occupational specialty (MOS) 11B that would be expected to conduct this type of offensive combat action (*2*). No specialized experience was required. However, the soldiers were shown how to negotiate the courses safely and were trained in specific procedures as required. Before the first training presentation, the soldiers were given a roster number, which was used to identify them throughout the experiment.

The initial MOUT training was accomplished at the McKenna MOUT site. The NCO in charge (NCOIC) of the Fort Benning Field Element presented TTPs for crossing a danger area and entering a building through a hole provided by an explosive demolition. The demolition was simulated, since no demolitions were used during this experiment. The PM provided dimensions of sizes of holes to be investigated. During this presentation, the soldiers were taught the key elements of battlefield maneuvers in a MOUT environment. Figures 5 and 6 show a typical squad entering the ingress holes during training while wearing the "fighting load."

Figure 5. Alpha fire team entering ingress hole.

Figure 6. Bravo fire team entering ingress hole.

2.4.2 Ingress Times

Thirty squads participated in the attack of a building, entered through one of three candidate breaching holes by fire team, and cleared the initial room. This was accomplished in accordance with guidance in references (*2*) and (*3*).

The soldiers were organized into four 12-man units, with one unit participating each day. The 12-man units were organized into a standard 9-man squad with the extra soldiers rotating in and out, forming new squads. This allowed ample resting time and provided the flexibility of staffing six to eight different squad compositions per day. The table in appendix A shows the squad composition of the 30 squads. Although the units were officially tasked to provide soldiers, it was made clear that soldier participation in the experimentation was voluntary.

The squad started in building A2 of the McKenna MOUT site (see figure 7). The Alpha fire team crossed the street and aligned themselves on the outside of building A1 (see figure 8) while the Bravo fire team provided covering fires. The SAW gunner, who was the first soldier in the stack, threw a practice grenade into the opening, and upon command from the controller, started the fire team's ingress of the specified hole. Time was started when the first soldier from Alpha fire team started through the hole and ended when the last soldier in that fire team had entered the building. When the Alpha fire team had cleared the room, the fire team leader gave an all-clear signal, which was the signal for the squad leader and the Bravo fire team to cross the street and enter the building. The same method of timing was used for the Bravo fire team. The times for both fire teams were added for a total time for the squad.

Figure 7. Starting point.

Figure 8. Ingress hole B.

2.5 Experimental Design

2.5.1 Independent Variable

The experimental design was a cross-over design with hole (A, B, and C), trial number (first, second, or third), and squad number (1 through 30) as the independent variables.

2.5.2 Dependent Variables

The primary dependent measure was the time it took for the two fire teams of the squad to traverse the breach hole. Questionnaires addressing the ease of access through the breach holes were administered after each trial.

2.5.3 Experimental Design Matrix

Table 3 shows the experimental design matrix used during the experiment. Every effort was made to ensure that the matrix did not duplicate any one participant traversing one of the three ingress holes while in the same duty position within the squad.

Table 3. Experimental design matrix

Squad	Trial 1	Trial 2	Trial 3
1	A	B	C
2	B	C	A
3	C	A	B
4	C	A	B
5	B	C	A
6	A	B	C
7	C	B	A
8	B	A	C
9	A	C	B
10	C	A	B
11	B	C	A
12	A	B	C
13	C	B	A
14	B	A	C
15	A	C	B
16	A	B	C
17	B	C	A
18	C	A	B
19	C	B	A
20	B	A	C
21	A	C	B
22	A	B	C
23	B	C	A
24	C	A	B
25	C	A	B
26	B	C	A
27	A	B	C
28	A	B	C
29	B	C	A
30	C	A	B

2.6 Limitations

Last-minute notification of a shortage of soldiers by the unit tasked to support this experiment created a problem with the sample size. The experiment director was able to replace some of these soldiers by requesting soldiers from the 3/11th Infantry.

In addition to the time data, we also attempted to collect killed in action (KIA) and wounded in action (WIA) data for each trial.

Because of a malfunction in the soldier integrated multiple laser system (SIMLAS), the KIA and WIA data were not collected. The experiment directorate experienced too many malfunctions with the system to provide accurate data.

3. Results

3.1 KIA and WIA Results

Data were not collected because of problems identified in section 2.6.

3.2 Training

All soldiers were trained in the correct TTPs for crossing a danger area and entering and clearing a room each day. There were no reported problems or deficiencies in the training, and all soldiers reported they were adequately trained to participate in the experiment.

3.3 Demographics

Demographic data were taken from each soldier. Data concerning their infantry experience were included in the demographic data sheet. A summary of demographic data is shown in appendix C. Figures 9 through 11 show a typical largest and smallest man standing beside each of the candidate ingress holes in their "fighting load."

Figure 9. Ingress hole A.

Figure 10. Ingress hole B.

Figure 11. Ingress hole C.

3.4 Ingress Time Data

An analysis of variance (ANOVA) was conducted with hole (A, B, and C), trial number (first, second, or third), and squad number (1 through 30) as the independent variables and ingress time in seconds as the dependent variable. (See appendix D for the raw ingress time data.) The results of the ANOVA are summarized in table 4. There was no significant effect for trial number: $F(2,56) < 1.00$. The main effect for squad was statistically significant: $F(29, 56) = 6.70$, $p < .001$. This reflects the fact that there was a learning curve for ingress times; the later squads were faster than the earlier ones. The correlation between squad (numbered sequentially by order of participation) and ingress time was $r = -.553$, $p < .001$. The main effect for hole was statistically significant: $F(2,56) = 64.37$, $p < .001$. The means and standard deviations for the three holes were hole A, M = 10.90, SD = 1.04; hole B, M = 13.34, SD = 1.69; hole C, M = 12.78, SD = 1.64.

Table 4. ANOVA summary table, ingress times

Source	Type III Sum of Squares	df	Mean Square	F	p
Order	.93	2	.46	.61	.547
Hole	98.23	2	49.11	64.37	.000
Squad	148.24	29	5.11	6.70	.000
Error	42.73	56	.76		

The mean ingress times for the three breach holes are illustrated in figure 12. Ensuing paired comparison *t*-tests among the three means were conducted with Holm's sequential Bonferroni to control for family-wise error (see table 5). The mean for each hole was significantly different from the other two means.

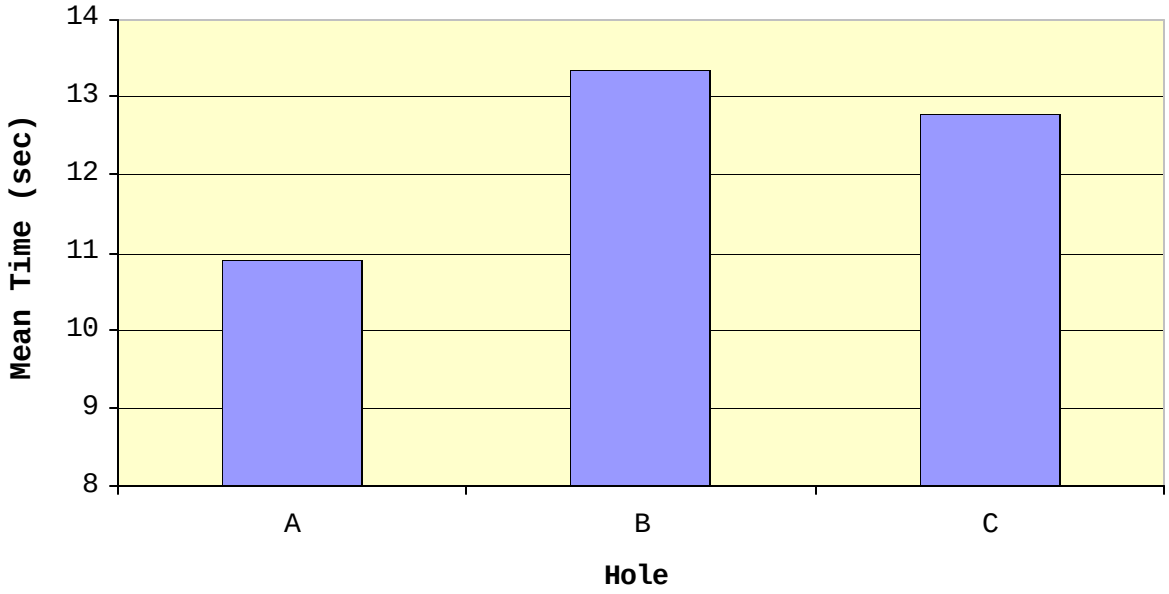

Figure 12. Mean ingress times in seconds by hole.

Table 5. Holm's sequential Bonferroni ensuing comparisons of mean ingress times in seconds n = 30 squads

Comparison	Required alpha	t	df	Significance
A versus B	.017	10.2	29	< .001*
A versus C	.025	9.27	29	< .001*
B versus C	.05	2.44	29	.021*

*Statistically significant

The breach hole ingress times were also analyzed separately for the lead (Alpha) and ensuing (Bravo) fire teams. The lead team always consisted of four soldiers, and the ensuing team always consisted of five soldiers. The descriptive statistics for the fire teams are shown in table 6 and figure 13.

Table 6. Mean and SD ingress times in seconds for the fire teams

	Lead Fire Team		Ensuing Fire Team	
Hole	Mean	SD	Mean	SD
A	5.04	0.60	5.86	0.85
B	6.14	1.19	7.00	0.95
C	5.81	0.64	6.98	1.29

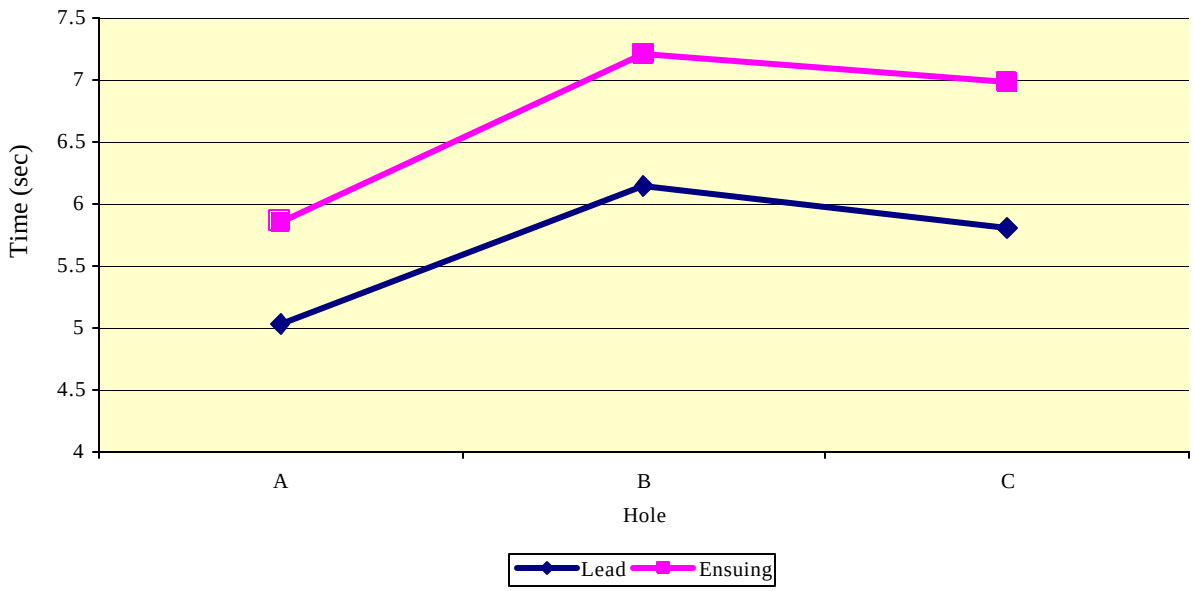

Figure 13. Mean ingress times in seconds for fire teams.

In the ANOVA for the lead fire team ingress times, there was no significant effect for Order [F(2,56) < 1.00. The F value for squad was significant [F(2,56) = 4.02, *p* = .000.] As in the analysis of squad ingress times, this indicates that there was a learning curve; the later fire teams breached the holes more quickly than the earlier ones. The main effect for hole was statistically significant [F(2,56) = 26.14, *p* = .001.]

The ANOVA on ingress times for the ensuing fire team indicated no significant effect for Order [F(2,56) < 1.00.] There was a significant effect for squad [F(2,56) = 6.90, *p* = .000.] The main effect for hole was significant [F(2,56) = 41.74, *p* , .001.]

Ensuing pair-wise comparison *t*-tests among means were done with Holm's sequential Bonferroni to control for family-wise error (see table 7). For both the lead and ensuing fire teams, the mean ingress time for hole A was significantly less than the mean times for holes B and C. There was no significant difference between the mean ingress times for holes B and C.

Table 7. Holm's sequential Bonferroni ensuing comparisons fire team ingress times in seconds

Fire Team	Comparison	Required alpha	t	df	Significance
Lead	A versus B	.025	6.33	29	< .000*
	A versus C	.017	6.72	29	< .000*
	B versus C	.05	1.94	29	.062
Ensuing	A versus B	.017	10.43	29	< .000*
	A versus C	.025	6.63	29	< .000*
	B versus C	.05	1.36	29	.183

*Statistically significant

3.5 Questionnaire Data

Each participant was given a brief questionnaire after each ingress trial. The first three questions used a seven-point Likert scale, with 1 indicating "extremely hard" and 7 indicating "extremely easy." The first question asked about the ease of traversing the hole. As shown in table 8, the soldiers found hole A to be the easiest, hole C to be somewhat harder, and hole B to be the hardest. The next question asked about the soldier's ability to observe objects inside the room while he traversed the hole. The soldiers rated visual access the best with hole A and the worst with hole B. The third question addressed the soldiers' confidence in the ability of the fire team to traverse the hole quickly. Again, hole A received the best rating, hole B the worst, and hole C was in the middle.

Table 8. Mean Likert scale questionnaire ratings

Question	Hole A	Hole B	Hole C	F	p
Ease of traversing hole	5.37	3.43	4.40	122.5	< .01
Vision while traversing hole	5.11	3.28	4.26	101.6	< .01
Fire team's ability to traverse hole quickly	5.35	3.37	4.33	135.1	< .01

Four other questions were answered in a "yes/no" format. The responses are summarized in table 9. Two of the questions asked whether there was a problem with equipment becoming entangled in the hole or the simulated re-bar. On both questions, hole B was seen as the most problematic and hole A, the least. Another question asked if there were safety issues while soldiers breached the hole. Safety concerns were the greatest with hole B and the least with

hole A. A final question asked if the height of the hole off the ground was adequate for ingress. Almost all the soldiers reported that hole A was adequate, but only 58% said that the height of hole B was adequate; 84% of the soldiers commented that hole C was adequate. All three holes were the same height off the ground, and the intent of the question was to determine if hole size and height off the ground interacted to impact ingress ease. However, it is believed the soldiers equated this question, and possibly the height off the ground, with the overall height of the hole.

Table 9. Percent of soldiers responding "yes" to questions

Question	Hole A	Hole B	Hole C	Chi^2	p
Equipment entangled in hole?	1.5	15.5	9.6	33.1	< .01
Equipment entangled in rebars?	1.1	14.4	10.7	31.8	< .01
Safety issues?	2.2	15.9	5.2	30.1	< .01
Height of hole off ground adequate?	97.4	57.6	84.0	137	< .01

A synopsis of soldier comments is shown in table 10. These comments are a recapitulation of the soldier's written comments on the questionnaires. The soldiers reported the least problems with hole A and the most with hole B.

Note: There appears to be some confusion on the soldiers' comments in regards to threshold height. It is possible that the soldiers were indicating that the top of the hole needed to be higher and not necessarily the threshold.

4. Discussion

The mean time for an infantry squad to enter through candidate hole A is significantly faster than the mean times for holes B and C. The mean time for the infantry squad to enter through candidate hole C is significantly faster than for hole B. Differences in the mean times of hole A and hole B are critical, given the assumption that a trained infantryman can place his second and subsequent shots in less than 3 seconds. FM 21-75 (*4*) states:

> The rush is the fastest way to move from one position to another. Each rush should last from 3 to 5 seconds. The rushes are kept short to keep enemy machine gunners or riflemen from tracking you.

If an infantry squad is crossing a danger area such as a street and entering a building through a hole blown in the side of a building by the RWBK or other means, then the faster times achieved with hole A could mean the difference between one to two additional casualties in this combat action.

Table 10. Soldier comments

Hole A	Hole B	Hole C	Comments
55	38	69	Height of hole is good
26			Height of threshold is OK
1			Best hole
10			Good size did not get entangled
5			Good hole
		22	Hole is too small, too low, or not wide enough
	4	2	Poor visibility traversing hole (could not see inside)
5		17	Height of hole off floor should be higher and/or wider (too low) or (too narrow)
		1	Height of hole off floor should be lower
		1	Had to high step
	1	1	Took too long
	1		Round hole is harder to get through; rectangular is better
	1		Hole circumference needs to be larger all around
13	23	14	Adjust the height of the threshold up 3 to 5 inches
16	59	48	Adjust the height of the threshold up 6 to 9 inches
6	64	4	Adjust the height of the threshold up 9 inches or more
	16		Adjust the height of the threshold up 12 to 24 inches
	1		Adjust the height of the threshold up 36 inches
1			Height of hole off floor should be wider
	56		Height of hole off floor should be higher (too low)
1			Height is good; higher and feet get caught; lower and you bump your head.
1	15		Hole not tall (high) enough
1			Poor visibility traversing hole (could not see inside)
1			Large step made movement slower
2	32	23	Had to duck (stoop) low to get in
	3		Had to step too high to be fast (slowed down movement)
	30		Hole is too small, too low, not wide enough
3	2	6	Adjust the height of the threshold down 3 to 5 inches
1	5	1	Adjust the height of the threshold down 6 to 9 inches
	3	1	Adjust the height of the threshold down 9 inches or more
	8		Hit head on top of hole
3	13	29	Snagged equipment on frame
1	6	3	Snagged rifle on frame
1	6	6	Snagged BDU on frame
	27	7	Snagged or hit Kevlar helmet
		1	Snagged everything
	1	3	Snagged parts of body
	3		Difficult with SAW
		1	Individual in front of me had a snag as I was trying to follow
		1	Right side first so bandolier did not snag
	1		With no need to stack and wait, direct entry was easier than from side when stacked
1			I got killed
	1		Re-bar is safety issue

During this experiment, the soldiers made significantly more negative comments about the candidate holes B and C than hole A. Of particular concern in the soldier comments are those directed at the soldiers' ability to be able to observe inside the room while traversing through holes B and C. The soldiers reported difficulty because of the size of hole B and, to some extent, hole C. The smaller size of these two holes required the soldiers to duck their heads or look down to move through these holes. The soldier's view of the interior of the room is critical during entry because he must be prepared to defend himself if the enemy is present. Lowering the head to accommodate entry through the smaller holes greatly reduces the soldier's situation awareness. Entry through hole A did not require the soldiers to duck their heads. The additional negative comments made by soldiers about holes B and C are an indication of the soldiers' preference for hole A because of the ease with which soldiers moved through the hole and into the building.

The soldiers made significantly more comments about their difficulties with equipment and weapons becoming entangled or otherwise slowing their entry progress through holes B and C than with hole A. This is troublesome and is an indication that holes B and C are borderline at best and possibly too small for a squad to enter through efficiently.

5. Conclusion

Infantry squads were able to enter the building through hole A significantly faster than through either hole B or hole C. All three holes allowed an infantry squad to enter. However, both holes B and C presented more problems with the soldiers' situational awareness (i.e., having to duck their heads while entering and losing "heads up" eye contact with the interior of the room) and the soldier's equipment and weapons being snagged during ingress. It is possible that increasing the height of the threshold distance from the ground might allow better visibility during ingress, but the width, length, and/or circumference of holes B and C will continue to cause problems with weapons and equipment entanglement.

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Appendix A. Squad Composition and Experimental Design Matrix

Squad Composition

SQD	SL	ATL	SAW	GREN	RFLM	BTL	SAW	GREN	RFLM
1	1	2	3	4	5	6	7	8	9
2	12	1	2	10	4	5	6	11	8
3	3	6	11	12	7	2	10	9	4
4	7	9	10	5	3	8	11	1	12
5	8	3	4	9	6	7	2	5	1
6	4	5	1	2	8	10	12	6	11
7	6	4	7	3	2	9	3	7	9
8	11	8	9	1	10	3	5	12	7
9	13	14	15	16	17	18	19	20	21
10	24	13	14	22	16	17	18	23	20
11	15	18	23	24	19	14	22	21	16
12	19	21	22	17	15	20	23	13	24
13	20	15	16	21	18	19	14	17	13
14	16	17	13	14	20	22	24	18	23
15	18	16	19	15	14	21	15	19	21
16	23	20	21	13	22	15	17	24	19
17	25	26	27	28	29	30	31	32	33
18	36	25	26	34	28	29	30	35	32
19	27	30	35	36	31	26	34	33	28
20	31	33	34	29	27	32	35	25	36
21	32	27	28	33	30	31	26	29	25
22	28	29	25	26	32	34	36	30	35
23	30	28	31	27	26	33	27	31	33
24	35	32	33	25	34	27	29	36	31
25	37	38	39	40	41	42	43	44	45
26	48	37	38	47	40	41	42	47	44
27	39	42	47	48	43	38	46	45	40
28	43	45	46	41	39	44	47	37	48
29	44	39	40	45	42	43	38	41	37
30	40	41	37	38	44	46	48	42	47

Experimental Design Matrix

Squad	Trial 1	Trial 2	Trial 3
1	A	B	C
2	B	C	A
3	C	A	B
4	C	A	B
5	B	C	A
6	A	B	C
7	C	B	A
8	B	A	C
9	A	C	B
10	C	A	B
11	B	C	A
12	A	B	C
13	C	B	A
14	B	A	C
15	A	C	B
16	A	B	C
17	B	C	A
18	C	A	B
19	C	B	A
20	B	A	C
21	A	C	B
22	A	B	C
23	B	C	A
24	C	A	B
25	C	A	B
26	B	C	A
27	A	B	C
28	A	B	C
29	B	C	A
30	C	A	B

Appendix B. Medical Status Form

Experiment participant: Please answer all questions honestly and completely. Although we are asking your name on this form, this document will be kept strictly confidential. It will not be entered into your official health records.

Participant Number: _____ Date: _____

1. Do you have any physical injury at the present time?

Yes ___ No ___ If yes, please describe. _____

2. Have you had any surgery in the last two months?

Yes ___ No ___ If yes, please describe. _____

3. Are you presently on a profile of any type?

Yes ___ No ___ If yes, please describe your current limitations.
_____

4. If the APFT (Army Physical Fitness Test) were held today, could you obtain a passing score on it? Yes ___ No ___

5. Do you have any medical concerns about carrying your combat "fighting load" while performing this exercise? Yes ___ No ___

If yes, please describe your concerns. _____
_____

6. Have you had any type of eye surgery or eye injury?
Yes ___ No ___ If yes, please describe. _____

Signature: _____

Date: _____

NOTE: RESULTS FROM ALL PARTICIPANTS ON FILE

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Appendix C. Soldier Demographics

N = 34

1. Handedness: 30 right 4 left

2. Height (inches): 70 (mean)
   Weight (pounds): 175.44 (mean)

3. Vision:

   a. Is your vision in each eye 20/20 or correctable to 20/20?\
   31 Yes 4 No

   b. Do you wear glasses when performing military duties?
   11 Yes 23 No

   c. Do you wear contact lenses when performing military duties? 4 Yes 30 No

4. Education (in years): 15 (mean)

5. Current MOS: 11B - 10
   09S - 19
   31U - 2
   62J - 1

   2 Officers: 11 - 1
   21 - 1

   Months in current MOS: 29.76 (mean)

6. Years and Months in current job: 8.35 Months (mean)

7. Years and Months of Military Service: 46.24 Months (mean)

8. If you have been an Infantry fire team leader, squad leader, or platoon sergeant, list the number of years and months you served in these leadership positions:

Fire Team Leader	4.24	Months (mean)
Squad Leader	4.00	Months (mean)
Platoon Sergeant	3.94	Months (mean)

9. Weeks or months of military training/instruction you have received in light Infantry operations:

   a. Classroom training (Basic, AIT, BNCOC, Etc.) 4.52 Months
   b. Field exercises (i.e., NTC (Fort Irwin, CA), 4.69

Months
JOTC(Panama), CRTC (Fort Greeley, AK), JRTC (Fort Polk, LA) or MOUT training facilities (Hammelberg, Ger; etc.,or FTXs with your unit)

10. Weeks or months of military training/instruction you have received in the following areas:

a. Land navigation (map reading, use of GPS data, following planned route) 11.68 Weeks
b. Route planning 11.27 Weeks
c. Communications 11.62 Weeks

11. Latest Physical Fitness Test (PFT) Score: 267 (mean)
Maximum score possible: 300

12. Latest Firing Qualification Test (FQT) Score: 31.43 (mean)
Maximum score possible: 40.00
Type weapon: M16/M4

Self-Ratings of Knowledge, Skills, and Abilities (KSAs) Related to Infantry Duties

1	2	3	4	5
Poor	Below Average	Average	Above Average	Outstanding

	MEAN RESPONSE
13. Knowledge of Infantry tactics, techniques, and procedures (TTPs).	2.44
14. Knowledge of MOUT specific TTPs.	2.06
15. Knowledge of breaching TTPs.	1.97
16. Knowledge of room clearing TTPs.	2.06
17. Knowledge of map reading and orientation in MOUT setting.	2.29
18. Knowledge of reconnaissance, surveillance, and target acquisition (RSTA) procedures.	2.09
19. Communications skills (ability to use communications equipment and face-to-face communications to enhance mission accomplishment).	2.44
20. Knowledge related to communications equipment and communications procedures and communications procedures in a MOUT situation.	2.15
21. Marksmanship skills.	3.15
22. Leadership skills.	3.35

Anthropometrics Measurements:

Stature/Height	Inches	69.72
Weight	Pounds	176.56
Shoulder Circumference	Inches	49.70

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Appendix D. Ingress Times by Hole Size

Day 1 - Squads 1-8									
Squad	**Trial 1**		Total Squad Time	**Trial 2**		Total Squad Time	**Trial 3**		Total Squad Time
1	**A**			**B**			**C**		
1	FTA	FTB		FTA	FTB		FTA	FTB	
1	5.00	6.10	**11.10**	6.80	8.40	**15.20**	5.50	10.70	**16.20**
2	**B**			**C**			**A**		
2	FTA	FTB	Total	FTA	FTB	Total	FTA	FTB	Total
2	6.05	8.90	**14.95**	6.40	9.00	**15.40**	4.50	7.40	**11.90**
3	**C**			**A**			**B**		
3	FTA	FTB	**0.00**	FTA	FTB	Total	FTA	FTB	Total
3	6.20	7.50	**13.70**	6.40	6.00	**12.40**	8.20	8.40	**16.60**
4	**C**			**A**			**B**		
4	FTA	FTB	Total	FTA	FTB	Total	FTA	FTB	Total
4	7.50	7.90	**15.40**	5.60	6.30	**11.90**	10.60	8.00	**18.60**
5	**B**			**C**			**A**		
5	FTA	FTB	Total	FTA	FTB	Total	FTA	FTB	Total
5	6.87	7.80	**14.67**	6.16	7.92	**14.08**	5.48	6.36	**11.84**
6	**A**			**B**			**C**		
6	FTA	FTB	Total	FTA	FTB	Total	FTA	FTB	Total
6	4.69	8.46	**13.15**	5.76	8.44	**14.20**	5.94	9.34	**15.28**
7	**C**			**B**			**A**		
7	FTA	FTB	Total	FTA	FTB	Total	FTA	FTB	Total
7	6.70	9.48	**16.18**	5.18	9.05	**14.23**	5.33	7.89	**13.22**
8	**B**			**A**			**C**		
8	FTA	FTB	Total	FTA	FTB	Total	FTA	FTB	Total
8	7.32	7.41	**14.73**	5.72	5.70	**11.42**	6.33	6.90	**13.23**

Day 2 - Squads 9-16									
Squad	**Trial 1**		Total Squad Time	**Trial 2**		Total Squad Time	**Trial 3**		Total Squad Time
9	**A**			**C**			**B**		
9	FTA	FTB		FTA	FTB		FTA	FTB	
9	5.48	6.15	**11.63**	5.68	6.98	**12.66**	6.97	7.88	**14.85**
10	**C**			**A**			**B**		
10	FTA	FTB	Total	FTA	FTB	Total	FTA	FTB	Total
10	5.34	6.71	**12.05**	4.82	5.53	**10.35**	5.52	6.51	**12.03**
11	**B**			**C**			**A**		
11	FTA	FTB	Total	FTA	FTB	Total	FTA	FTB	Total
11	6.38	7.29	**13.67**	6.08	5.85	**11.93**	4.71	5.55	**10.26**
12	**A**			**B**			**C**		
12	FTA	FTB	Total	FTA	FTB	Total	FTA	FTB	Total
12	4.40	6.28	**10.68**	4.60	8.29	**12.89**	5.31	7.11	**12.42**
13	**C**			**B**			**A**		
13	FTA	FTB	Total	FTA	FTB	Total	FTA	FTB	Total
13	6.29	8.23	**14.52**	6.61	6.75	**13.36**	5.76	5.95	**11.71**
14	**B**			**A**			**C**		
14	FTA	FTB	Total	FTA	FTB	Total	FTA	FTB	Total
14	5.36	5.85	**11.21**	5.11	4.72	**9.83**	5.56	6.18	**11.74**
15	**A**			**C**			**B**		
15	FTA	FTB	Total	FTA	FTB	Total	FTA	FTB	Total
15	4.16	5.15	**9.31**	4.93	7.39	**12.32**	4.92	6.84	**11.76**
16	**A**			**B**			**C**		
16	FTA	FTB	Total	FTA	FTB	Total	FTA	FTB	Total
16	4.91	5.35	**10.26**	5.18	7.15	**12.33**	5.94	5.70	**11.64**

Day 3 - Squads 17-24									
Squad	**Trial 1**		Total Squad Time	**Trial 2**		Total Squad Time	**Trial 3**		Total Squad Time
17	**B**			**C**			**A**		
17	FTA	FTB		FTA	FTB		FTA	FTB	
17	6.58	6.76	**13.34**	6.78	6.67	**13.45**	5.42	5.13	**10.55**
18	**C**			**A**			**B**		
18	FTA	FTB	Total	FTA	FTB	Total	FTA	FTB	Total
18	6.13	6.32	**12.45**	4.02	5.54	**9.56**	5.48	6.26	**11.74**
19	**C**			**B**			**A**		
19	FTA	FTB		FTA	FTB	Total	FTA	FTB	Total
19	6.15	6.98	**13.13**	6.41	8.11	**14.52**	5.13	5.28	**10.41**
20	**B**			**A**			**C**		
20	FTA	FTB	Total	FTA	FTB	Total	FTA	FTB	Total
20	6.82	6.43	**13.25**	5.70	5.56	**11.26**	5.62	6.29	**11.91**
21	**A**			**C**			**B**		
21	FTA	FTB	Total	FTA	FTB	Total	FTA	FTB	Total
21	4.73	4.55	**9.28**	5.12	5.68	**10.80**	5.75	7.13	**12.88**
22	**A**			**B**			**C**		
22	FTA	FTB	Total	FTA	FTB	Total	FTA	FTB	Total
22	4.31	6.18	**10.49**	4.75	6.47	**11.22**	5.04	5.75	**10.79**
23	**B**			**C**			**A**		
23	FTA	FTB	Total	FTA	FTB	Total	FTA	FTB	Total
23	5.59	7.37	**12.96**	6.02	5.75	**11.77**	4.52	6.05	**10.57**
24	**C**			**A**			**B**		
24	FTA	FTB	Total	FTA	FTB	Total	FTA	FTB	Total
24	4.36	5.84	**10.20**	4.70	5.36	**10.06**	5.61	6.21	**11.82**

Day 4 - Squads 25-32									
Squad	**Trial 1**		Total Squad Time	**Trial 2**		Total Squad Time	**Trial 3**		Total Squad Time
25	**C**			**A**			**B**		
25	FTA	FTB		FTA	FTB		FTA	FTB	
25	5.86	6.01	**11.87**	5.48	5.39	**10.87**	6.92	5.45	**12.37**
26	**B**			**C**			**A**		
26	FTA	FTB	Total	FTA	FTB	Total	FTA	FTB	Total
26	5.70	6.11	**11.81**	6.16	6.21	**12.37**	6.37	5.54	**11.91**
27	**A**			**B**			**C**		
27	FTA	FTB	Total	FTA	FTB	Total	FTA	FTB	Total
27	4.52	5.12	**9.64**	5.03	6.26	**11.29**	5.16	6.21	**11.37**
28	**A**			**B**			**C**		
28	FTA	FTB	Total	FTA	FTB	Total	FTA	FTB	Total
28	4.74	6.11	**10.85**	6.13	6.74	**12.87**	5.43	6.65	**12.08**
29	**B**			**C**			**A**		
29	FTA	FTB	Total	FTA	FTB	Total	FTA	FTB	Total
29	5.86	6.49	**12.35**	5.39	5.88	**11.27**	4.56	5.27	**9.83**
30	**C**			**A**			**B**		
30	FTA	FTB	Total	FTA	FTB	Total	FTA	FTB	Total
30	5.18	6.15	**11.33**	4.90	5.83	**10.73**	5.24	7.26	**12.50**

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