

# UNITED STATES AIR FORCE RESEARCH LABORATORY

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## Helmet Pointing Performance Differences between Males and Females During High-Sustained Acceleration

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The voluntary informed consent of the subjects used in this research was obtained as required by Air Force Instruction 40-402.

This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE DIRECTOR

  
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<b>13. ABSTRACT (Maximum 200 words)</b> Because females only recently became fighter pilots, the literature contains very little information on female performance during high-sustained acceleration. The hypothesis of this research was that female subjects would have similar helmet pointing task performance during high-sustained acceleration compared to males. Five female and five male subjects performed simple and complex tracking tasks at 1.4, 4.0, and 6.5 Gz in a human centrifuge. There was no significant difference in helmet pointing performance between males and females under the different gravity (G) settings. Overall, male subjects performed 17% better but this difference was not statistically significant. Means followed trends where increasing helmet weight or a movement in the center of gravity away from a reference position resulted in poorer tracking performance; however, the mean differences were very small compared to the effects of task and Gz.
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## PREFACE

This research was performed in conjunction with an Air Force Research Laboratory (AFRL) helmet biodynamics research project at AFRL/HEPA, Bldg 33. The project was partially funded by the Joint Strike Fighter Systems Program Office at Wright-Patterson AFB OH.

The AFRL Human Effectiveness Directorate has a memorandum of agreement with Wright State University (WSU) to "pursue common research and education goals through cooperative and supportive efforts." Aerospace medicine residents at WSU conduct research in the directorate as partial fulfillment of the MS degree in Aerospace Medicine.

Dr. Al-Nuaimi was a graduate student and completed this thesis research as a partial fulfillment of the MS in Aerospace Medicine degree at Wright State University in 2000.

Additional subject data were collected and analyzed after Dr. Al-Nuaimi completed the report for his MS degree. This technical report has been changed to reflect the findings from those data.

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## INTRODUCTION

As of recent times, very little information is known about female gravity (G) tolerance and performance in high-G environments. With female pilots now flying high-performance aircraft, in both the US Air Force and Navy, gender-specific factors that may affect female acceleration tolerance have become increasingly essential (1, 2, 3, 4, 6, 7, 8, 9, 11, 15, 16, 17, 20, 21). G-tolerance differs widely among individuals (males and females) (5, 10, 13, 14, 19). It stands to reason that aircrew with higher G-tolerance are less likely to experience symptoms of G-stress in flight than are those with lower G-tolerance, and that they can fly highly maneuverable aircraft with greater safety and effectiveness. To give surety that aircrew with abnormally low G-tolerance are not assigned to aircraft that function in the high-G environment, a G-tolerance standard and the means to execute that standard are crucial (10, 12).

Helmet-mounted systems (e.g., night vision goggles, missile aiming systems) are being introduced to the fighter cockpit. Helmets can now weigh 1 - 2.5 lbs. heavier with these systems (18). How will this added weight and change in the center of gravity (CG) of the helmet affect pilot performance? How will females perform in this environment when, in general, it is believed they have weaker neck muscles than their male counterparts?

The neck musculoskeletal system must bear increased loads with the addition of weights on the helmet. These loads were expected to produce some minor muscular pain or soreness in some subjects. The symptoms should be alleviated within 24-48 hours, similar to what would be expected following weight-bearing exercise. The purpose of the study was to compare the genders in their ability to perform a helmet pointing task at high G.

## MATERIAL AND METHODS

### Subjects

Ten subjects (five females and five males) were included in this study. The average age of the female subjects was 26.6 years (range = 22-32), their average weight was 59.4 kg (range = 52.2-66.2), and their average height was 162.6 cm (range = 157.5-177.8). The average age for the male subjects was 30.2 years (range = 26-36), their average weight was 70.9 kg (range = 57.6-79.3), and their average height was 169.4 cm (range = 157.5-177.8). All

subjects tested were members of the Air Force Research Laboratory (AFRL) Sustained Acceleration Panel of Wright-Patterson Air Force Base (WPAFB), Ohio.

The Institutional Review Boards of Wright State University (WSU) and AFRL approved the research protocol of this study, which is part of the AFRL helmet study. According to guidelines established by both the AFRL and WSU and prior to participation in this study, all subjects were briefed on the research protocol, including the potential risks, and then their informed consent was collected. Each subject passed the medical screening examinations including: spinal and cranial radiographs, blood analysis, electrocardiogram (ECG), and a neurological exam. Subjects were protected by the appropriate G-suits necessary for the G-level of the trial. They were trained to experience multiple G-exposures and were provided by verbal feedback of their physical and visual status throughout the profiles.

#### Centrifuge

The Dynamic Environment Simulator (DES), located at the AFRL, was used to produce the sustained acceleration environment for the study. The DES, a 19-foot radius man-rated centrifuge, has the capability of precision three-axis motion and can simulate any of the three G-vectors independently or combined in either open- or closed-looped mode (Figure 1). Subjects were seated in the gondola with the seat, ACES II-type, configured with a 15-degree seat back, facing forward with adequate restraint belts for positive sustained acceleration. The DES arm speed and cab position was operated under open-loop computer control with hypergravity experiences in the +Gz axis.

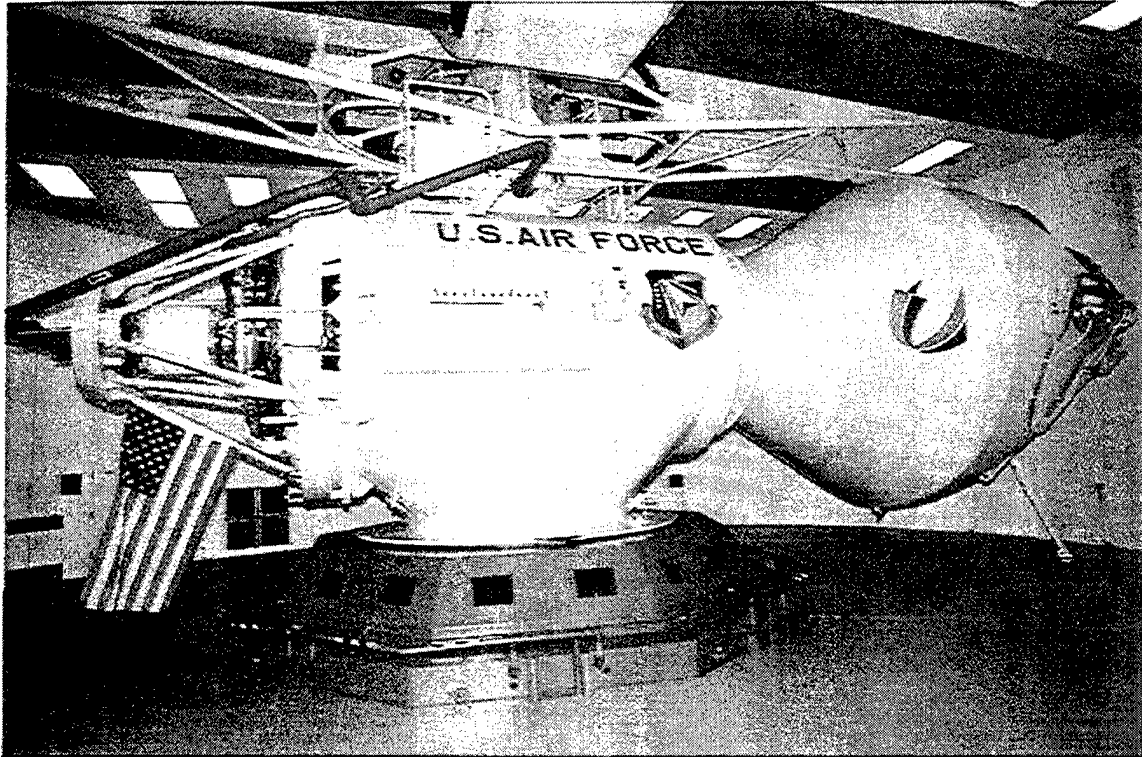


Figure 1. Dynamic Environment Simulator (DES) Centrifuge

This experimental configuration was similar to the one used in evaluation of the Interim-Night Integrated Goggle Head Tracking Systems (I-NIGHTS) performed in the AFRL (18).

#### Study Design

The first phase of the study required a few G-exposures for training and familiarization before exposing the subjects to the range of accelerations used in the study. Subjects were placed in the cab of the DES centrifuge and exposed to a 1.4 Gz "baseline" condition (12 revolutions/minute) and a 6.5 Gz peak (30 revolutions/minute) Simulated Air Combat Maneuver (SACM). Each run was 6 minutes in duration including 2 minutes of pre baseline, 2 minutes of SACM, and 2 minutes at post baseline (Figure 2).

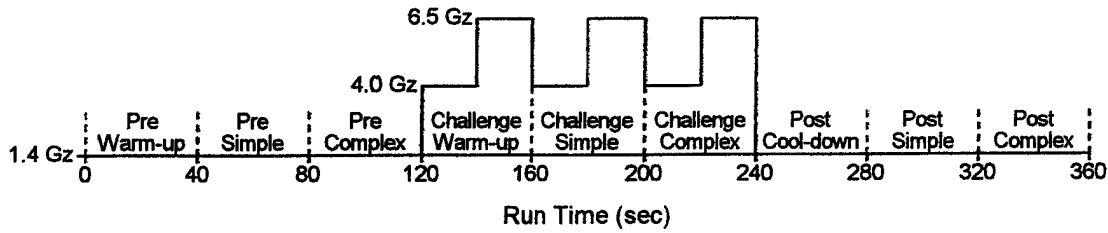


Figure 2. Sample Run

For the tracking task, a screen was mounted in front of the subject. A head-slaved tracking task was projected onto the screen to measure performance. A target (box in Fig. 4) was projected onto the screen in front of the subject to simulate the motion of an object outside and beyond the aircraft. The field-of-view for the tracking task was  $56^{\circ}$  H x  $44^{\circ}$  V (Figure 3). The task consisted of aiming the helmet-mounted laser pointer (circle) at the randomly moving box projected on the screen in the dark cab (Figure 4). Video capture tracking software was used to measure the pilot error during the tracking task. The helmet system, developed by the AFRL, allows for varying the system weight and CG (Figure 5).



Figure 3. Back View of Subject Sitting in the DES Cab Performing the Helmet Pointing/Aiming Task

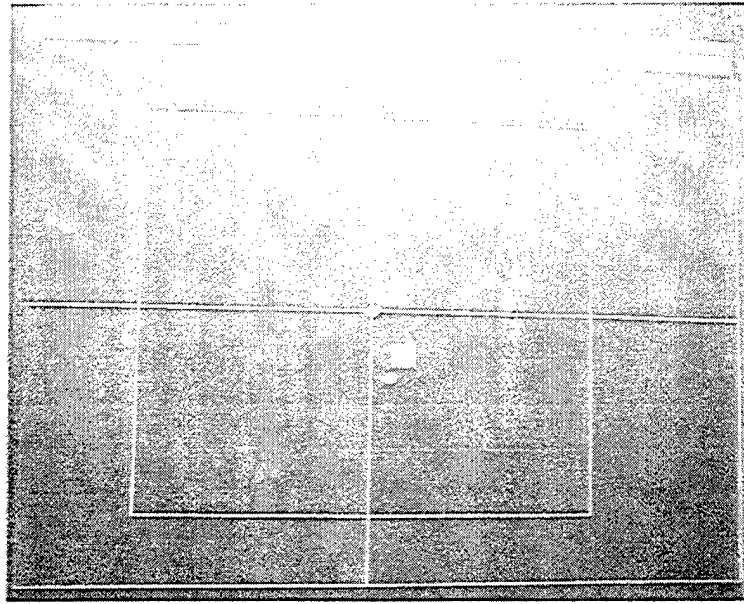


Figure 4. Helmet Pointing Task on DES Cab Screen

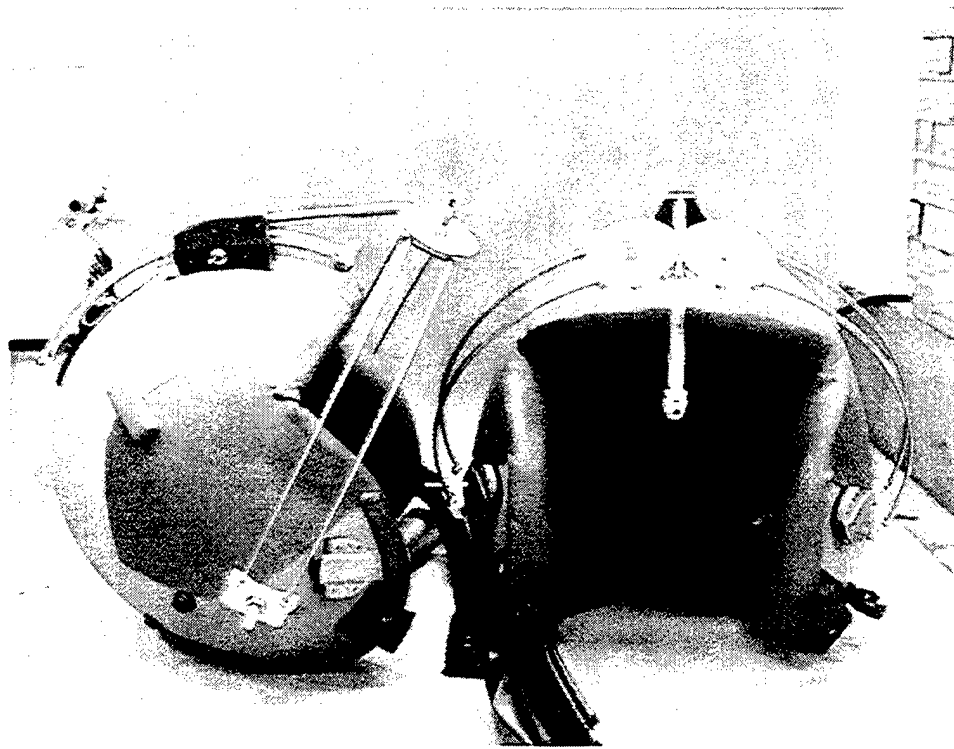


Figure 5. Variable Weight/Center-of-Gravity Research Helmet (Side and Front Views)

Helmet weight and CG was controlled using a set of weighted attachments to allow the CG to be adjusted by changing the position of attachments securely mounted on the side of the helmet. Two helmet configurations weighing 2.5 lbs. (no added weight) and 3.5 lbs. (1 lb. added) were used for testing (Figure 5). Adequate sizing to insure proper "fit" for all subjects was used. Experienced personnel were appointed to help insure the best fit of helmets for all subjects.

From the performance data, tracking error was calculated using root mean square error (RMSE). Statistical Analysis Software (SAS) was used to perform a mixed design analysis of variance (ANOVA). Post-hoc paired comparisons used the Bonferroni paired comparison procedure with a familywise error level of 0.05.

All on-site monitoring was conducted by a qualified flight surgeon, who evaluated every G-exposure. All subjects were clinically examined to ensure fitness both before and after each run.

## RESULTS

Factors used in the analysis were gender (female, male), tracking task (simple, complex), Gz (1.4, 4.0, 6.5), and helmet (2.5-0, 3.5-0, 3.5-1). Helmet is a combination of helmet weight and CG where the number before the dash is the helmet weight in pounds and the number after the dash is CG in inches.

After the initial period of training, each subject had six experimental days with two runs per day. During a particular day, the subject would wear one of the two helmet weights for both runs. On days using the 3.5 lb. helmet, each CG (0 or 1) was used for one of the runs. The presentation of task and helmet were counterbalanced within each subject in order to help minimize order effects. During each test run, the subject would perform both tasks at pre baseline (1.4 Gz), at 4.0 and 6.5 Gz, and end with both tasks at post baseline (1.4 Gz).

The tracking RMSE was determined for each subject, day, run, Gz (pre and post separately), and task. The tracking RMSE values were logged for analysis due to positive skewness. The logged values were then averaged for each combination of subject, task, Gz (pre and post baseline combined), and helmet. Across days and runs, there were 16 replications at 1.4 Gz and 4 replications at 4.0 and 6.5 Gz. These averaged values were used as the dependent

variable in a mixed design ANOVA with gender (female and male) a between factor and within factors helmet (2.5-0, 3.5-0, 3.5-1), task (simple, complex), and Gz (1.4, 4.0, 6.5).

Table 1 presents the ANOVA results. The Greenhouse-Geisser corrections are given. The error term for the test of gender was subject nested in gender. For all other tests, appropriate subject interactions were used as the error term. Figure 6 contains main effect means.

Table 1. Analysis of Variance (ANOVA) Results. The Dependent Variable was Log (Tracking RMSE).

Source	DF	SS	DFE	SSE	F-value	P-value	G-G P-value	G-G Epsilon
Gender (G)	1	2.39E-01	8	1.30E+00	1.47	0.2599		
Helmet (H)	2	1.23E-02	16	2.38E-02	4.15	0.0353	0.0403	0.9131
Task (T)	1	1.36E+00	8	1.61E-02	678.75	0.0001		
Gz (Gz)	2	2.18E-01	16	1.79E-01	9.75	0.0017	0.0036	0.8222
G*H	2	5.75E-03	16	2.38E-02	1.94	0.1766	0.1814	0.9131
G*T	1	1.98E-04	8	1.61E-02	0.10	0.7614		
G*Gz	2	4.10E-02	16	1.79E-01	1.84	0.1915	0.2001	0.8222
H*T	2	2.87E-03	16	1.72E-02	1.33	0.2919	0.2908	0.7842
H*Gz	4	7.23E-03	32	2.40E-02	2.41	0.0696	0.0941	0.7275
T*Gz	2	1.75E-02	16	1.36E-02	10.28	0.0013	0.0034	0.7901
G*H*T	2	4.29E-03	16	1.72E-02	1.99	0.1688	0.1811	0.7842
G*H*Gz	4	5.99E-03	32	2.40E-02	2.00	0.1184	0.1433	0.7275
G*T*Gz	2	2.74E-03	16	1.36E-02	1.61	0.2312	0.2372	0.7901
H*T*Gz	4	1.58E-03	32	2.09E-02	0.60	0.6630	0.6041	0.6785
G*H*T*Gz	4	1.86E-03	32	2.09E-02	0.71	0.5892	0.5417	0.6785

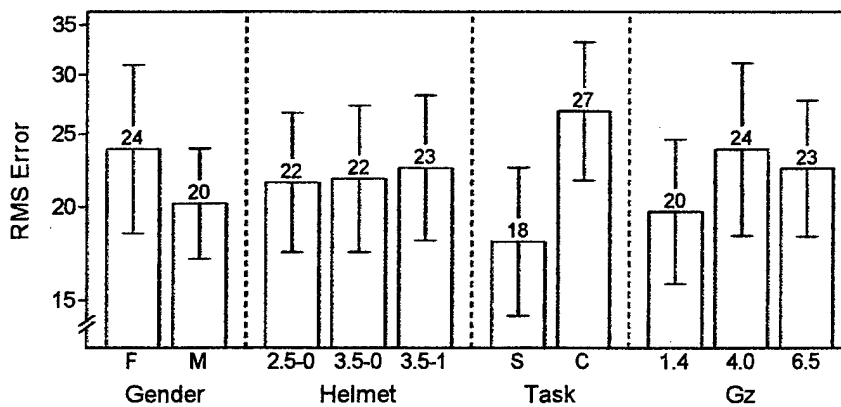


Figure 6. Main effect means ± standard deviation of subjects

As seen in Table 1, there was not a significant main effect of gender ( $p = 0.2599$ ) or any significant interactions with gender ( $0.1433 < p$ ). There was a significant main effect of helmet ( $p = 0.0403$ ) with post-hoc paired comparisons showing 2.5-0 significantly different from 3.5-1 and no other paired comparisons significant. There were also significant main effects of task ( $p = 0.0001$ ) and Gz ( $p = 0.0036$ ), however, there was also a significant interaction between task and Gz ( $p = 0.0034$ ). Simple main effect tests and paired comparisons within the task\*Gz interaction did not show mean differences in Gz with the complex task varying much compared with mean differences with the simple task. The significance of the interaction is more a result of very consistent mean differences across subjects.

Figure 7 shows the mean tracking error for each subject at Gz = 6.5. Since the primary purpose of this study was to examine genders under Gz stress, this figure indicates performance under the highest Gz in the study.

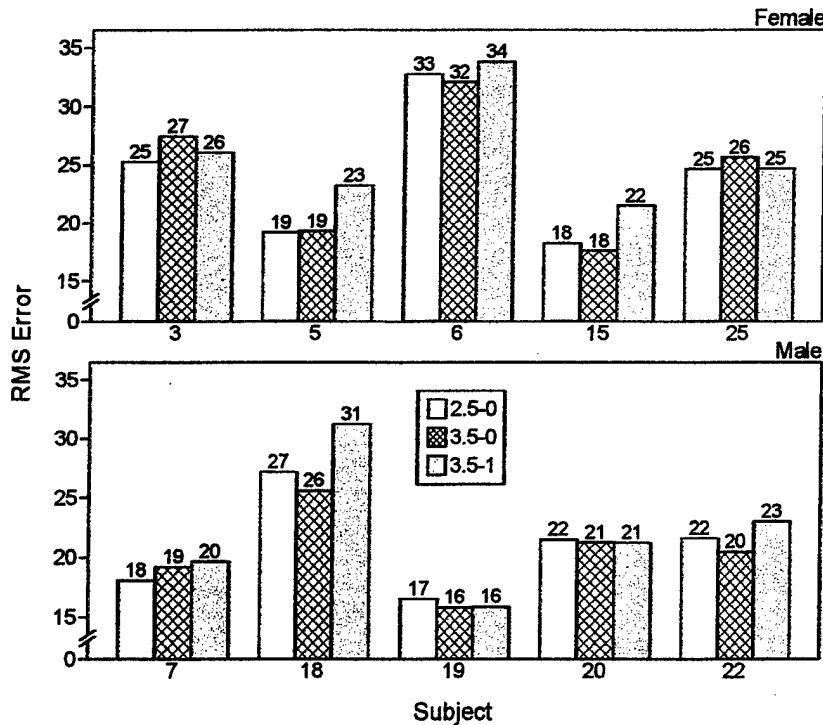


Figure 7. RMS Error at Gz = 6.5 averaged across task for each subject. Bar style represents helmet condition.

## DISCUSSION

The main objective of this study was to compare helmet pointing performance between males and females under the G-environments examined herein. Additional factors were included in the study, such as helmet weight, CG, and task (simple or complex) to answer additional helmet and acceleration performance issues. All subjects participating in the experiment were able, without great difficulties, to perform all the required tasks under G. There were no incidents of G-induced physiological sequelae or loss of consciousness.

The study showed no significant difference in tracking task performance under Gz between females and males. Males, on average, performed better by 17%. When examining individual means, the tracking performance of the genders was similar, however, one of the five females was a relatively poor tracker while one of the five males was a relatively good tracker, accounting for much of the gender difference. Whether these tracking differences among subjects is related to their neck muscle activity will be examined in future analyses.

As expected, all subjects had more accurate tracking performance at 1.4 Gz. This stresses the fact that there is an inverse relationship between performance and the G-amplitude. When this stress is added to the actual flying task, it can further diminish performance.

Means followed trends where increasing helmet weight or a change in the CG resulted in poorer tracking performance, however, the mean differences were very small compared to the effects of task and Gz. The average weight of the HGU-55P flight helmet is 2.5 lbs. Adding 1 lb. of weight plus changing the CG of this added weight had little effect on performance. This added weight might have resulted in a big performance difference if a different pointing task or a multiple task (e.g., the dual task of pointing and communication) were used. It was determined early on, however, that the subjects had great difficulty in keeping their heads erect and pointing when more than 1 lb. of weight was added to the helmet at an extended position near the helmet brow.

Further research on the topic of helmet-mounted systems and performance in the high-G environment should include more operationally relevant tasks (e.g., dropping bombs, laser-guided munitions) for longer durations and at higher G-levels.

## CONCLUSIONS

In this experiment, with the helmet aiming tracking task described and with the weights, CG, and G-levels described, there was not a significant difference in helmet pointing performance between males and females. Neither the addition of 1 lb. of weight near the CG of the standard HGU-55P helmet or moving half the pound to a position near the helmet brow pad had much effect on the helmet aiming and pointing task. There was a significant difference in helmet pointing performance between simple and complex tasks.

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