ARMY RESEARCH LABORATORY

Human Factors Assessment of U.S. Marine Lightweight Helmet Suspension Systems: Standard “A” Pad System vs. a Proposed Suspension System “B” HeadGard

by Richard S. Bruno, Jim A. Faughn, and Paul Shorter

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14. ABSTRACT
The U.S. Naval Research Laboratory requested that the U.S. Army Research Laboratory's Human Research and Engineering Directorate compare the HeadGard helmet suspension system with the Marine standard "A" pad suspension system currently used with the lightweight helmet (LWH). The goal of this effort was to assess the HeadGard helmet suspension's ability to protect the head without compromising the user's comfort and other factors, such as fit and stability. Human factors issues, such as helmet stability, effects of helmet weight on the head, fit, sizing, system comfort, airflow, and others, were assessed. Overall, the HeadGard mounted in the LWH must be compatible with the Marine standard modular tactical vest and not hinder the user's mobility and comfort. HeadGard with the LWH must be compatible with sights and shoulder-fired weapons. The objective of this assessment was to provide the Marine Corps System Command with user feedback information about the HeadGard helmet suspension from U.S. Marines performing generic combat tasks.
The results of this study proved that the HeadGard suspension was rated better than the pad suspension on several design factors during dynamic combat-related maneuvers or scenarios. The participants favored the design factors of the HeadGard suspension system, such as perceived airflow, improved design, and comfortable fit. There were no statistical differences between the suspensions during less dynamic scenarios or activities, such as weapon firing, mask and balaclava interface, sand bag filling, and suspension washing and reinstallation.

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HeadGard, human factors, helmet suspension, lightweight helmet, Marine

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1. Introduction

U.S. Marine Corps Systems Command (MARCORSYSCOM) Project Manager (PM) Infantry Combat and Equipment (ICE) funded the U.S. Naval Research Laboratory Code 6360 in FY08 to explore domestic worldwide options for ICE. PM ICE supported the MARCORSYSCOM in their head-borne development programs specifically to demonstrate the utility, positive or negative, of a German helmet suspension identified as the HeadGard helmet suspension system, henceforth referred to as "Helmet B." Currently, the HeadGard suspension system is being used by German and Swiss forces.

The U.S. Naval Research Laboratory (NRL) requested that the U.S. Army Research Laboratory's (ARL's) Human Research and Engineering Directorate, Dismounted Warrior Branch, assess the HeadGard helmet suspension system in comparison with the Marine standard "A" pad suspension system currently used with the lightweight helmet (LWH), henceforth referred to as "Helmet A."

The goal of this effort was to assess the HeadGard helmet suspension's ability to protect the head without compromising the user's comfort and other factors, such as fit and stability. Overall, the HeadGard mounted in the LWH must be compatible with the Marine standard modular tactical vest and must not hinder the user's mobility and comfort. HeadGard with the LWH must also be compatible with shoulder-fired weapons and weapon sights.

ARL human factors researchers, subject matter experts from the U.S. Marines, and NRL representatives participated in the conduct of the limited human factors assessment. Initial sizing and fitting of the Marine participants with the helmets and the suspension systems were performed by representatives of ARL, NRL, and the Marine Helmet Project Manager Office.

This limited human factors assessment will be used by MARCORSYSCOM to undertake the final development of the HeadGard helmet suspension system, should they choose to do so.

2. Objective

The objective of this assessment was to provide MARCORSYSCOM with user feedback information about the HeadGard helmet suspension from U.S. Marines performing generic combat tasks. Specifically, the goals were to assess the helmet suspension with respect to the following factors:

- Fit
- Participant opinions after exposure to the obstacle and maneuvering courses

- Participant opinions after selected shoulder-fired weapons are fired
- Participant opinions after sand bags are filled
- Compatibility with the M50 Joint Service General Purpose (JSGP) mask
- Compatibility with the cold weather balaclava
- Detachment/reattachment methodology and washing/cleaning

3. Method

3.1 Participants

Twenty-four U.S. Marines assigned to the Aberdeen Proving Ground U.S. Marine Corps Detachment participated in this assessment. There were 22 male and 2 female Marines.

3.2 Experience

The Marines were in excellent physical shape and passed the Marine Physical Fitness Test. These Marines had gone through basic training wearing the Personal Armor System for Ground Troop (PASGT) helmet. The PASGT helmet has a modified "Riddel" suspension and fabric loops with center height adjustment and crown strap with a two-point chin strap.[1] The participants were first-time users of both helmet suspensions to be assessed.

3.3 Screening Techniques

The investigators asked all participants if they had any injury or medical problem that would have precluded them from participating in this assessment; none reported any injury or medical problems.

3.4 Prestudy Orientation, Demographics, Photographic Release, and Volunteer Agreement

The Marines were briefed about the purpose, risks, and importance of the assessment. They were given the Volunteer Agreement Affidavit form to sign (see appendix A). Participants signed a photographic/video and audio release (part of appendix A). They also signed a consent release that would allow others to view the conduct of the assessment and to note items of interest related to the helmet assessment for release in conferences or public forums. All questions the participants might have had regarding the assessment were answered by the ARL investigators.

[1]Corona, B. M.; Jones, R. D.; Randall, R. B.; Bruno, R. *Human Factors Evaluation of Two Proposed Army/Infantry Marine Fragmentation Protective System*; HEL-TM-24-74; U.S. Army Human Engineering Laboratory: Aberdeen Proving Ground, MD, 1974.

3.5 Helmet Suspension Systems Assessed

Two helmet suspension systems were evaluated: the standard “A” pad suspension system (A) and HeadGard suspension system (B).

3.5.1 Standard “A” Pad Suspension System (A)

Currently, the U.S. Army and the U.S. Marine Corps both use the standard “A” suspension. It comprises seven foam pads that attach to the interior of the helmet by means of hook and loop material. It is designed to ensure the proper standoff and impact protection. The chin strap is attached to the helmet by a four-point strap. The Marine pads system is exclusively manufactured and supplied to the Marines by Team Wendy, Inc. Figure 1 shows the standard “A” suspension in the LWH.

Figure 1. View of the standard “A” suspension in the LWH.

3.5.2 HeadGard Suspension System (B)

The main component of HeadGard is interconnected extruded plastic strips with hollow posts extending perpendicularly to the strips. The posts contact the inside of the helmet shell and maintain consistent head-helmet distance. A wider headband plastic strip with a hydrophobic replaceable comfort liner contacts the head and is adjustable via a baseball cap–type slider snap. An adjustable net in contact with the crown of the head maintains the vertical height. A circular piece of foam maintains a minimum standoff distance between the crown and the inside of the helmet. The suspension is held in place at three points by bolts attached to the system through holes drilled into the helmet. The same points are used to attach the retention strap system. In addition, three clips hold the suspension system in place with the retention system. The clips unsnap readily to remove the suspension. In this way, the suspension system can be cleaned and reinstalled with minimum effort. Presently, the holes for the LWH and the suspension do not align. For the human factors assessment, three new holes were drilled into the helmet to retain the suspension system. The "B" liner manufacturer is designing a universal mount that will attach to the existing holes in the LWH and use the same retention system. Figure 2 shows the HeadGard "B" suspension system.

Figure 2. Views of the HeadGard or "B" suspension system (note the two helmet retention loops in photograph to the right).

3.6 Research Facilities

3.6.1 Mobility and Portability Obstacle Course

The mobility and portability obstacle course (also known as "KD" range) (figure 3) consists of 20 individual obstacles spread over a twisting course of about 500 m. Two participants can begin the course at the same time, each using one of the two lanes. The obstacles subject the participants to the kinds of maneuvers they should expect to perform in combat, such as running, jumping, climbing, balancing, negotiating buildings, stairs, windows, and crawling. Any issues regarding helmet compatibility, fit, and comfort will likely be evident and noticeable to the participant after he/she negotiates the obstacle course. Any issues identified by the researchers were recorded, and pictures were taken to document the issues.

Figure 3. A 500-m mobility and portability obstacle course.

3.6.2 Grenade-Throwing Pit

The grenade-throwing pit was a circular area 15 m in diameter with a pole as a marker/target in the center of the pit. There was a graveled area 35 m away from the center of the pit where the participants laid on the ground on their backs, faced upward, with inert grenade in hand and then rotated toward the pit while throwing the grenade. Helmet-related issues of compatibility fit, comfort, and range of motion restriction were observed, and pictures were taken to document the issues.

3.6.3 Individual Movement Technique (IMT) Course

The IMT course is laid out in an open field adjacent to the mobility-portability course. The two-lane course is 100 m long with a staggered log placed every 10 m. The participants were required to run the course and assume a prone firing position behind each log. They then simulated firing the weapon, performed a combat roll, got to their feet, and ran to the next log to assume the next firing position in a leapfrog fashion. Helmet-related compatibility, fit, comfort, and mobility issues were observed, and pictures were taken to document the issues.

3.6.4 Road-Marching Course

The road-marching course (536 m in length) surrounds the 500-m obstacle course. The surface consists of 323 m of asphalt and 213 m of grass and gravel. The participants completed the course at a self-paced rate while wearing the designated LWH with suspension system and carrying an inert weapon.

The questionnaire in appendix B solicits user opinion of the suspension system related to the obstacle course, grenade-throwing pit, IMT course, and road-marching course.

3.6.5 M-Range

M-Range is an outdoor small arms live-firing range (figure 4) that is subdivided into four firing lanes (A, B, C, and D lanes). Each lane is designed to present to a single shooter, located at a fixed firing position, targets at ranges of 50, 75, 100, 150, 200, 250, 300, 400, and 500 m. During this assessment, lanes B and C were used. For this evaluation, participants fired at static targets to identify any compatibility problems between the suspension and helmet systems and the weapon systems. No hit data were collected for this assessment.

Figure 4. M-Range, an outdoor small arms live-firing range.

3.6.6 Helmet Suspension System Compatibility Assessment Tasks

The participants were instructed to fire small arms in the semiautomatic and automatic mode down range. Firing small arms (M16A2, M4, M240B, and M14) in this manner was to provide weapon experience while the participants wore the helmets with the two suspension systems, “A” and “B.”

Other helmet compatibility assessment tasks included were (1) donning the M50 JSGP mask and the cold weather balaclava and (2) filling six sand bags.

After each described task, the participants completed a questionnaire, shown in appendix C.

The participants were instructed to remove the liner system from the LWH “A” or “B” and then wash it in liquid soap and water. After washing the suspension system, the participant reinstalled the suspension system into the helmet. A questionnaire, shown in appendix D, was administered after this task to solicit participant feedback to assess one’s ability and ease of removing the liner system from the helmet, washing it, and then reinstalling it into the helmet.

3.7 Measurement Devices: Anthropometry

Anthropometry is the systematic measurement of the human body. These measurements are used to guide the design and sizing of clothing, equipment, and workstations. The anthropometer (figure 5) is the basic tool used for anthropometry. The anthropometer is used to measure all linear dimensions of the human anatomy. These linear dimensions can be heights or body segment lengths and widths. Other devices used to measure the body are calipers and linen tapes (figure 6). Calipers are used to measure dimensions of the head and hands. Linen tapes are used to measure body circumferences. A scale was used to measure the weight of the subject. All measurements were taken in accordance with methods detailed in Clauser et al.[2] Anthropometric measurements (body measurements) were recorded to document size and fit and to make comparisons to the general military population. A summary of anthropometric measures taken and percentiles of the test participants in this study is shown in appendix E.

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[2]Clauser, C.; Tebbetts, I.; Bradtmiller, B.; McConville, J.; Gordon, C. C. *Measurer’s Handbook: U.S. Army Anthropometric Survey 1987–1988*; TR-88/043; U.S. Army Natick RD&E Center: Natick, MA, 1988.

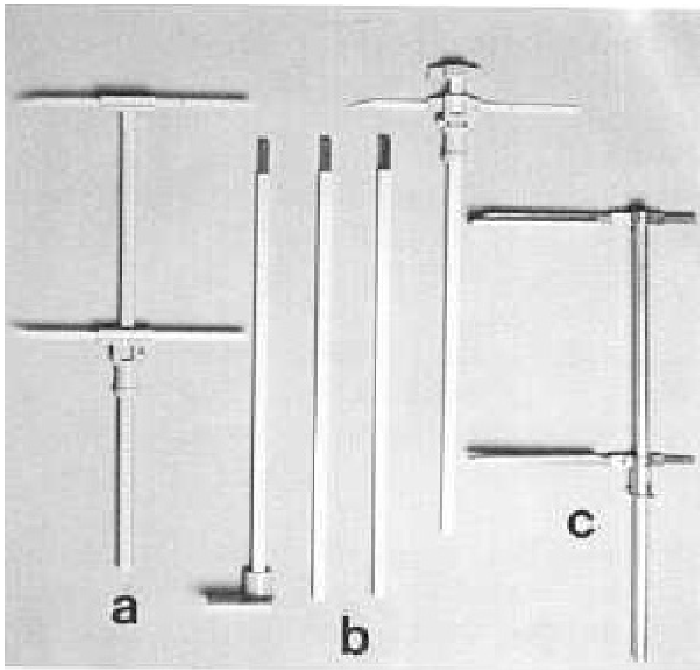


Figure 5. Anthropometer.

Notes: (a) Beam caliper, (b) four sections of basic anthropometer, and (c) beam caliper with paddles.

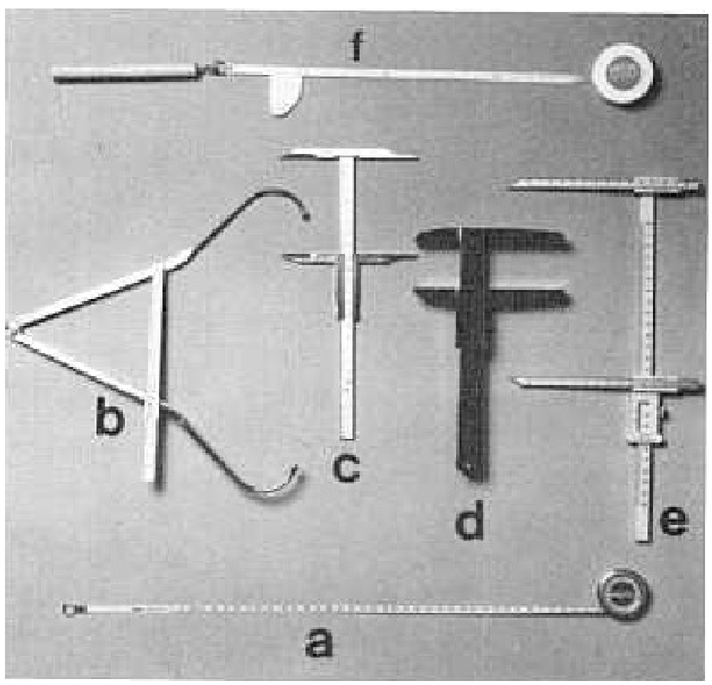


Figure 6. Calipers and tape used to measure anthropometric data.

Notes: (a) Steel tape, (b) spreading caliper, (c) sliding caliper, (d) Holtain caliper, (e) Poech caliper, and (f) linen tape.

4. Procedures

Twenty-four U.S. Marines participated in the helmet suspension system assessment during which they carried an inert M4 while negotiating the ARL mobility-portability obstacle course at a self-paced rate. Each Marine went through the full set of activities twice, once with each helmet suspension system. Twelve of the 24 participants wore the LWH with the attached night vision goggle (NVG) ANPVS 7 and NVG mount (figures 7 and 8). Table 1 shows the participant's activity schedule. In the morning, the participants twice negotiated the obstacle and the IMT courses, grenade throw, and then a 536-m road march. A questionnaire was administered after each activity (appendix B). These maneuvers were performed at a self-paced rate.

Figure 7. Front view of participant wearing the LWH with the mounted NVG.

Figure 8. Side view of participant wearing the LWH with the mounted NVG.

Table 1. Participant's activities schedule.

1	Transported from barracks to "KD" range – morning
2	Obstacle course activities (OCA) (trial 1)[a]
3	OCA (trial 2)[a]
4	Lunch break
5	Transported to M-Range – afternoon
6	M-Range
7	Fired weapons[a]
8	Filled sand bags[a]
9	Donned M50 JSGP mask[a]
10	Donned cold weather balaclava[a]
11	Transported to back to "KD" range
12	Removed/washed/reinstalled suspension systems[a]
13	Transported back to barracks

[a]Questionnaires were administered after each activity (appendices B, C, and D).
Note: OCAs = negotiate the obstacle course, individual movement course, and 536-m road march, and throw an inert grenade.

After lunch, the participants were transported to the M-Range for weapon firing, donning of the mask, and sand bag filling while they wore the LWHs "A" or "B", with or without the NVG. Weapons fired were M16A2, M4, M240B, and the M14 rifle, all in the standing posture. The standing posture was chosen for this evaluation because we were primarily interested in the movement of the helmet on the head during firing. In the prone firing position, the helmet would be partially supported by the vest and would limit movement and vibration. Participants also wore the Marine standard body armor while firing weapons to assess personal safety and any compatibility issues related to the helmets and weapons. Also, participants donned an M50 JSPG mask and then a balaclava with the LWH "A" and "B" (see figures 9 and 10). After removing the mask and/or balaclava, the participants then filled six sand bags while wearing the LWH "A" and "B" for work/task exposure. After each task was completed, a questionnaire was administered (appendix C).

Figure 9. Participant wearing the LWH, NVG, and M50 JSGP mask.

Figure 10. Participant wearing the LWH, NVG mount, and balaclava with wind, sand, and dust goggles.

After activities at the M-Range, the participants were transported back to the KD range. After a full of day wearing the assigned LWH, the participants were instructed to remove the suspension system from their helmet, wash the liner system in soapy water, and rinse it with clean water. After cleaning the suspension systems, the participant then reattached the suspension to the LWH. They were then administered a helmet suspension removal, wash, and reinstallation questionnaire (appendix D).

At the end of their two-day trial, each group of eight participants was administered a final debriefing questionnaire about the helmet suspension systems (appendix F). The participants were instructed to not remove their helmets during the entire day of testing with the exception of trying on the balaclava and the M50 JSGP mask.

The wet bulb globe temperature and weather-related data were collected and monitored, which dictated the work/rest cycle throughout the duration of the assessment (appendix G).

5. Experimental Design

Twenty-four Marines participated. Participants were divided into two NVG groups. One group of 12 participants completed all tasks with NVG. The other group of 12 participants completed all tasks without NVG. Regardless of NVG, all participants participated in all tasks twice, once with each helmet suspension system (see figures 7 and 8).

5.1 Independent Variables

There was one within-subjects variable of helmet suspension for this evaluation that had two levels (helmet suspension "A" or "A" pads and helmet suspension "B" or HeadGard). There was also one between-subjects variable of NVG. The NVG variable had two levels (NVG or no NVG).

5.2 Dependent Variables

The dependent variables were the participants' subjective responses to the helmet suspension design conditions.

5.3 Experimental Matrix

A mixed model design was used to expose each participant to each experimental condition. The sequence of exposure was counterbalanced, as shown in table 2. The experiment was executed for 6 days and employed 24 participants divided in three subgroups of 8. The first subgroup (participants 1–8) was employed on days 1 and 2, the second subgroup (participants 9–16) was employed on days 3 and 4, and the third subgroup (participants 17–24) was employed on days 5 and 6.

Table 2. Experimental matrix for participants and days.

	Subjects	1 & 2	3 & 4	5 & 6	7 & 8	9 & 10	11 & 12	13 & 14	15 & 16	17 & 18	19 & 20	21 & 22	23 & 24
Day - 1	Trial - 1	A_{NVG}	A	B_{NVG}	B								
	Trial – 2	A_{NVG}	A	B_{NVG}	B								
Day - 2	Trial – 1	B_{NVG}	B	A_{NVG}	A								
	Trial – 2	B_{NVG}	B	A_{NVG}	A								
Day - 3	Trial – 1					A_{NVG}	A	B_{NVG}	B				
	Trial – 2					A_{NVG}	A	B_{NVG}	B				
Day - 4	Trial – 1					B_{NVG}	B	A_{NVG}	A				
	Trial – 2					B_{NVG}	B	A_{NVG}	A				
Day - 5	Trial – 1									A_{NVG}	A	B_{NVG}	B
	Trial – 2									A_{NVG}	A	B_{NVG}	B
Day - 6	Trial – 1									B_{NVG}	B	A_{NVG}	A
	Trial - 2									B_{NVG}	B	A_{NVG}	A

A = Lightweight helmet A
A_{NVG} = Lightweight helmet A with Night Vision Goggles
B = Lightweight helmet B
B_{NVG} = Lightweight helmet B with Night Vision Goggles

Two testing trials per design condition were conducted for the IMT, grenade throw, obstacle course, and road march scenarios. One testing trial was conducted for M-Range and removal and wash scenarios, which resulted in a sample size of 12 for each design condition.

After participants completed a given testing trial, questionnaires pertaining to the helmet design conditions were presented. Copies of the questionnaires are in appendices B, C, D, and F. The following design considerations are presented in the questionnaires:

- Comfort
- Allowed air circulation
- Fits well on head
- Stayed in position
- Protective
- Well designed
- Supports evenly
- Effective
- Distributes weight evenly on head
- Compatible
- Stability
- Easy to put on
- Easy to take off

The participants were instructed to rate each design condition based on a five-point scale. The ratings were assigned numerical values that ranged as follows:

5 = Strongly Agree

4 = Agree

3 = Neutral

2 = Disagree

1 = Strongly Disagree

6. Data Analysis

The data obtained from the questionnaires were delineated by test scenario. The null hypothesis was tested at an alpha level of 0.05. The effect of two factors was considered in the mixed Analysis of Variants (ANOVA), the helmet suspension types (A and B), and the use of NVG (worn and not worn). In addition, the interaction between helmet suspension type and NVG was considered (denoted as Helmet × NVG). The helmet suspension type was analyzed as a within-subjects variable. NVG presence was analyzed as a between-subjects variable. The figures and tables provided in the following subsections show the results of the mixed ANOVA for each scenario.

6.1 IMT Questionnaire Results

The means, standard deviations, and ANOVAs were calculated for the IMT data. The helmet factor p-values listed in table 3 indicate that 8 of the 11 design considerations have p-values that are statistically significant at alpha 0.05, indicating a statistically significant difference in mean ratings values between the two helmet suspension configurations. For those design conditions, as illustrated in figure 4, the mean ratings values for helmet suspension "B" were greater than helmet suspension "A," indicating that the participants rated the performance of helmet suspension "B" more favorably. The remaining three design considerations with p-values that are not statistically significant (highlighted in figure 11 in yellow circles) are (4) Fits well, (6) Protective, and (10) Distributes weight (evenly).

Table 3. Mixed ANOVA results for IMT questionnaire data.

No. of Design Considerations	Helmet Suspension Design Condition	Helmet Factor p-value	NVG Factor p-value	Helmet × NVG p-value
1	Comfortable	[a]0.015	0.934	0.387
2	Stable on head	[a]0.009	0.646	0.686
3	Air circulation	[a]0.000	1.000	0.861
4	Fits well	0.052	0.600	0.216
5	Stays in position	[a]0.006	0.575	0.487
6	Protective	0.088	0.539	0.204
7	Well designed	[a]0.002	0.881	0.458
8	Supports evenly	[a]0.008	0.164	0.094
9	Effective	[a]0.024	1.000	0.283
10	Distributes weight	0.126	[a]0.026	0.520
11	Compatible	[a]0.007	0.872	0.264

[a]Indicates p-value <0.05.

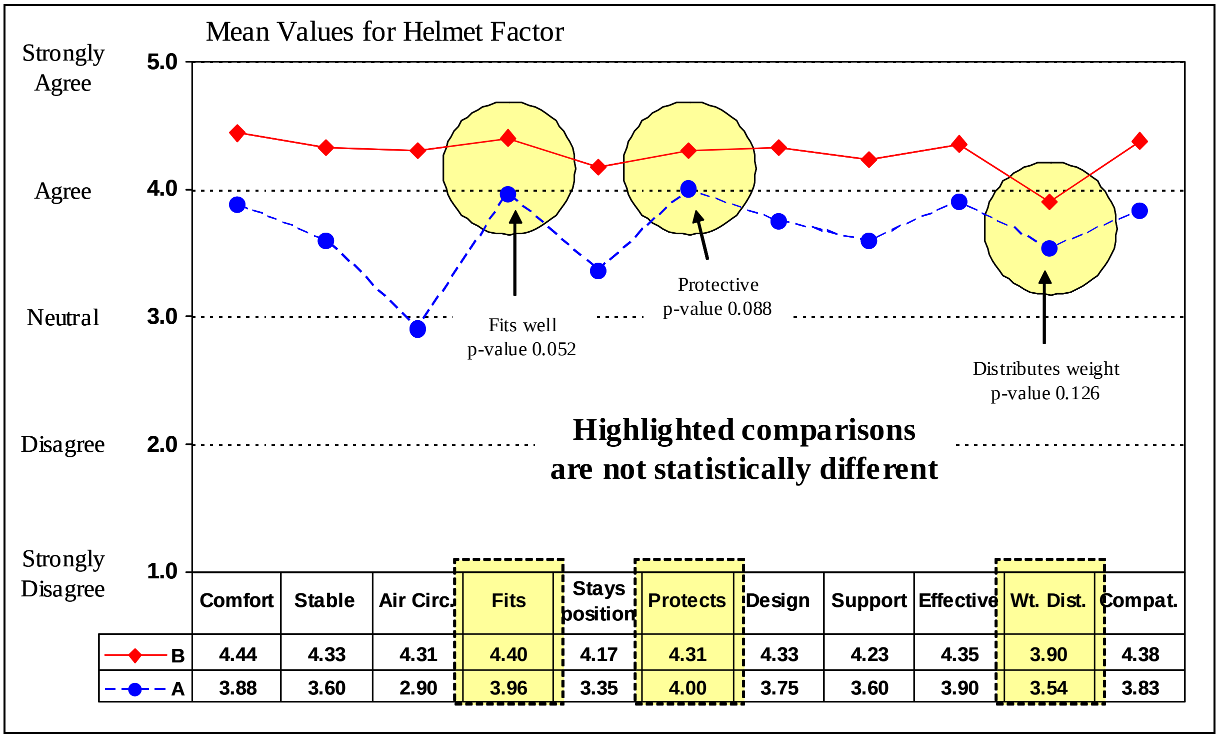


Figure 11. Means comparison for IMT questionnaire data.

The NVG factor p-values for the IMT evaluation listed in table 3 indicate that one of the 11 design considerations, (10) Distributes weight evenly, has a p-value that is statistically significant at alpha 0.05. The mean response for helmets equipped with NVG is 3.38. Comparing this value to the mean response value of helmets equipped without NVG, 4.063, indicates that the participants preferred the weight distribution of helmets equipped without NVG. All other design considerations have p-values that are not statistically significant. The remaining 10 design considerations have p-values that are not statistically significant, thus indicating that the use of NVG did not affect the subjective responses for those design considerations.

The helmet × NVG (interaction) p-values listed in table 3 indicate that none of the 11 design considerations have p-values that are statistically significant at alpha 0.05, thus indicating that participant's subjective responses were not affected by the combination of helmet suspension configuration and the use of NVG.

Design conditions (12) Easy to put on and (13) Easy to take off were not considered in the IMT scenario; therefore, no data relating to those design considerations were collected.

6.2 Obstacle Course Questionnaire Results

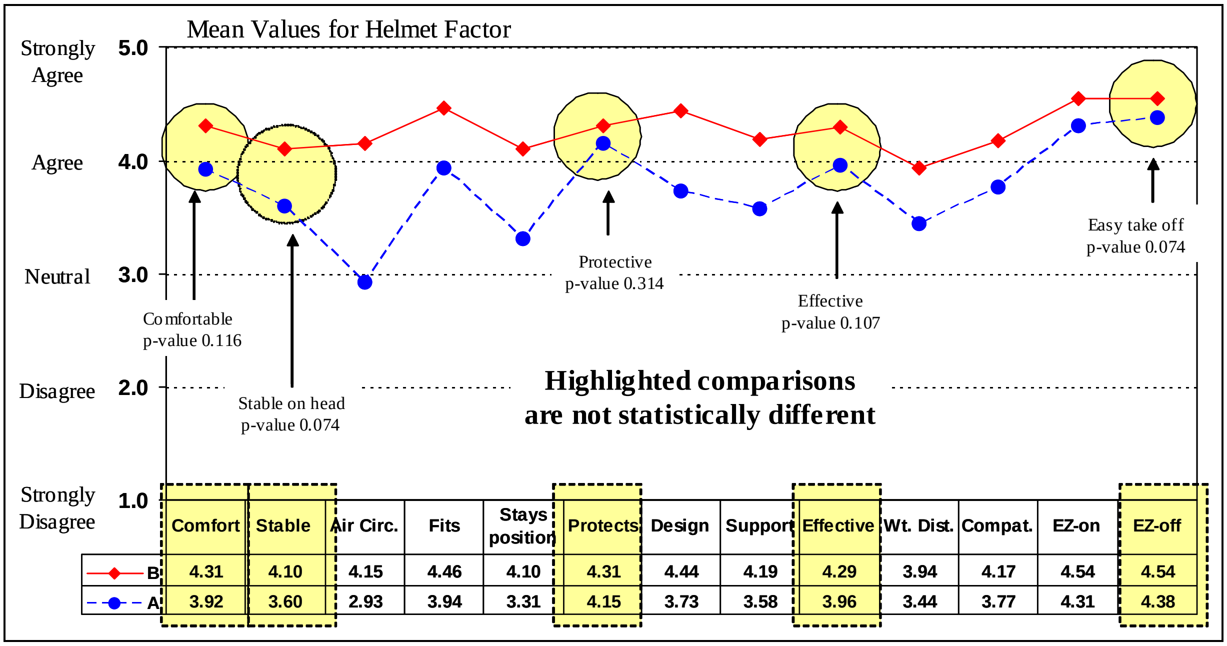
The means, standard deviations, and ANOVAs were calculated for the obstacle course questionnaire data. The helmet factor p-values listed in table 4 indicate that 8 of the 13 design

Table 4. Mixed ANOVA results for obstacle course questionnaire data.

No. of Design Considerations	Helmet Suspension Design Condition	Helmet Factor p-value	NVG Factor p-value	Helmet × NVG p-value
1	Comfortable	0.116	0.802	0.553
2	Stable on head	0.074	0.743	0.442
3	Air circulation	[a]0.000	0.602	0.284
4	Fits well	[a]0.031	0.498	0.649
5	Stays in position	[a]0.011	0.525	0.251
6	Protective	0.314	0.863	0.137
7	Well designed	0.001	0.669	0.367
8	Supports evenly	[a]0.002	0.269	0.198
9	Effective	0.107	0.879	0.156
10	Distributes weight	[a]0.049	0.141	0.494
11	Compatible	[a]0.039	0.929	0.097
12	Easy to put on	[a]0.042	[a]0.036	0.847
13	Easy to take off	0.074	0.118	0.358

[a]Indicates p-value <0.05.

considerations have p-values that are statistically significant at alpha 0.05, thus indicating a statistically significant difference in mean ratings values between the two helmet suspension configurations. For those design conditions, as illustrated in figure 5, the mean ratings values for helmet suspension "B" were found to be greater than helmet suspension "A," indicating that the participants perceived the performance of helmet suspension "B" more favorably. The remaining five design considerations with p-values that are not statistically significant (highlighted in yellow circles in figure 12) are (1) Comfortable, (2) Stable on head, (6) Protective, (9) Effective, and (13) Easy to take off.



	Comfort	Stable	Air Circ.	Fits	Stays position	Protects	Design	Support	Effective	Wt. Dist.	Compat.	EZ-on	EZ-off
B	4.31	4.10	4.15	4.46	4.10	4.31	4.44	4.19	4.29	3.94	4.17	4.54	4.54
A	3.92	3.60	2.93	3.94	3.31	4.15	3.73	3.58	3.96	3.44	3.77	4.31	4.38

Figure 12. Means comparison for obstacle course questionnaire data.

The NVG factor p-values listed in table 4 indicate that one of the 13 design considerations, (12) Easy to put on, has a p-value that is statistically significant at alpha 0.05. The mean rating for the helmet with the NVG was 4.65 and was 4.21 for the helmets without the NVG. In this case, the participants rated the helmets with NVGs higher than those without NVGs on the design factor of "easy to put on."

The helmet × NVG (interaction) p-values listed in table 4 indicate that none of the 13 design considerations have p-values that are statistically significant at alpha 0.05, indicating that neither helmet suspension performance was affected by the combination of a given helmet suspension configuration and the use of NVG.

6.3 Grenade Throw Questionnaire Results

The means and standard deviations and ANOVAs were calculated for the grenade throw questionnaire data. The helmet factor p-values listed in table 5 indicate that 8 of the 11 design considerations have p-values that are statistically significant at alpha 0.05, indicating a statistically significant difference in mean rating values between the two helmet suspension configurations. For those design conditions, the mean ratings values for helmet suspension "B" were found to be greater than helmet suspension "A," thus indicating that the participants perceived the performance of helmet suspension "B" more favorably. The remaining three design considerations with p-values that are not statistically significant (highlighted in yellow circles in figure 13) are (6) Protective, (10) Distributes weight (evenly), and (11) Compatible.

Table 5. Mixed ANOVA results for grenade throw questionnaire data.

No. of Design Considerations	Helmet Suspension Design Condition	Helmet Factor p-value	NVG Factor p-value	Helmet × NVG p-value
1	Comfortable	[a]0.032	0.864	0.682
2	Stable on head	[a]0.008	0.326	0.926
3	Air circulation	[a]0.000	1.659	0.550
4	Fits well	[a]0.004	1.000	0.835
5	Stays in position	[a]0.006	0.864	0.596
6	Protective	0.395	0.589	0.260
7	Well designed	[a]0.004	1.000	0.269
8	Supports evenly	[a]0.021	0.601	0.321
9	Effective	[a]0.022	0.719	0.169
10	Distributes weight	0.079	[a]0.266	0.111
11	Compatible	0.072	0.272	0.234

[a]Indicates p-value <0.05.

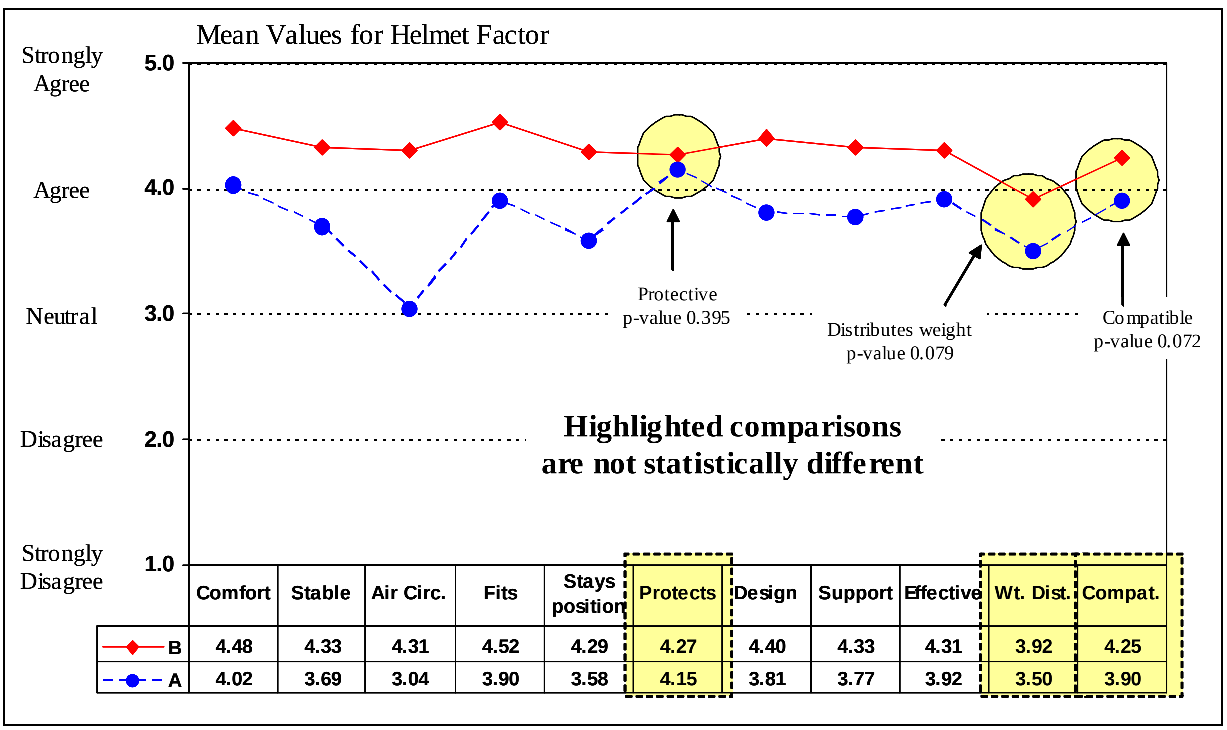


Figure 13. Means comparison for grenade throw questionnaire data.

The NVG factor p-values listed in table 5 indicate that none of the 11 design considerations have p-values that are statistically significant, indicating that the use of NVG did not affect the subjective responses for those design considerations.

The helmet × NVG (interaction) p-values listed in table 5 indicate that none of the 11 design considerations have p-values that are statistically significant at alpha 0.05, thus indicating that the use of NVG did not affect the subjective responses for those design considerations.

Design conditions (12) Easy to put on and (13) Easy to take off were not considered in the grenade-throwing scenario; therefore, no data relating to those design considerations were collected.

6.4 Road March Questionnaire Results

The means and standard deviations and ANOVAs were calculated for the road march questionnaire data. The helmet factor p-values listed in table 6 indicate that 6 of the 11 design considerations have p-values that are statistically significant at alpha 0.05, indicating a statistically significant difference in mean rating values between the two helmet suspension configurations. For those design conditions, the mean ratings values for helmet suspension "B" were found to be greater than helmet suspension "A," thus indicating that the participants perceived the performance of helmet suspension "B" more favorably. The remaining five design considerations with p-values that are not statistically significant (highlighted in yellow circles in figure 14) are (1) Comfortable, (6) Protective, (8) Supports evenly, (9) Effective, and (11) Compatible.

Table 6. Mixed ANOVA results for road march questionnaire data.

No. of Design Considerations	Helmet Suspension Design Condition	Helmet Factor p-value	NVG Factor p-value	Helmet × NVG p-value
1	Comfortable	0.056	0.659	0.790
2	Stable on head	[a]0.007	0.668	0.810
3	Air circulation	[a]0.046	1.698	0.643
4	Fits well	[a]0.019	1.447	0.592
5	Stays in position	[a]0.000	0.698	0.343
6	Protective	0.051	0.792	0.499
7	Well designed	[a]0.001	1.937	0.150
8	Supports evenly	0.113	0.199	0.558
9	Effective	0.081	1.000	0.235
10	Distributes weight	[a]0.017	0.119	0.470
11	Compatible	0.078	0.472	0.339

[a]Indicates p-value <0.05.

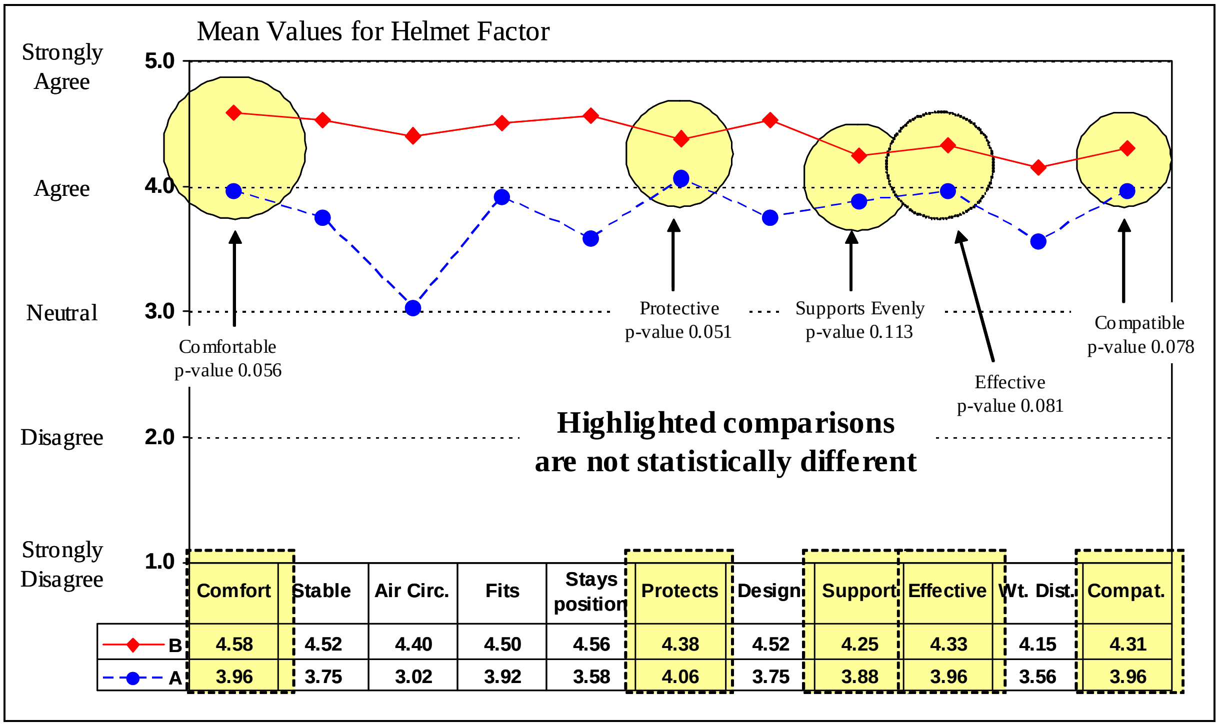


Figure 14. Means comparison for road march questionnaire data.

The NVG factor p-values listed in table 6 indicate that none of the 11 design considerations have p-values that are statistically significant, indicating that the use of NVG did not affect the subjective responses for those design considerations.

The helmet × NVG (interaction) p-values listed in table 6 indicate that none of the 11 design considerations have p-values that are statistically significant at alpha 0.05, thus indicating that neither helmet suspension performance was affected by the combination of a given helmet suspension configuration and the use of NVG.

Design conditions (12) Easy to put on and (13) Easy to take off were not considered in the road-marching scenario; therefore, no data relating to those design considerations were collected.

6.5 M-Range Weapon-Firing Questionnaire Results

The means and standard deviations and ANOVAs were calculated for the M-Range weapon-firing questionnaire data. The helmet factor p-values listed in table 7 indicate that none of the 11 design considerations have p-values that are statistically significant at alpha 0.05, indicating no statistically significant difference in mean ratings values between the two helmet suspension configurations (figure 15).

Table 7. Mixed ANOVA results for weapon-firing questionnaire data.

No. of Design Considerations	Helmet Suspension Design Condition	Helmet Factor p-value	NVG Factor p-value	Helmet × NVG p-value
1	Comfortable	0.445	0.460	0.288
2	Stable on head	0.145	0.705	0.411
3	Air circulation	0.136	0.934	0.364
4	Fits well	0.243	0.730	0.813
5	Stays in position	0.053	0.593	0.109
6	Protective	0.504	0.635	0.320
7	Well designed	1.000	0.596	0.501
8	Supports evenly	0.466	0.635	0.466
9	Effective	0.752	0.771	0.752
10	Distributes weight	0.729	0.269	1.000
11	Compatible	0.476	0.529	0.288

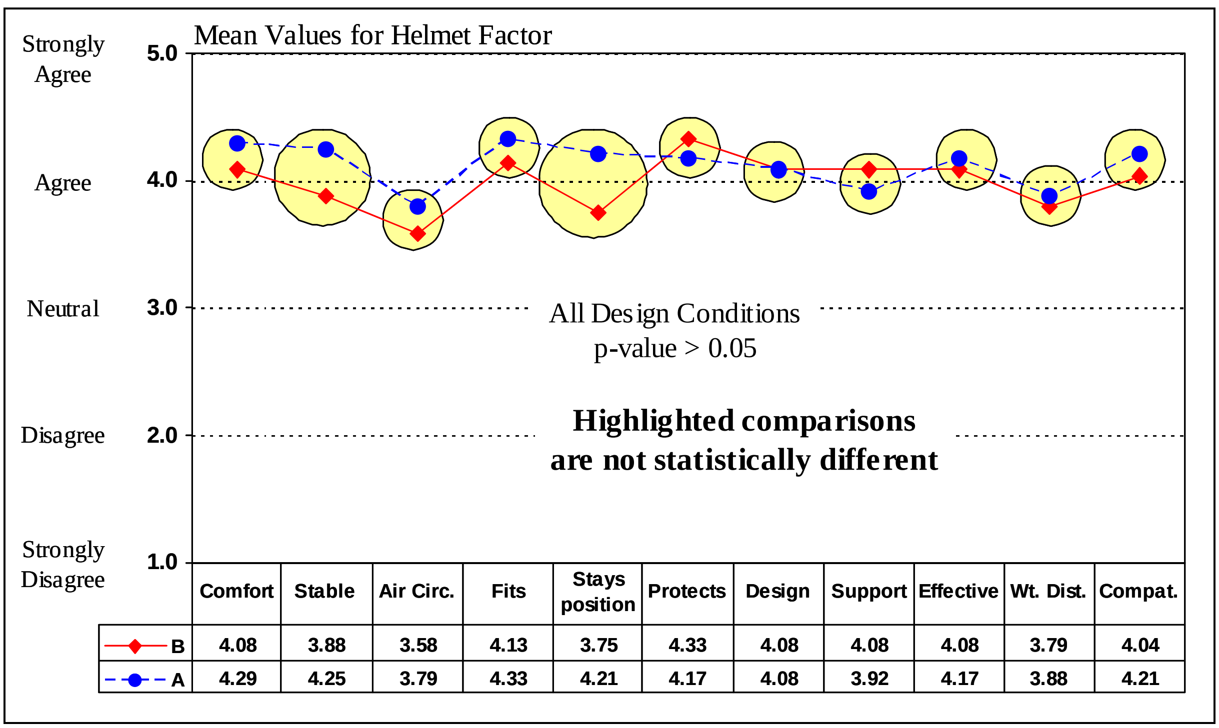


Figure 15. Means comparison for weapon-firing questionnaire data.

The NVG factor p-values listed in table 7 indicate that none of the 11 design considerations have p-values that are statistically significant, thus indicating that the use of NVG did not affect the subjective responses for those design considerations.

The helmet × NVG (interaction) p-values listed in table 7 indicate that none of the 11 design considerations have p-values that are statistically significant at alpha 0.05, thus indicating that neither helmet suspension performance was affected by the combination of a given helmet suspension configuration and the use of NVG.

Design conditions (12) Easy to put on and (13) Easy to take off were not considered in the M-Range scenario; therefore, no data relating to those design considerations were collected.

6.6 Suspension System Removal and Wash Questionnaire Results

The means and standard deviations and ANOVAs were calculated for the suspension system removable and wash questionnaire data. The helmet factor p-values listed in table 8 indicate that one of the six design considerations has a p-value that is statistically significant at alpha 0.05, thus indicating a statistically significant difference in mean ratings value between the two helmet suspension configurations. For the design condition (2) Easy to wash, the helmet suspension "B" was rated higher than helmet suspension "A."

The NVG factor p-values listed in table 8 indicate that none of the six design considerations have p-values that are statistically significant, thus indicating that the use of NVG did not affect the subjective responses for those design considerations (figure 16).

Table 8. Mixed ANOVA results for removal and wash questionnaire data.

No. of Design Considerations	Helmet Suspension Design Condition	Helmet Factor p-value	NVG Factor p-value	Helmet × NVG p-value
1	Easy to disengage from helmet	0.239	0.517	1.000
2	Easy to wash	0.003	0.228	0.764
3	Easy to reassemble	0.358	0.510	0.358
4	Simple to reinstall	0.633	0.466	0.633
5	Effective reattachment	0.152	0.095	0.152
6	Not complicated	0.852	0.161	0.103

[a]Indicates p-value <0.05.

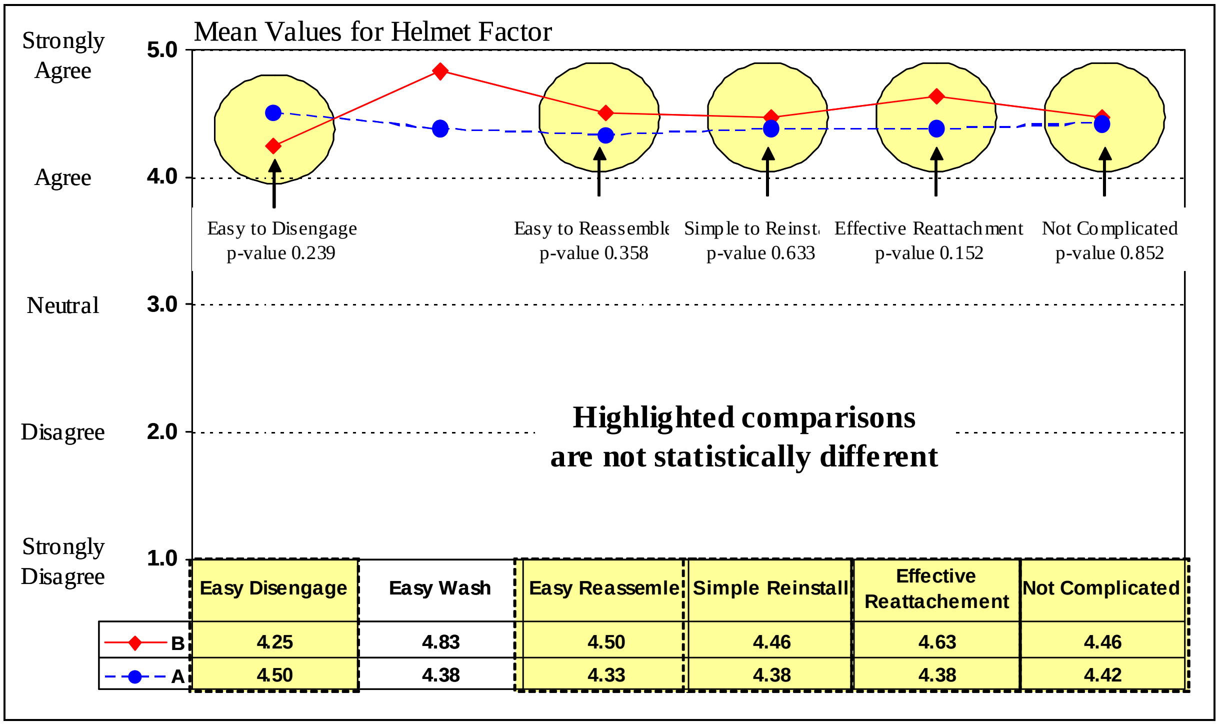


Figure 16. Means comparison for removal and washing questionnaire data.

The helmet × NVG (interaction) p-values listed in table 8 indicate that none of the six design considerations have p-values that are statistically significant at alpha 0.05, thus indicating that the subjects did not perceive the use of NVG to have affected the performance of either helmet suspension configuration.

6.7 Debriefing

In the final debriefing session, test participants were asked to choose their preference between suspension system "A" and "B" on each of the design considerations as well as their overall preference. Figure 17 summarizes the preference for the "A" or "B" suspension system per question or area of concern related to design considerations.

As can be seen in figure 17, the majority of the test participants perceived "B" to be better than "A" in 12 of the 13 design considerations by about a 2:1 ratio. In one design consideration, Easy to take off, the preference was fairly evenly split between the "A" and "B" systems, with "A" being the preference of 52% of the participants.

When asked for their overall preference of the suspension systems during the debriefing, 21 of 24 participants chose suspension system "B" over suspension system "A."

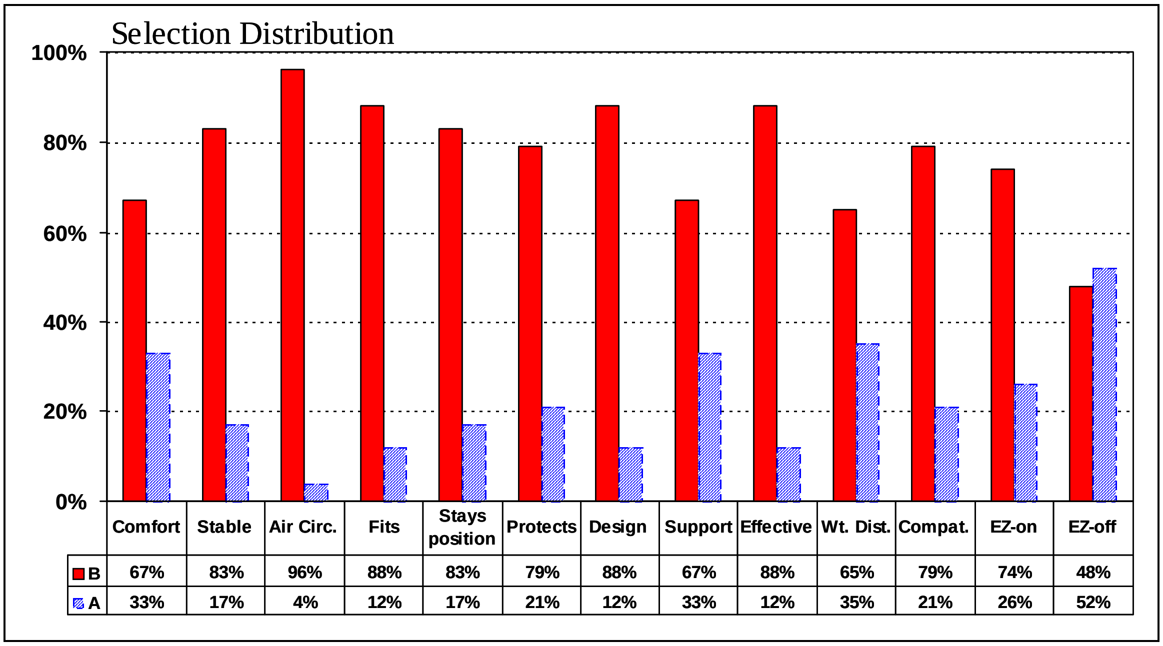


Figure 17. Participant selection distribution by design consideration.

7. Discussion

7.1 Test Participant Subjective Ratings

For the relatively static scenarios (firing and removal and wash), there were very few significant differences in the preferences for either helmet suspension system. For the firing scenario, there were no significant differences in the preferences for either helmet system. For the removal and wash scenario, the "B" suspension system was preferred over the "A" system for ease of washing, but no other preferences were statistically different between the systems.

For the four dynamic maneuver scenarios (obstacle course, IMT, grenade throw, and road march), results from the subjective data collected from the test participants generally favored the "B" suspension system over the "A" system. For the dynamic scenarios, helmet suspension "A" was never preferred over the "B" system, and the "B" system was preferred over the "A" system for most design characteristics. The mixed ANOVA for the four dynamic maneuver scenarios provided 46 possible outcomes: 11 for IMT, 11 for grenade throw, 11 for road march, and 13 for obstacle course. Of the 46 possible outcomes, 30 outcomes (65%) proved to be statistically significant in favor of the "B" suspension system.

Table 9 and the following narrative summarize the mixed ANOVA results from the four dynamic maneuver scenarios.

Table 9. Mixed ANOVA results summary for dynamic maneuver scenarios.

No. of Design Considerations	Dynamic Maneuver Scenario				
	Design Consideration	IMT	Obstacle Course	Grenade Throw	Road March
1	Comfortable	B	—	B	—
2	Stable on head	B	—	B	B
3	Air circulation	B	B	B	B
4	Fits well	—	B	B	B
5	Stay in position	B	B	B	B
6	Protective	—	—	—	—
7	Well designed	B	B	B	B
8	Support evenly	B	B	B	—
9	Effective	B	—	B	—
10	Distributes weight evenly	—	B	—	B
11	Compatible	B	B	—	—
12	Easy to put on	NA	B	NA	NA
13	Easy to take off	NA	—	NA	NA

Notes: A: liner system "A" preferred over liner system "B."
B: liner system "B" preferred over liner system "A."
NA = not applicable.

- Comfort
  - The comfort of the "B" suspension system was rated more favorably than the "A" system for both the IMT and grenade throw scenarios. It could be that the adjustability and the increased airflow of the "B" suspension system contributed to its favorable ratings.
- Stable on head
  - The "B" suspension system was preferred by the test participants over the "A" system for stability during the IMT, grenade throw, and road march scenarios. The headband and crown mesh configuration adjustability of the "B" system appear to provide improved stability over the pad system. The headband and the crown mesh can be adjusted to accommodate different head shapes and sizes.
- Air circulation
  - The test participants reported better air circulation with the "B" suspension system in all four dynamic maneuver scenarios. The area of contact between the suspension system and the user's head was reduced by the "B" suspension. The "B" suspension system had 29.75 in^2 of contact, and the "A" suspension pad system had 62.3 in^2 of contact. The "B" system reduced the contact area by 32.5 in^2.
- Fits well

- In the obstacle course, grenade throw, and road march scenarios, participants preferred the fit of the “B” suspension system over the “A” system. Adjustability features of the “B” helmet suspension may have allowed a better fit to a wider range of users.

- Stays in position

  - The headband and crown mesh method of suspension interface with the head used in suspension system “B” was preferred by the test participants in each of the four dynamic maneuver scenarios for its ability to keep the helmet in position.

- Protective

  - The design consideration for protection was rated evenly for the “A” and “B” suspension systems for all scenarios. With the outer shell of the helmet being identical, test participants may have had little knowledge on what the differences might be, for both ballistic and blunt trauma protection differences may exist between the two suspension systems.

- Well designed

  - The “B” suspension system was preferred by the test participants in each of the four dynamic maneuver scenarios for how well it was designed. This preference in design may have been because the “B” suspension system permits customized incremental adjustment of the sweat/headband and also allows for vertical adjustment with the crown mesh. These adjustments provide better conformity to every head shape and size.

- Supports evenly

  - The “B” suspension system was preferred over the “A” system on the design consideration of “supports evenly” for the IMT, obstacle course, and grenade throw scenarios. The “A” pad system was reported to have “hot spots” that would indicate uneven suspension support. The “B” suspension system received no reports of “hot spots.”

- Effective

  - For the IMT and grenade throw scenarios, the “B” suspension was perceived as being more effective overall than the pad system.

- Distributes weight evenly

  - For the obstacle course and road march scenarios, the test participants rated the “B” suspension system higher than the “A” suspension system for distributing weight evenly. The headband and crown mesh configuration of the “B” suspension had a perceived effect of distributing weight more evenly than the “A” suspension.

- Compatible
    - For the obstacle course and IMT trials, the “B” suspension was reported higher on compatibility than the “A” suspension system. The fact that test participants thought the “B” system kept the helmet in place better than the “A” suspension system may have been a factor in the higher compatibility rating. If the helmet stays in place better and is not moving other head-borne equipment (e.g., JSGP mask and balaclava), it may receive higher compatibility ratings.
- Easy to put on
    - The “B” system was rated higher on the design consideration of “ease to putting on” than the “A” system. The “B” suspension system has two adjustments (sweatband and crown mesh) and once set will remain. The “A” pad suspension system has multiple pad adjustments and may require readjustment when wearing the JSGP mask.
- Easy to take off
    - There was no difference in ratings between the two suspension systems for the ease in taking off the helmet.

7.2 Subject Matter Expert Assessment

7.2.1 “A” Suspension System

During the suspension washing and removal exercise, the Marines complained of the pad’s outer fabric delaminating from the pad itself. Also, some of the hook and loop fastener dots were pulled away from the interior of the helmet (see figure 18). This issue must be resolved in order to have pads that can be worn, cleaned, and reused with confidence.

In addition to the pads coming apart, the self-adhesive hook dots, which are located inside the helmet and grab the pads, were losing adhesion with the inside of the helmet and coming off. Even with the preparatory solution (which came with the pad kit) to clean the inside of the helmet surface for application of the adhesive, the hook dots did not work 100%. The hook dots continued to have adhesion problems inside the helmet. This issue must be resolved in order to have pads that can be worn, cleaned, and reused with confidence with the helmet.

Most of the participants reported that the weight of the NVG mounted on the LWH with “A” suspension system rotated the helmet forward on the head as the participant maneuvered on the obstacle course and IMT course (see figure 19). The forward movement of the helmet could reduce the vertical visual field by the front rim of the helmet.

Figure 18. Helmet "A" suspension pads after the pads were removed from the helmet to wash. (Some of the hook and loop fastener dots were pulled away from the interior of the helmet.)

Figure 19. Forward rotation of the LWH with "A" and mounted NVG as the participant maneuvered on the obstacle and IMT courses.

7.2.2 "B" Suspension System

During the initial suspension fitting process, participants complained of "two pressure points" at the crown pad on the "B" suspension. NRL and ARL investigators observed that the mounting tabs for the crown pad were too long. These tabs were then cut flush with the grommet, thus eliminating the pressure points (figures 20 and 21); no other complaints were noted.

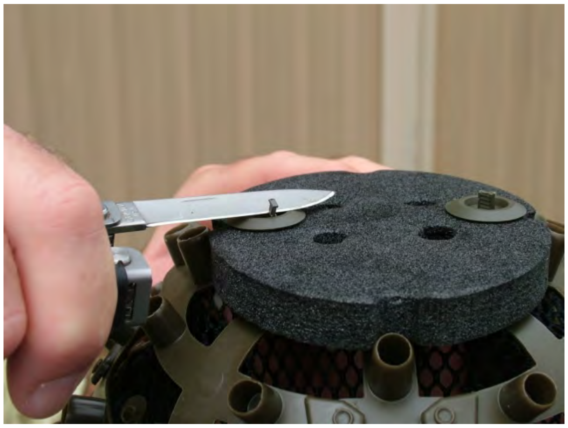


Figure 20. Cutting "A" grommet mounting tab with a knife.

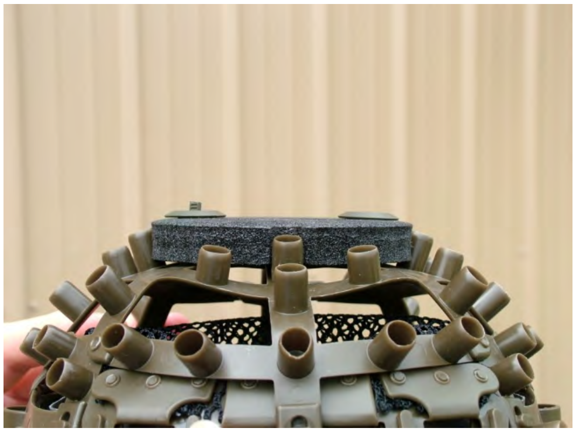


Figure 21. Flush cut of the tab on the right (front view).

Initially, the HeadGard suspension was not hard mounted to the helmet. During the first day of the assessment, Marines complained about the HeadGard helmet and "B" suspension shifting on the head. NRL personnel then modified the helmets to hard mount the suspension with the helmet, which resolved the helmet/suspension stability issue. NRL drilled and appropriately mounted the suspension to the helmet. The typical suspension mounting holes in the helmet did not align with the "B" suspension. The mounting holes in the "B" suspension will have to be relocated to match the current helmet hardware holes. The nape strap hardware on “B” helmet’s three-point chin strap was reported to be uncomfortable at the back of the head and just behind the participant’s ears (figure 22).

Figure 22. “B” helmet’s three-point hardware interacts with the back of the head and behind the participant’s ears.

During the wash and reinstallation event, one of the mounting tabs of suspension system “B” had broken in the joint between the horizontal and vertical leg (see figure 23). It is not known what caused this malfunction, but it may indicate a weak design point, weakened material, or an improper technique/method of suspension insertion and removal. To help correct this from happening in the future, the material and design should be reviewed for correctness, and proper training must always be administered to the Marines before the suspension is used.

Figure 23. Suspension system “B” (note the broken mounting tab).

8. Conclusions and Recommendations

The statistical analysis conducted on the test data indicates a preponderance of ratings where “B” suspension was perceived to perform better than “A,” particularly in the four dynamic maneuver scenarios. In addition, the qualitative assessment of each helmet suspension suggests that “A” suspension had several design/structural shortcomings that adversely affected the perception of its performance, whereas initial shortcomings of the “B” suspension were easily corrected during testing.

The imperative design considerations of a helmet suspension system are air circulation, stability, fit, comfort, compatibility with head-borne equipment, even distribution of head-borne weight, and wearer’s perception of the system.

The major contributing factor for the increased air circulation in the “B” suspension was the fact that the “A” pads have 62.3 in^2 of contact between the head and pads (all seven required pads). The “B” suspension has 29.75 in^2 of contact between the sweatband and head. The “B” suspension crown mesh is breathable and was therefore considered negligible in the calculation. The difference between the areas of surface contact was 32.5 in^2 between the “A” vs. the “B” suspension systems. This is a reduction of almost one-half over the “A” pad system. This reduction in the “B” suspension may allow significantly more airflow between the head/suspension and the helmet interior, which may result in a much cooler system.

The “A” pads are in direct contact with the head and may act as insulation. This insulation effect combined with the reported reduced airflow causes heat buildup under the helmet as user wear time increases. The “B” suspension system does not have this insulation issue. Although there is 29.75 in^2 of contact with the headband, it comprises a thin sweat wicking material backed by a plastic adjustment band. This band assembly seems to allow the heat to dissipate more readily and may not contribute to heat buildup like system “A.” The participants reported better airflow with the “B” suspension system.

The “A” pad system requires seven pads to meet ultimate design and protection compliance for combat conditions. Typically, users in the field remove some of the pads to increase the airflow for an additional cooling effect. This action reduces the standoff and protection capability required for maximum user protection.

The “B” suspension system does not allow a reduction in any effectiveness because none of the suspension components are removable.

Based on our conclusions, we’ve compiled the following recommendations:

- Trim the “B” suspension crown retention tabs during manufacture so the suspension is “field ready.”
- Modify the “B” suspension mounting holes to align with the current helmet mounting hardware locations.
- Review the “B” suspension material and design to prevent material breakage at the mounting tabs.
- Examine the “B” helmet’s three-point retention system hardware to determine if interaction between the back of the head and behind the ears can be eliminated.
- Review pad cover material/design of “A” suspension for better durability and better adhesion of pads to the hook dot. Also, review the attachment means of the hook dots with the interior of the helmet.

Appendix A. Volunteer Agreement Affidavit

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

VOLUNTEER AGREEMENT AFFIDAVIT:
ARL-HRED Local Adaptation of DA Form 5303-R. For use of this form, see AR 70-25 or AR 40-38

The proponents for this research are: U. S. Naval Research Laboratory and the U.S. Army Research Laboratory and the Human Research and Engineering Directorate
at Aberdeen Proving Ground, MD 21005

Authority:	Privacy Act of 1974, 10 USC 3013, 44 USC 3101, and 10 USC 1071-1087
Principal purpose:	To document voluntary participation in the Research program. Social Security number (SSN) and home address will be used for identification and locating purposes.
Routine Uses:	The SSN and home address will be used for identification and locating purposes. Information derived from the project will be used for documentation, adjudication of claims, and mandatory reporting of medical conditions as required by law. Information may be furnished to Federal, State, and local agencies.
Disclosure:	The furnishing of your SSN and home address is mandatory and necessary to provide identification and to contact you if future information indicates that your health may be adversely affected. Failure to provide the information may preclude your voluntary participation in this data collection.

Part A • Volunteer agreement affidavit for subjects in approved Department of Army research projects

Note: Volunteers are authorized all necessary medical care for injury or disease that is the proximate result of their participation in such studies under the provisions of AR 40-38 and AR 70-25.

Title of Research Project:	Title: A Human Factors Assessment of U. S. Marine Light Weight Helmet Suspension Systems – Standard Pad vs. a Proposed Liner, HeadGard	
Human Use Protocol Log		
Principal Investigator(s):	Richard Bruno U. S. Army Human Research and Engineering Directorate, APG, MD.	Phone: 410 278 5931 E-Mail: rbruno@arl.army.mil
Associate Investigator(s)	Jim Faughn U. S. Army Human Research and Engineering Directorate, APG, MD.	Phone: 410 278 2573 E-Mail: jfaughn@arl.army.mil
Location of Research:	KD Range (mobility portability course) and M Range (firing range)	
Dates of Participation:	1 June to 30 June 2008	

I do hereby volunteer to participate in the research project described in the table above. I have full capacity to consent and have attained my 18th birthday. The implications of my voluntary participation, duration, and purpose of the research project, the methods and means by which it is to be conducted, and the inconveniences and hazards that may reasonably be expected have been explained to me. I have been given an opportunity to ask questions concerning this research project. Any such questions were answered to my full and complete satisfaction. Should any further questions arise concerning my rights or project related injury, I may contact the ARL-HRED Human Use Committee Chairperson at Aberdeen Proving Ground, Maryland, USA by telephone at 410-278-0612 or DSN 298-0612. I understand that any published data will not reveal my identity. If I choose not to participate, or later wish to withdraw from any portion of it, I may do so without penalty. I understand that military personnel are not subject to punishment under the Uniform Code of Military Justice for choosing not to take part as human volunteers and that no administrative sanctions can be given me for choosing not to participate. I may at any time during the course of the project revoke my consent and withdraw without penalty or loss of benefits. However, I may be required (military volunteer) or requested (civilian volunteer) to undergo certain examinations if, in the opinion of an attending physician, such examinations are necessary for my health and well being.

Part B • To be completed by the Principal Investigator
Note: Instruction for elements of the informed consent provided as detailed explanation in accordance with
Appendix C, AR 40-38 or AR 70-25.

Purpose of the Research

The purpose or objective of this assessment is to assess the Marine Light Weight Helmet compatibility with the HeadGard helmet suspension system in a dynamic setting for fit and compatibility issues.

Procedures

You will be sized and fitted with the Marine Light Weight Helmet configured with standard “A” PADS helmet suspension system and a proposed suspension system – HeadGard or “B” suspension. The helmet weighs approximately 3 pounds. A night vision device, standard version, will be mounted on the helmet. You will then negotiate the ARL HRED Mobility Portability (MP) obstacle course, either or without the night vision device, for the dynamic portion of the evaluation. The kinds of dynamic maneuvers required are those a soldier would be expected to perform in a combat assault, like running, jumping, climbing, balancing, crawling and swinging. After completing the obstacle course, you will be debriefed and administered a questionnaire regarding the fit of the helmet suspension systems. After the course completion, you will then fire weapons from the standing posture at the ARL HRED firing range known as M-range. You will be wearing the standard body armor and the Marine Light Weight Helmet with candidate suspension systems. You will be debriefed and administered a questionnaire regarding your ability to fire while wearing the helmet with the suspensions. After completing weapons firing, you will complete three additional tasks: donning the M50 JSGP mask and balaclava and filling six sand bags. Again you will fill out questionnaires related to these tasks. Upon returning to the KD Range, you will then remove the suspension from the helmet and wash the suspension, then reinstall it back into the helmet. A questionnaire related to this task will be administered. Rest periods between the course and task activities will be dictated by experimenters to ensure adequate rest/work cycles are followed. Drinking water will be provided by the investigator. All safeguards and weather considerations will be monitored to ensure a safe and accident free operation. You will be briefed on all phases of this limited evaluation and can ask questions at any time, and quit at any time, without penalty.

During the conduct of this assessment, all identification/information will be removed from the uniform and equipment, therefore, your identity will be protected. Photographs/videos will be taken to document the assessment and to identify issues. These photos/videos may be used in briefings and reports. Please give your consent to be photographed/videoed during this assessment. YES ___ //// NO ___ please initial next to yes or no.

Benefits

You will receive no benefits from participating in this limited evaluation or demonstration, other than the personal satisfaction of supporting the U. S. military effort to develop an improved helmet suspension system for the U. S. Marine Corp.

Risks

Your risk associated with this limited evaluation or demonstration is minimal. Injuries that could occur are minor cuts, and abrasions, however there is always associated potential risk from falling from an obstacle. All activities are within MOS related tasks. There is a risk of tick bites and the potential for Lyme disease. You will be instructed on this risk, the symptoms associated with this disease, and what you should do if you experience any of these symptoms after this assessment. You will be presented with information in Appendix D to read.

Confidentiality

All data and information obtained about you will be considered privileged and held in confidence. Photographic or video images of you taken during this data collection will not be identified with any of your personal information (name, rank, or status). All examinations will be recorded using a volunteer identifier code and a separate file with your consent form. The Principal Investigator will keep your assigned volunteer identifier code in a locked cabinet. Complete confidentiality cannot be promised, particularly if you are a military service member, because information bearing on your health may be required to be reported to appropriate medical or command authorities. In addition, applicable regulations note the possibility that the U.S. Army Medical Research and Materiel Command (MRMC-RCQ) officials may inspect the records.

Compensation

No compensation is associated with this effort.

Disposition of Volunteer Agreement Affidavit

The Principal Investigator will retain the original signed Volunteer Agreement Affidavit and forward a photocopy of it to the Chair of the Human Use Committee after the data collection. The test administrator will provide a copy to the volunteer upon request.

Include this section only if GREATER THAN MINIMAL RISK
or REQUIRED BY THE HUMAN USE APPROVAL AUTHORITY

Volunteer Registry Database

It is the policy of the ARL-HRED that personal contact information of all volunteers participating in research that involves "Greater than Minimal Risk" is entered into a Volunteer Registry Data Base. The information to be entered into this confidential database includes your name, address, Social Security number, project name, and dates. The intent of the data base is twofold: first, to readily answer questions concerning an individual's participation in research sponsored by ARL-HRED; and second , to ensure that the ARL-HRED can exercise its obligation to ensure research volunteers are adequately warned (duty to warn) of risks and to provide new information as it becomes available. The information will be stored at ARL-HRED for a minimum of 75 years.

Your signature below indicates that you: (1) are at least 18 years of age, (2) have read the information on this form, (3) have been given the opportunity to ask questions and they have been answered to your satisfaction, and (4) have decided to participate based on the information provided on this form.

Printed Name Of Participating Volunteer (First, MI., Last)	
Social Security Number (SSN)	***Permanent Address Of Participating Volunteer***
Date Of Birth (Month, Day, Year)	
Today's Date (Month, Day, Year)	***Signature Of Participating Volunteer***
Signature Of Administrator	

Contacts for Additional Assistance

If you have questions concerning your rights on research-related injury, or if you have any complaints about your treatment while participating in this research, you can contact:

Chair, Human Use Committee U.S. Army Research Laboratory Human Research and Engineering Directorate Aberdeen Proving Ground, MD 21005 (410) 278-0612 or (DSN) 298-0612	**OR**	Office of the Chief Counsel U.S. Army Research Laboratory 2800 Powder Mill Road Adelphi, MD 20783-1197 (301) 394-1070 or (DSN) 290-1070

Appendix B. Obstacle Course Questionnaire

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

Marine Lightweight Helmet Suspension System Assessment

Date_____ Participant# ______ Suspension System: A // B

Night Vision Device attached - circle yes // no

Obstacle Course ___ IMT ___ Grenade Throw ___ Road March___

The helmet suspension system was:

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Comfortable					
Stable on my head					
Allowed air circulation/flow					
Fits well on head					
Stayed in position					
Protective					
Well designed					
Supports evenly					
Effective					
Distributes weight evenly on head					
Compatible					
Easy to put on					
Easy to take off					

Appendix C. M-Range Questionnaire

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

Marine Lightweight Helmet Suspension System Assessment

Date_____ Participant# ______ Suspension System: A // B

M-range Weapon Firing _____ Sand Bag Fill Task ___

Mask Interface ___ Balaclava Interface ____

The helmet suspension system was:

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Comfortable					
Stable on my head					
Allowed air circulation/flow					
Fits well on head					
Stayed in position					
Protective					
Well designed					
Supports evenly					
Effective					
Distributes weight evenly on head					
Compatible					
Easy to put on					
Easy to take off					

Appendix D. Helmet Suspension Wash and Reinstallation Questionnaire

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

Marine Lightweight Helmet Suspension System Assessment

Date_____ Participant# ______ Suspension System: A // B

Helmet Suspension System Removal from the LWH and Washing and then Reinstallation

The helmet suspension system was:

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Easy to disengage from helmet					
Easy to wash					
Easy to reassemble					
Simple to reinstall					
Effective reattachment					
Not complicated					

Comments/Suggestion:____
____
____
____
____

Appendix E. Summary of Anthropometric Measures

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

Anthropometric Data

21 U. S. Marines (males)

Measures	Range	Percentile Range
Stature range:	164.3 – 185.8 cm	5 to 93
Weight range:	130 – 195 lbs	3 to 82
Head breadth:	14.7 – 16.1 cm	20 to 97
Head length:	18.6 – 21.0 cm	6 to 97
Head circumference:	53.7 – 59.8 cm	2 to 59
Bitragion coronal arc:	33.2 – 36.4 cm	5 to 80

2 U. S. Marines (females)

Measures	Range	Percentile Range
Stature range:	158.73 – 175.9 cm	25 to 98
Weight range:	115 – 150 lbs	11 to 78
Head breadth:	14.4 – 15.6 cm	50 to 99
Head length:	19.3 – 19.7 cm	82 to 94
Head circumference:	55.5 – 58.9 cm	75 to 99
Bitragion coronal arc:	35.9 – 36.9 cm	96 to 99

Anthropometric Data from "1988 Anthropometric Survey of U.S. Army Personnel:

Methods and Summary Statistics, " NATICK/TR-89/044, 1988.

Note: Used 1988 Survey of U. S. Army Population Data to catalog these participants.

Appendix F. Debriefing Questionnaire

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

SUSPENSION SYSTEM DEBRIEFING QUESTIONNAIRE:

Participant Number:__________

Please rate your overall choice for the best of the two suspensions either A or B in the following categories.

	A	**B**	COMMENTS		
Comfortable					
Stable on my head					
Allowed air circulation/flow					
Fits well on head					
Stayed in position					
Protective					
Well designed					
Supports evenly					
Effective					
Distributes weight evenly on head					
Compatible					
Easy to put on					
Easy to take off					

ADDITIONAL COMMENTS:____

____

____

____

____

Appendix G. Weather Data

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

Weather Data

Date	Time of Day Hours	Temperature F	Wind Speed (Knots)	WBGT F
17 June 2008	0800	63	0	69.2
17 June 2008	1200	81	12	75.2
17 June 2008	1600	75	8	71.9
18 June 2008	0800	54	0	62.1
18 June 2008	1200	73	12	66.8
18 June 2008	1600	77	4	72.2
23 June 2008	0800	70	0	70.7
23 June 2008	1200	82	0	85.2
23 June 2008	1600	84	4	80.7
24 June 2008	0800	57	14	66.5
24 June 2008	1200	79	10	75.0
24 June 2008	1600	82	7	75.9
25 June 2008	0800	59	0	73.2
25 June 2008	1200	82	4	76.3
25 June 2008	1600	88	0	79.7
26 June 2008	0800	68	0	74.6
26 June 2008	1200	88	8	78.1
26 June 2008	1600	90	9	82.5

F = degrees Fahrenheit

Data sources: Aberdeen Test Center and Phillips Army Airfield, APG, MD.
The airfield is approximately 1.5 miles from the KD Range.

Appendix H. Photographs of the Participants Wearing the Lightweight Helmet (LWH) With the Suspension Systems "A" and "B"

H.1 Photographs of the Participants on the Obstacle Course

Figure H-1. Participants negotiating the low wall.

Figure H-2. Participant negotiating the logs.

Figure H-3. Participants negotiating the cargo net.

Figure H-4. Participant negotiating up and down.

Figure H-5. Participant negotiating the tires.

Figure H-6. Participant negotiating the "belly buster."

Figure H-7. Participant negotiating the high crawl.

Figure H-8. Participant negotiating low crawl.

Figure H-9. Participant negotiating the inverted fox hole.

Figure H-10. Participant negotiating the over and under hurdles.

Figure H-11. Participant negotiating the high fence.

Figure H-12. Participant negotiating the drainage pipe.

Figure H-13. Participant negotiating the high wall.

Figure H-14. Participant negotiating the low window.

Figure H-15. Participants negotiating the high windows.

Figure H-16. Participant negotiating the stairs and building.

Figure H-17. Participant negotiating the zig zag.

H.2 Photographs of the Participants on the Individual Movement Technique (IMT) Course, Grenade Throw, and Road March

Figure H-18. Two participants negotiating the IMT course.

Figure H-19. Participant throwing an inert grenade.

Figure H-20. Participants on the road march.

Figure H-21. Participants answering questionnaires.

H.3 Photographs of the Participants at the M-Range

Figure H-22. Participant firing the M16A2 rifle.

Figure H-23. Participant firing the M4 rifle.

Figure H-24. Participant firing the M14A1 rifle.

Figure H-25. Participant firing the M240B machine gun.

Figure H-26. Participants filling sand bags.

Figure H-27. Participants donning the M50 Joint Service General Purpose (JSGP) mask.

Figure H-28. Participants donning the balaclava with the LWH.

Figure H-29. One of the three groups of eight participants.

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R BRUNO (75 CPS)
P SAVAGE-KNEPSHIELD

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