Assessment of a Prototype Apache Flight Eyewear

David V. Walsh; Gina M. Jurek; William E. McLean; Jonathan K. Statz; Roddricus L. Allen; Daniel W. Riggs

BACKGROUND: Apache pilots needing refractive correction are issued modified HGU-4/P aviator spectacles. However, a recently published survey found field of view (FOV) dissatisfaction with the current spectacles when sighting in with a Helmet Display Unit (HDU). A current Air Force flight frame was modified in-lab and the purpose of this study was to evaluate the FOV with the current Apache flight frame vs. the modified flight frame.

METHODS: Recruited were 21 Apache pilots to assess FOV under three conditions: 1) wearing the current Apache frame; 2) wearing the modified Apache frame; and 3) wearing no frame. The main outcome measure was total FOV of four quadrants tested: superior left (45°); superior right (135°); inferior right (225°); and inferior left (315°).

RESULTS: No significant differences in FOV were seen between the two frames tested while wearing the current Apache helmet ($P = 0.33$) and the new Apache helmet ($P = 0.64$). However, there were significant differences in FOV between the no frame condition and the two frame conditions tested with both helmets ($P < 0.001$).

DISCUSSION: No significant differences in FOV were seen between the two frames tested while wearing either Apache helmet. However, with both helmets there were significant differences in FOV between the no frame condition and the two frame conditions tested. This suggests that wearing no eyewear is still optimal in integrating the HDU device. With advances in contact lens technology, future research can study the viability of the latest generation of multifocal contact lenses with Apache aviators.

KEYWORDS: modified HGU-4/P Apache spectacles, field of view, helmet display unit, military, vision correction.

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Army aircrew members require optimal visual acuity to perform their mission in a variety of operational and training environments. Aircrew not meeting aviation visual standards are issued the Army aviator frame, HGU-4/P (Randolph Engineering., Inc, Randolph, MA). The HGU-4/P has been the standard Army-issue aviator frame since 1959 with various changes in frame material and shape throughout subsequent years.[2,9,13] However, pilots who fly the Apache AH-64 attack helicopter and require aviator glasses cannot wear the standard Army aviator frame due to the visual requirements of the Apache-unique integrated helmet and display sight system (IHADSS), which was incorporated into the Apache cockpit in the early 1980s.[8]

The IHADSS is a helmet-mounted system that uses video imagery provided by the Pilot Night Vision System and is presented to the pilot's right eye on a 1″ cathode ray tube which is fitted into an optical relay tube. The tube assembly is called the Helmet Display Unit (HDU) and provides a 40° horizontal by 30° vertical field[5,7] (**Fig. 1**). The HDU, being mounted on the side of the helmet, has a particularly short eye relief (**Fig. 2**), so, to maximize the available field of view (FOV) for the pilot, the "eye relief distance must be minimized."[5] Therefore, any device that is worn between the HDU and the eye (e.g., spectacles) has the potential of reducing the pilot's FOV. Thus, in 1983 the U.S. Army Aeromedical Research Laboratory (USAARL) was tasked to test the FOV of a modified HGU-4/P frame vs. no frame condition with the HDU in place. The study found no significant differences in FOV between the modified frame and no frame condition; thus, the modified spectacle frame was implemented by the Army for use by Apache pilots.[5] However, anecdotal complaints of a decrease in FOV through the HDU still arose from pilots wearing the new modified HGU-4/P frame.

The ongoing FOV concerns led to a contact lens (CL) study that assessed the viability of single-vision CL usage by Apache

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Fig. 1. The Helmet Display Unit (HDU) device fitted over the right eye.

pilots.[3,4] The study's positive results led to the implementation of the Army Apache Pilot Contact Lens Program. With the approval of CL usage and the Army's acceptance of refractive surgery for aircrew, the FOV concerns with the HDU seemed to subside. However, CLs and refractive surgery cannot benefit Apache pilots who are CL intolerant, or ineligible for the surgery. An even larger issue is with prepresbyopic or presbyopic Apache pilots. Multifocal contacts are not authorized for Army aviators,[1] so older pilots requiring bifocals must wear the modified HGU-4/P Apache frame. The modified frame for older pilots uses a bifocal lens in the left eyepiece to assist in visualizing near-point details, and a single vision distance lens in the right eyepiece to visualize the imagery from the HDU. However, these older Apache pilots are now faced with the same FOV issues reported earlier with the integration of the modified frame and the HDU.

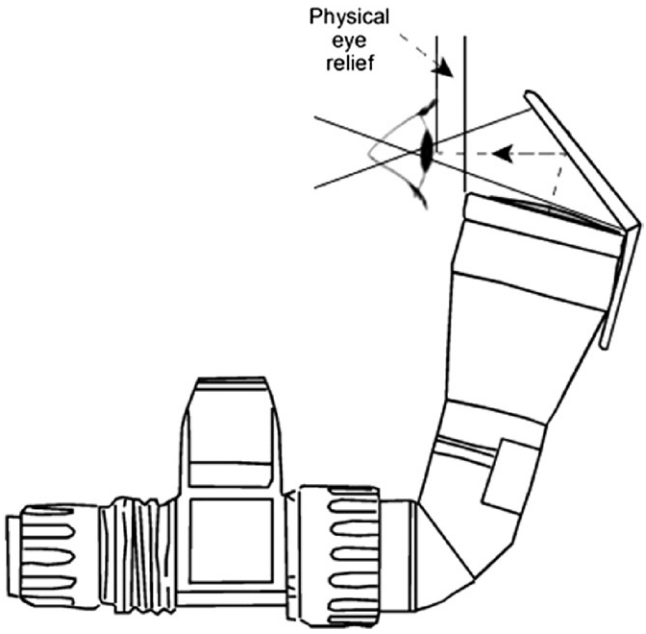

Fig. 2. Diagram showing relationship of HDU, physical eye relief, and the eye.

In 2012, an online survey conducted by USAARL and the U.S. Army Public Health Command (USAPHC) Triservice Vision Conservation and Readiness Team (VCRT) found 79.9% dissatisfaction among Apache pilots with the current modified HGU-4/P frames, with the most common complaint being loss of FOV while wearing the current frames with the HDU.[2] In response to the perceived FOV deficiency, some pilots are known to cut the inferior portion of the right frame, removing the lens to move the HDU closer to the eye to improve their flight performance. Any uncorrected right eye refractive error can be corrected with the HDU dioptric sleeve (Range: +2 to −6 diopters); however, this will not eliminate residual astigmatism. Furthermore, the problem with cutting away the right lower lens wire is the exposing of the eye to the sharp edges of the frame, which can lead to injury. Finally, the imbalance of the cut frame, along with vibration from the aircraft, could potentially dislodge the frame from the face of the pilot, creating flight safety issues.

The purpose of this study was to assess a USAARL developed prototype Apache flight frame as a potential replacement for the current modified HGU-4/P currently used by Apache aviators. The results of this study will help focus decision makers on resolving known issues with the current Apache flight frame, with the intent of significantly improving Army Apache aircrew performance and safety.

METHODS

Subjects

Recruited for the study were 21 (active duty, Department of the Army civilians, contractors) subjects. All subjects recruited were male and rated Apache pilots. The study protocol was approved by the U.S. Army Medical Research and Materiel Command Institutional Review Board, and each subject provided written informed consent before participating.

Equipment

Two eyewear frames were evaluated in the study: the current Apache modified HGU-4/P frame and a USAARL prototype Apache frame (**Fig. 3**). The prototype frame was designed from a current Air Force Aircrew Flight Frame [AFF-Operational (OP); Art-Craft Optical Co., Inc., Rochester, NY] and was modified in-house based on operationally based ophthalmic standards while preserving the safety characteristic of the frame. The AFF-OP frame meets ANSI Z87.1 safety standards and a recent study with non-Apache Army aircrew demonstrated a strong preference for the unmodified AFF-OP frame over the current HGU-4/P aviator frame.[10,12] In addition, with its greater face-form angle (FFA), as shown in **Fig. 4**, it was hypothesized

Fig. 3. Current modified HGU-4/P Apache aviator frame (left) and USAARL prototype Apache aviator frame (right).

Fig. 4. Top view showing face form angles of current modified HGU-4/P Apache aviator frame (left) and USAARL prototype Apache aviator frame (right).

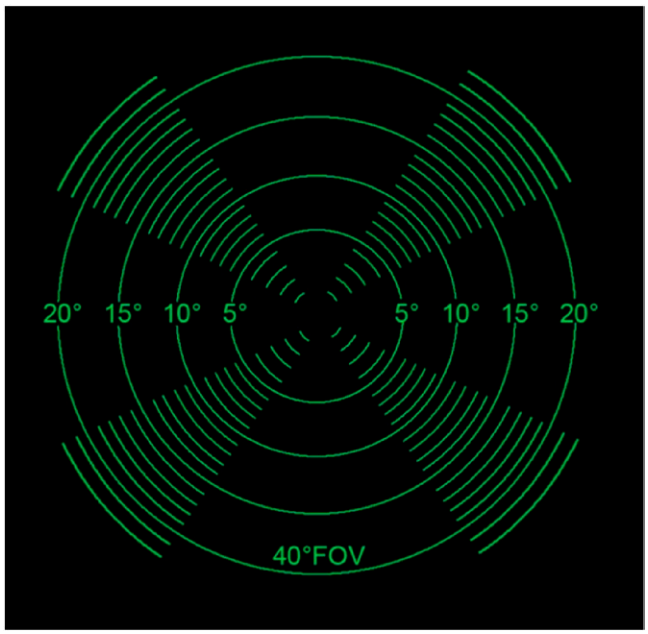

Fig. 5. Field of view (FOV) image with curved lines extending out 22° in each of the four quadrants.

that a modified AFF-OP frame may allow Apache pilots to adjust the HDU closer to their right eye, which would optimize their FOV. The temple styles for both frames tested were bayonet and the sizes were 52-18-140 and 52-20-140 for the USAARL prototype Apache frame and current modified Apache HGU-4/P frame, respectively.

The HDU used to collect data for this study contained built-in FOV imagery (**Fig. 5**). To illuminate the FOV target, an off-the-shelf white light-emitting diode flashlight was inserted in the rear tube opening of the HDU. There were four quadrants in the FOV target: superior left (45°); superior right (135°); inferior right (225°); and inferior left (315°). The target consisted of curved lines separated by 1° with the maximum of 22° in each quadrant.

Finally, the Apache pilot community is gradually transitioning to a new Apache helmet (Echo). The current Apache helmet (the Delta version) is currently worn by most Apache pilots; however, the fitting alignment angle of the HDU is slightly different for both helmets (**Fig. 6**). Therefore, pilots who flew with both Delta and Echo helmets were encouraged to bring in both for testing.

Procedures

The frames were to be evaluated with two approaches. First, a FOV test was performed comparing the FOV while wearing the current Apache frame vs. the prototype Apache frame with the HDU device. Second, if there was a significant difference seen in FOV, the frames would be evaluated in the operational field environment with a survey/questionnaire. For FOV testing, Plano lenses were inserted in both the prototype and current Apache frames. If the pilot had difficulty visualizing the FOV target with Plano lenses, a refraction would be performed to determine the refraction error and corrective lenses would be integrated into the tested frames. However, none of the pilots complained of difficulties visualizing the FOV target.

FOV was assessed on the right eye only (the eye with the HDU device). Once the HDU was in place, the subject's objective was to align the HDU so the number of curved lines were maximized in each quadrant. Prior to collecting data, subjects were trained to adjust the helmet(s) or HDU device to maximize their FOV in each quadrant. From the aft position, subjects moved the HDU as close to the cheek as possible and rotated the HDU up and down and in and out to center the outer circles. Training took ~1-2 min, and measurements of FOV degrees without any of the frames were performed first. Three measurements were taken with three conditions: no frame, current Apache flight frame, and prototype Apache flight frame. The testing order of the frames was

Fig. 6. Illustration of the HDU with angle differences between the current Delta Apache helmet (left), and the new Echo Apache helmet (right).

counterbalanced between subjects and total testing time for each subject was ~20 min.

Statistical Analysis

Means and standard deviations were calculated for each quadrant of measurement with total FOV being the primary outcome measure. A test for normality was performed (Shapiro-Wilk) on both pre- and postlog transformation data and in each case the data was determined to be nonparametric. Therefore, a Mann-Whitney U test was used to compare FOV results from the control (current Apache frame) and the prototype Apache frame, and each frame separately against the no frame condition. All significance levels were $P < 0.05$ and statistical analyses were performed with the Statistical Package for Social Sciences (SPSS) 20.0 software and GraphPad Prism 6 (GraphPad Software, San Diego, CA).

RESULTS

Of the 21 pilots recruited, 20 wore only the Delta helmet and 9 of the 21 brought in both Delta and Echo helmets to be tested. Consequently, 9 sets of data were collected with the new helmet (Echo) and 20 sets of data with the current helmet (Delta). There was no significant difference in total FOV seen between the prototype Apache aviator frame and the current Apache flight frame while wearing the Delta ($U = 1613$, $P = 0.33$) or Echo helmets ($U = 338$, $P = 0.64$). Evaluation of each quadrant separately showed significant difference only at 225° (inferior right) while wearing the Delta helmet ($U = 1430$, $P = 0.048$). There was a significant difference between the no frame condition and both the current Apache frame ($U = 132$, $P < 0.001$) and prototype Apache frame ($U = 122$, $P < 0.001$) while wearing the Delta helmet. In addition, there was a significant difference between the no frame condition and both the current Apache frame ($U = 504$, $P < 0.001$) and prototype Apache frame ($U = 561$, $P < 0.001$) while wearing the Echo helmet **(Table I** and **Table II**). Finally, since no significant difference was seen in total FOV (primary outcome measure) between the two frames, the frames were not tested in the operational field environment.

DISCUSSION

The primary aim of the present study was to investigate the potential implementation of a USAARL developed prototype Apache frame to replace the current Apache frame using total FOV as the primary outcome measure. The current Apache frame has been utilized by Apache aviators for over 30 yr and a recently published Army aircrew survey highlighted FOV dissatisfaction while wearing the frame.[13] Results from the present study indicated no significant differences in FOV between the prototype Apache frame and the current Apache frame with either type of Apache helmets worn. However, there were significant differences between the no frame condition and the frames condition while wearing both helmets, which suggests wearing no spectacle frames is still the best option in integrating the HDU device with the Apache pilot.

Our finding of significant differences in FOV between the current modified HGU-4/P Apache frame and the no frame condition was not observed by McLean and Rash.[5] This difference in findings between the two studies may be due to three factors. First, the McLean and Rash study had a 45% smaller sample size (11 vs. 20), and only 7 of their subjects were rated Apache pilots. Second, McLean and Rash custom fitted the

Table I. Field of View with Delta Helmet Worn ($N = 20$).

	CF (°)	MF (°)	NF (°)	CF vs. MF	CF vs. NF	MF vs. NF
QUADRANT	$\bar{x} \pm$ SD	$\bar{x} \pm$ SD	$\bar{x} \pm$ SD	*P*-VALUE	*P*-VALUE	*P*-VALUE
45 °	16.78 ± 1.89	16.40 ± 2.62	19.07 ± 1.04	0.71	<0.001*	<0.001*
135 °	17.55 ± 1.76	18.00 ± 1.74	19.23 ± 1.28	0.09	<0.001*	<0.001*
225 °	17.10 ± 1.69	17.65 ± 1.79	19.15 ± 1.31	0.048*	<0.001*	<0.001*
315 °	17.47 ± 1.84	17.73 ± 1.58	19.53 ± 1.17	0.40	<0.001*	<0.001*
Total	68.90 ± 6.19	69.78 ± 6.16	76.98 ± 3.72	0.33	<0.001*	<0.001*

$\bar{x}$ = mean; SD = standard deviation; CF = Current Frame; MF = Modified Frame; NF = No Frame; *$P < 0.05$.

Table II. Field of View with Echo Helmet Worn ($N = 9$).

	CF (°)	MF (°)	NF (°)	CF vs. MF	CF vs. NF	MF vs. NF
QUADRANT	$\bar{x} \pm$ SD	$\bar{x} \pm$ SD	$\bar{x} \pm$ SD	*P*-VALUE	*P*-VALUE	*P*-VALUE
45 °	17.15 ± 1.98	16.22 ± 2 0.99	19.33 ± 1.59	0.38	<0.001*	<0.001*
135 °	17.85 ± 1.90	18.41 ± 1.37	19.44 ± 1.91	0.33	0.002*	<0.001*
225 °	17.89 ± 1.87	17.81 ± 1.30	19.52 ± 1.85	0.58	<0.001*	<0.001*
315 °	18.15 ± 1.61	18.22 ± 1.09	20.00 ± 1.64	0.99	<0.001*	<0.001*
Total	71.04 ± 6.43	70.67 ± 5.29	78.30 ± 6.38	0.64	<0.001*	<0.001*

$\bar{x}$ = mean; SD = standard deviation; CF = Current Frame; MF = Modified Frame; NF = No Frame; *$P < 0.05$.

modified HGU-4/P frame to increase the FFA, whereas in the present study no frame adjustments were used to improve the fit and HDU compatibility. Finally, to determine FOV in the previous study, subjects fixated centrally and the target was moved from the periphery to the center. However, in the present study, subjects looked to the edges of the field of view to see the most peripheral concentric ring and degree marks, which displaces the pupil in the HDU eye box and reduces the maximum FOV in that meridian. **Fig. 7** shows the calculated difference in FOVs between central and peripheral fixations when the pupil of the eye is located at the back of the optical eye box of the HDU. Wearing corrective lenses moves the eye box forward and reduces the available FOV more with peripheral viewing than central fixation.

Two limitations were seen in the present study. First, the sample size was small in testing the current Apache (Delta) and, particularly, the new Apache helmet (Echo). Because of the small sample size, the current study may be considered more of a "pilot" study. Second, the relatively short time period tested may not provide a complete assessment to uncover potential long-term problems with the current modified Apache frame.

Finally, though multifocal CLs are not authorized by the Army for soldier use, USAARL has performed two studies on the viability of multifocal lenses with aviators.[6,11] Though both studies demonstrated some success with multifocal lenses (especially modified monovision lenses), the overall conclusion was that multifocal CLs did not achieve the high-quality vision required by Army aviators to safely perform flying duties. However, with the advancement in multifocal CL optics over the past 10 yr, future studies can take another look at the viability of multifocal CLs with presbyopic Apache pilots.

In conclusion, the present study demonstrated no significant differences in FOV between the current modified HGU-4/P Apache frame and a USAARL developed prototype frame. However, there was a significant difference observed between the no frame condition and the frame conditions. This highlights the importance of re-exploring the usage of multifocal CLs in presbyopic Apache pilots. Utilization of the HDU in attaining optimal symbology and target information is vital to the Apache pilot's mission. If Apache pilots do not achieve optimal FOV when using the HDU, then this may adversely affect mission performance.

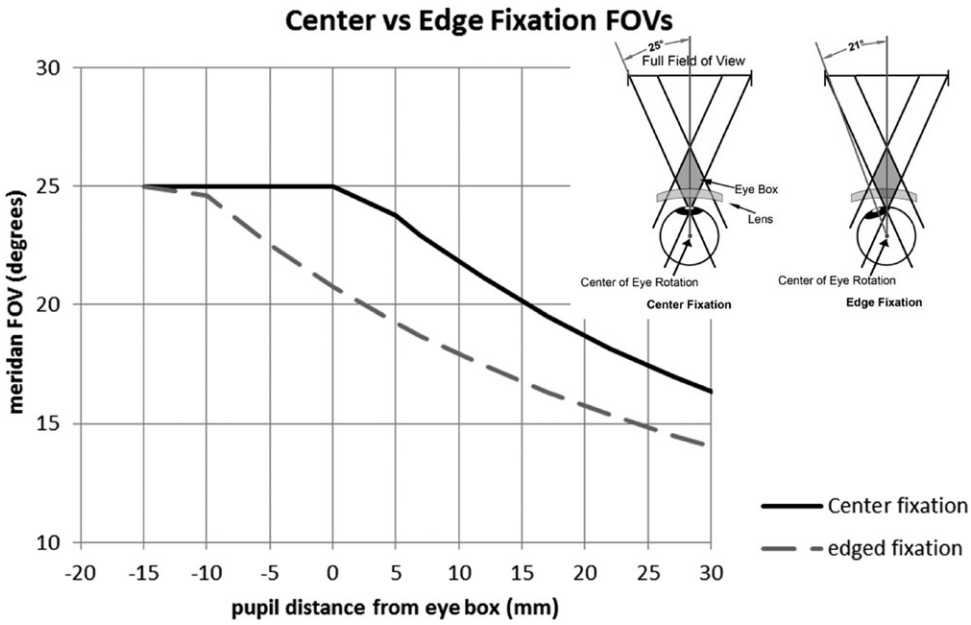

Fig. 7. Center vs. edge fixation field of views (FOVs) with increasing eye clearance.

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The views, opinions, and/or findings contained in this paper are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless designated by other official documentation. None of the authors has financial or other interest in the frames tested.

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