Assessment of an Alternative Army Aircrew Eyewear

David V. Walsh; Gina M. Jurek; José E. Capó-Aponte; Daniel W. Riggs; John A. Ramiccio

BACKGROUND: Currently, Army aircrews needing refractive correction are issued the HGU-4/P aviator spectacles. However, a recently published survey found dissatisfaction with the current spectacle frame. The Aircrew Flight Frame (AFF) has been used by the Air Force for over 14 yr, with the AFF-OP (Operational) style used the longest. The purpose of this study was to evaluate AFF-OP performance and compatibility among U.S. Army aircrew under operational conditions.

METHODS: At 1-, 6-, and 12-wk intervals, 73 Army aircrew members wore the AFF-OP eyewear and completed a Likert scale survey. There were 14 outcome measures surveyed, with the main outcome measure being frame preference.

RESULTS: The AFF-OP was preferred significantly more than the HGU-4/P spectacle. Overall, 94% of aircrew responses preferred the AFF-OP and the three highest subjective reasons for AFF-OP preference were: 1) comfort around the ears without helmet or headset; 2) comfort around the ears with helmet or headset; and 3) the effect on ear cup seal. There were no statistically significant differences in responses over the three surveyed time intervals.

DISCUSSION: Army aviation aircrew preferred the AFF-OP over the current HGU-4/P spectacles. Two of the top three highest subjective reasons for AFF-OP preference coincided with two of the top three operational eyewear problems reported in the recently published survey. If Army aircrew do not wear their issued eyewear, they may purchase their own frame "out of pocket." However, this can lead to use of a frame that has not been tested for compatibility and may compromise performance of aircrew life support equipment.

KEYWORDS: aviator spectacles, aircrew flight frame operational style, military, vision correction.

Walsh DV, Jurek GM, Capó-Aponte JE, Riggs DW, Ramiccio JA. *Assessment of an alternative army aircrew eyewear*. Aerosp Med Hum Perform. 2015; 86(12):1014–1019.

Army aircrew work under unique stress demands and often encounter visual environments requiring optimum visual acuity. Consequently, having optimal visual acuity is critical to all aircrew and those requiring refractive correction are issued the Army HGU-4/P aviator spectacles.[1] The HGU-4/P has been issued to both fixed- and rotary-wing aircrew in the U.S. Army since 1959,[4] and since its initiation there have been multiple changes to the spectacle material, shape, and components.[3,6,10] However, anecdotal complaints about the spectacles have persisted within the aviation community throughout the years.

In response to aircrew eyewear safety and operational concerns, the U.S. Army Aeromedical Research Laboratory (USAARL), in collaboration with the Vision Conservation and Readiness Team from the U.S. Public Health Command (USPHC), conducted the Army Aircrew Eyewear Survey to define aircrew operational and safety issues associated with existing eyewear.[3] The study showed that although nearly all aircrew requiring optical correction were issued the current HGU-4/P aviator spectacles (**Fig. 1A**), approximately one-half of the respondents were dissatisfied with the eyewear and did not wear their Army-issued aviator spectacles. The most common reasons for dissatisfaction with the HGU-4/P aviator spectacles were related to discomfort, durability, and incompatibility issues while wearing the flight helmet. Notably, not a single respondent was 'very satisfied' with the current aviator spectacles, and approximately one-third elected to self-purchase civilian eyewear.

Since 2000, the Aircrew Flight Frame (AFF; Art-Craft Optical Co., Inc., Rochester, NY) has been used by the Air Force (AF) aviation community.[8] The primary incentive for the AF to replace the HGU-4/P was due to anecdotal evidence in the late 1980s of safety concerns reported by aircrew.[9] Additionally, a 1995 AF survey noted a little over 50% of aviators reported a lens falling out of the frame sometime in flight or during nonflight, and 24% reported a lens had fallen out in flight from 1-10 times.[2] These safety concerns led the AF to require an aviation frame that met ANSI Z87.1 safety standards. Besides meeting ANSI Z87.1 safety

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This manuscript was received for review in May 2015. It was accepted for publication in September 2015.

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DOI: 10.3357/AMHP.4361.2015

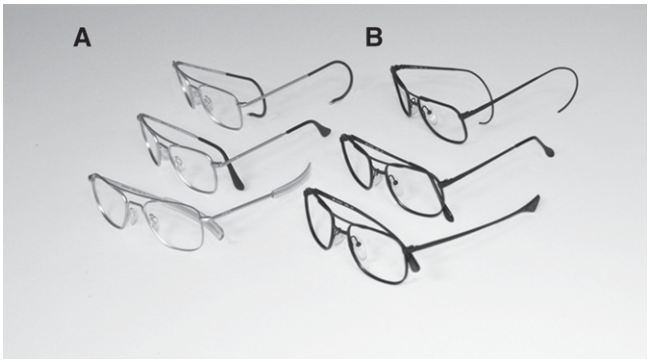

Fig. 1. Representative examples of the A) current Army issued HGU-4/P and B) current Air Force issued AFF-OP. From top to bottom are the three temple styles: comfort cable, skull, and bayonet.

standards, the AFF is a narrower frame with thinner temples and comes in a black color that may reduce reflections during operational missions.[7] Currently, the Air Force has three frames approved for flight duty: AFF-OP (Operational), AFF-Dress, and the most recently approved AFF-Joint Service.[11] The AFF-OP has been fielded the longest in the Air Force aviation community (**Fig. 1B**). It is available in three eye sizes and three temple styles/sizes. An important factor that must be considered prior to testing a new ophthalmic device with aviation aircrew is having a large enough vertical eye size dimension to make it compatible with Night Vision Goggles (NVGs) and those who wear multifocal lenses (bifocal or trifocals). The AFF-OP frame satisfies all these requirements.

The purpose of this study was to assess the compatibility of the AFF-OP with Army flight equipment and evaluate this frame as a potential replacement for the HGU-4/P currently used by Army aircrew. The results of this study will help to guide decision makers in resolving documented aviator spectacle issues, with the intent of significantly improving Army aircrew performance and safety.

METHODS

Subjects

There were 75 (i.e., active duty, Department of the Army civilians, contractors) subjects who were recruited for the study. For inclusion into the study, subjects must have at least 6 mo prior experience wearing the HGU-4/P spectacles. Of the 75 subjects, 2 were USAARL research pilots who only participated in "Fit, Form, and Function" (FFF) testing of the AFF-OP frame prior to testing the frame in the operational environment by the remaining subjects in the study. All subjects were refracted by an optometrist and two pairs of glasses were issued: one clear and one tinted. The study protocol was approved by the U.S. Army Medical Research and Materiel Command Institutional Review Board. Each subject provided written informed consent before participating.

Equipment

Subjects were offered three temple styles and sizes of AFF-OP frames. The temple styles and sizes were: bayonet temple: sizes 52-18-140, 55-18-140, 58-18-140; skull temple: sizes 52-18-140, 55-18-145, 58-18-150; and comfort cable temple: sizes 52-18-155, 55-18-160, and 58-18-160. All subjects were encouraged to wear the sample AFF-OP temple style (bayonet, skull, or comfort cable) and size that they wore with their current HGU-4/P. However, some aircrew preferred to try a different temple style or size frame than their habitual frame, and this is noted in the results section.

Procedures

FFF assessment was performed in both the USAARL NUH-60 flight simulator and UH-60 Black Hawk aircraft. Two research pilots assigned to USAARL assessed: 1) cockpit equipment checks (i.e., checklist and flight publication reading, flight instrument, and out the window scanning during visual meteorological flight, emergency procedures—autorotation and flight with degraded flight control systems and instrument meteorological flight—flight with reference to instrumentation only); 2) compatibility with the HGU-56/P helmet (i.e., doffing and donning the helmet and frames, integration of helmet with NVGs, and integration of helmet with communications earplug); and 3) field of view (i.e., distractions or limitations, reflectivity and glare, and interoperability with NVGs and visor).

Operational field testing with the AFF-OP frames used a questionnaire over a 3-mo period administered at 1-, 6-, and 12-wk intervals. There were 14 outcome measures in the survey; 2 of the 14 were not applicable to all subjects during the testing interval (compatibility with NVGs and reflection in visor). Finally, one outcome measure (compatibility with oxygen mask) was not included in the data analysis due to a limited sample size.

Statistical Analysis

A binomial test of proportions was performed on the main outcome measure (frame preference). Means and SDs were calculated for each secondary outcome measure based on Likert Scale values (1 = much better, 2 = slightly better, 3 = same, 4 = slightly worse, 5 = much worse) and a Wilcoxon signed-rank test was performed to determine any significant differences between their values and the "same" rating. Finally, a Friedman test was performed on complete sets of data to determine any significant differences in responses over the three surveyed time-intervals. 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

Demographics

All 75 subjects recruited in the study were men and 72 (96%) were pilots. Of the 73 aircrew members recruited for the operational testing, only 1 completed the 1-wk survey and two the 1- and 6-wk surveys. By the 12th week, the mean daytime and nighttime hours flown while wearing the AFF-OP frames were 43.42 ± 29.53 and 14.82 ± 14.69 h, respectively. The mean h/d wearing the frames during nonflight time by the 12th week were 4.70 ± 4.48 h/d (**Table I**). The average age of the subjects was

Table I. Flight Time During Evaluation.

CHARACTERISTIC	1 wk ($N = 73$) $\bar{x} \pm$ SD	6 wk ($N = 72$) $\bar{x} \pm$ SD	12 wk ($N = 70$) $\bar{x} \pm$ SD
Flight time with AFF-OP (h)			
Daytime	6.49 ± 4.91	24.74 ± 17.04	43.42 ± 29.53
Nighttime	1.52 ± 2.73	7.32 ± 7.34	14.82 ± 14.69
Non-Flight time w AFF-OP (h/d)	4.66 ± 5.26	5.93 ± 7.10	4.70 ± 4.48

$\bar{x}$ = mean; SD = standard deviation.

49 ± 8.76 yr and the age ranges of all the subjects are shown in **Fig. 2A**. The average flight time hours prior to beginning the study were 5737 ± 3113 h, with the range of flight hours shown in **Fig. 2B**. Finally, the aircraft used by the subjects during the operational testing is shown in **Fig. 2C**, with utility aircraft (e.g., UH-60 Blackhawk, UH-72 Lakota, and UH-1 Huey) being the most common (74%), followed by scout, fixed-wing, and cargo aircraft.

Fit, Form, and Function/Operational Field Testing

No significant problems with the AFF-OP frame were reported by either research pilot during the FFF testing. All outcome measures were graded "good" or better by both test pilots. For the operational field testing, the temple style of the eyewear worn by the aircrew is shown in **Fig. 2D**. Of the 73 aircrew that performed the operational testing, 57 (78%) chose to wear the same temple style as their current HGU-4/P. In those subjects, the most common temple style worn was the bayonet (42), followed by comfort cable (11), and skull (4). Of the remaining 16 subjects who chose to wear a different temple style than their HGU-4/P, the most common temple style change was from comfort cable to bayonet (10), followed by bayonet to skull (3), bayonet to comfort cable (1), and skull to bayonet (1) or to comfort cable (1).

Operational field survey results, broken down by the category of temple comparison, are shown in **Table II** and **Table III**. In both categories, the AFF-OP eyewear was significantly more preferred than the current HGU-4/P and on every evaluated characteristic ($P < 0.001$). In addition, mean ratings for all 14 outcome measures during all 3 testing intervals were rated less than "3" ("same" as current Army frame) on the Likert scale. The three highest rated reasons for AFF-OP preference reported by subjects who compared the same temple style were: 1) comfort around the ears without helmet or headset ($\bar{x} = 1.72 \pm 0.80$); 2) comfort around the ears with helmet or headset ($\bar{x} = 1.88 \pm 0.97$); and 3) comfort on the nose with helmet/headset ($\bar{x} = 1.92 \pm 0.80$). The three highest rated reasons for AFF-OP preference reported by subjects who compared different temple styles were: 1) comfort around the ears without helmet or headset ($\bar{x} = 1.87 \pm 0.95$); 2) comfort around the ears with helmet or headset ($\bar{x} = 1.96 \pm 1.22$); and 3) the effect on

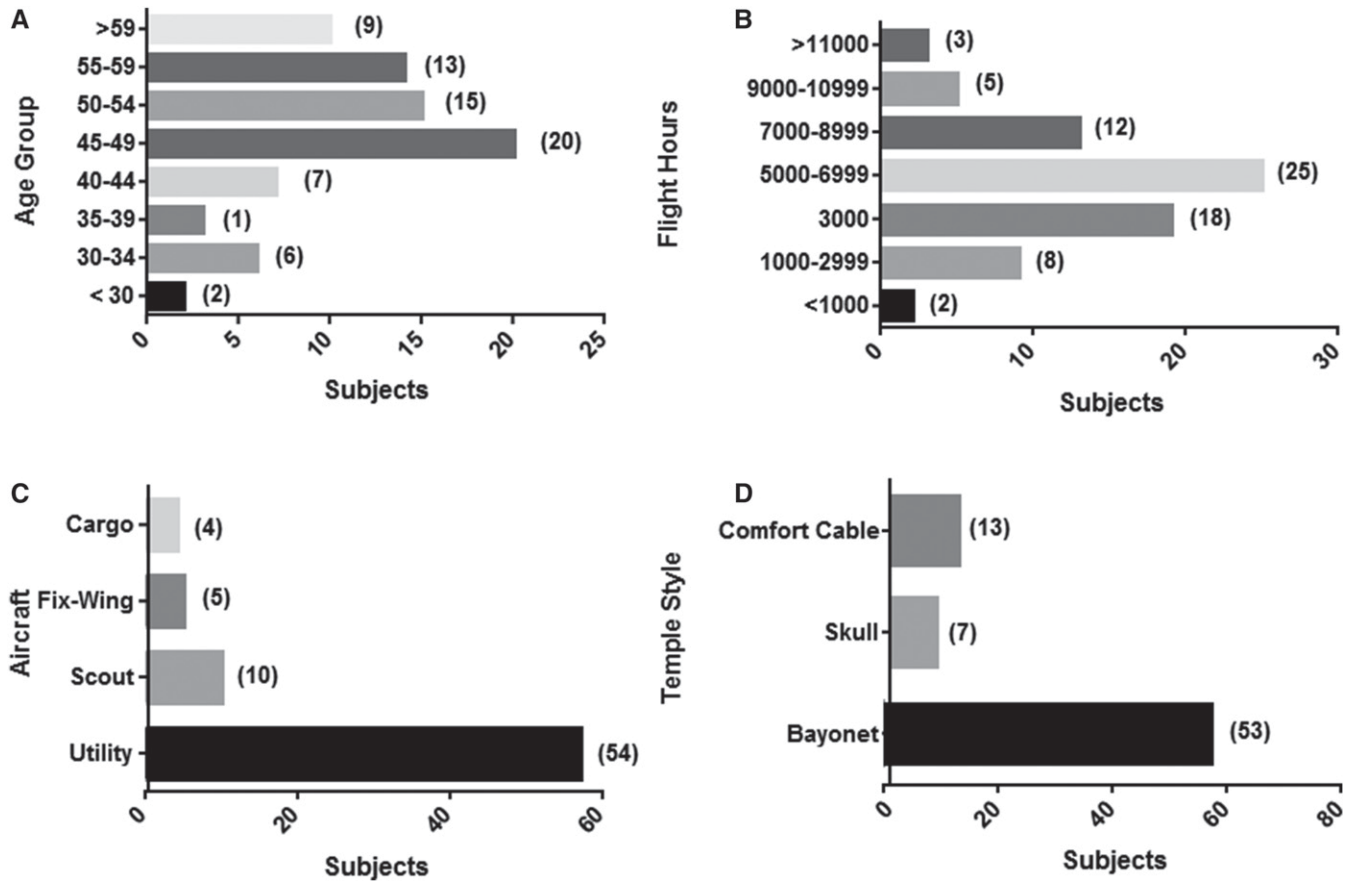

Fig. 2. Frequency of the 73 subjects by A) age, B) flight experience (flight hours), C) aircraft flown, and D) temple style of eyewear.

Table II. Study Outcome Measurements for the Same Temple Style.

CHARACTERISTIC	SCORE 1 wk (*N* = 57) $\bar{x} \pm$ SD	SCORE 6 wk (*N* = 56) $\bar{x} \pm$ SD	SCORE 12 wk (*N* = 55) $\bar{x} \pm$ SD	OVERALL SCORE $\bar{x} \pm$ SD	FRIEDMAN TEST *P*-VALUE
1. Frame preference	1.04 ± 0.19	1.05 ± 0.23	1.05 ± 0.23	1.05 ± 0.21	0.47
2. Comfort around ears without helmet or headset	1.75 ± 0.76	1.75 ± 0.86	1.67 ± 0.78	1.72 ± 0.80	0.47
3. Comfort around ears with helmet or headset	1.79 ± 0.88	1.96 ± 1.03	1.89 ± 1.00	1.88 ± 0.97	0.77
4. Comfort on nose with helmet/headset	1.95 ± 0.83	1.95 ± 0.82	1.87 ± 0.77	1.92 ± 0.80	0.77
5. Effect on ear cup seal	1.86 ± 0.84	1.93 ± 0.77	2.00 ± 0.80	1.93 ± 0.80	0.17
6. Secure on face	1.86 ± 0.81	1.88 ± 0.81	2.05 ± 0.99	1.93 ± 0.87	0.13
7. Color of frame	1.98 ± 1.03	1.93 ± 1.02	1.89 ± 1.05	1.93 ± 1.03	0.52
8. Comfort on nose without helmet/headset	2.07 ± 0.86	1.89 ± 0.85	1.87 ± 0.82	1.95 ± 0.84	0.09
9. Appearance	1.98 ± 0.94	1.95 ± 0.92	1.98 ± 0.95	1.97 ± 0.93	0.95
10. Weight	2.05 ± 0.85	2.04 ± 0.85	2.04 ± 0.82	2.04 ± 0.84	0.88
11. Compatibility with NVGs*	2.36 ± 0.73	2.22 ± 0.71	2.25 ± 0.81	2.26 ± 0.75	0.24
12. Reflections in visor**	2.33 ± 0.80	2.33 ± 0.76	2.26 ± 0.77	2.30 ± 0.77	0.52
13. Lens retention	2.60 ± 0.75	2.61 ± 0.80	2.56 ± 0.86	2.59 ± 0.80	0.84
14. Screw retention	2.67 ± 0.81	2.63 ± 0.89	2.53 ± 0.84	2.61 ± 0.84	0.22

$\bar{x}$ = mean; SD = standard deviation; *incomplete set of data (*N* = 22, 37, 36) for 1, 6, and 12 wk, respectively; **incomplete set of data (*N* = 43, 46, 46) for 1, 6, and 12 wk, respectively.

ear cup seal ($\bar{x} = 2.04 \pm 0.79$). In both comparison categories, Friedman's test showed no statistically significant difference in responses over the three surveyed time intervals in any of the outcome measures.

Finally, the overall operational field survey results, regardless of temple style comparison, are shown in **Table IV**. The three highest overall subjective reasons for AFF-OP preference reported by subjects were: 1) comfort around the ears without helmet or headset ($\bar{x} = 1.76 \pm 0.83$); 2) comfort around the ears with helmet or headset ($\bar{x} = 1.90 \pm 1.02$); and 3) the effect on ear cup seal ($\bar{x} = 1.95 \pm 0.80$). Friedman's test showed no statistically significant difference in responses over the three surveyed time-intervals in any of the outcome measures.

DISCUSSION

The primary aim of this study was to investigate the compatibility of the AFF-OP as an alternative aviator eyewear for Army aircrew and compare it to the currently issued HGU-4/P eyewear. We believe this is the first study to compare a current Air Force aviator frame (i.e., AFF-OP) to the current Army aviator frame (i.e., HGU-4/P). The HGU-4/P frame has been used by Army aviation for over 55 yr in various material forms and a recently published Army aircrew survey highlighted dissatisfaction with the frame.[3] The results from the present study indicate Army aircrew preferring the AFF-OP over the current HGU-4/P spectacles. The overall subjective reasons cited preferring the AFF-OP coincided with two of the top three

Table III. Study Outcome Measurements for Different Temple Styles.

CHARACTERISTIC	SCORE 1-wk (*N* = 16) $\bar{x} \pm$ SD	SCORE 6-wk (*N* = 16) $\bar{x} \pm$ SD	SCORE 12-wk (*N* = 15) $\bar{x} \pm$ SD	OVERALL SCORE $\bar{x} \pm$ SD	FRIEDMAN TEST *P*-VALUE
1. Frame preference	1.13 ± 0.35	1.06 ± 0.25	1.07 ± 0.26	1.09 ± 0.28	0.37
2. Comfort around ears without helmet or headset	1.88 ± 0.96	1.75 ± 0.86	2.00 ± 1.07	1.87 ± 0.95	0.37
3. Comfort around ears with helmet or headset	1.81 ± 1.17	2.00 ± 1.32	2.07 ± 1.32	1.96 ± 1.22	0.69
4. Effect on ear cup seal	1.88 ± 0.72	2.19 ± 0.91	2.07 ± 0.73	2.04 ± 0.79	0.67
5. Comfort on nose with helmet/headset	2.19 ± 0.75	2.19 ± 0.91	2.07 ± 0.59	2.15 ± 0.75	0.42
6. Comfort on nose without helmet/headset	2.13 ± 0.81	2.13 ± 0.81	2.27 ± 0.70	2.17 ± 0.76	0.88
7. Appearance	2.13 ± 0.81	2.25 ± 0.93	2.13 ± 0.83	2.17 ± 0.84	0.93
8. Weight	2.31 ± 0.79	2.31 ± 0.95	2.40 ± 0.91	2.34 ± 0.87	0.99
9. Secure on face	2.06 ± 0.85	2.44 ± 0.96	2.53 ± 1.06	2.34 ± 0.96	0.09
10. Color of frame	2.44 ± 0.96	2.38 ± 0.89	2.40 ± 0.99	2.40 ± 0.92	0.85
11. Compatibility with NVGs*	2.00 ± 0.82	2.56 ± 0.73	2.56 ± 0.73	2.45 ± 0.74	0.37
12. Reflections in visor**	2.54 ± 0.78	2.54 ± 0.88	2.58 ± 0.67	2.55 ± 0.76	0.61
13. Screw retention	2.63 ± 0.62	2.75 ± 0.58	2.67 ± 0.62	2.68 ± 0.59	0.61
14. Lens retention	2.75 ± 0.68	2.69 ± 0.60	2.67 ± 0.62	2.70 ± 0.62	0.72

$\bar{x}$ = mean; SD = standard deviation; *incomplete set of data (*N* = 4, 9, 9) for 1, 6, and 12 wk, respectively; **incomplete set of data (*N* = 13, 13, 12) for 1, 6, and 12 wk, respectively.

Table IV. Study Outcome Measurements Overall.

CHARACTERISTIC	SCORE 1 wk ($N = 73$) $\bar{x} \pm$ SD	SCORE 6-wk ($N = 72$) $\bar{x} \pm$ SD	SCORE 12-wk ($N = 70$) $\bar{x} \pm$ SD	OVERALL SCORE $\bar{x} \pm$ SD	FRIEDMAN TEST *P*-VALUE
1. Frame preference	1.05 ± 0.23	1.06 ± 0.23	1.06 ± 0.23	1.06 ± 0.23	0.82
2. Comfort around ears without helmet or headset	1.78 ± 0.80	1.75 ± 0.85	1.74 ± 0.85	1.76 ± 0.83	0.59
3. Comfort around ears with helmet or headset	1.79 ± 0.84	1.97 ± 0.89	1.93 ± 1.05	1.90 ± 1.02	0.69
4. Effect on ear cup seal	1.86 ± 0.81	1.99 ± 0.80	2.00 ± 0.78	1.95 ± 0.80	0.14
5. Comfort on nose with helmet/headset	2.00 ± 0.82	2.00 ± 0.84	1.91 ± 0.74	1.97 ± 0.80	0.46
6. Comfort on nose without helmet/headset	2.08 ± 0.85	1.94 ± 0.84	1.96 ± 0.81	2.00 ± 0.83	0.18
7. Appearance	2.01 ± 0.91	2.01 ± 0.93	2.01 ± 0.92	2.01 ± 0.91	0.94
8. Secure on face	1.90 ± 0.82	2.00 ± 0.87	2.16 ± 1.02	2.02 ± 0.91	0.06
9. Color of frame	2.08 ± 1.02	2.03 ± 1.01	2.00 ± 1.05	2.04 ± 1.02	0.66
10. Weight	2.11 ± 0.84	2.10 ± 0.87	2.11 ± 0.84	2.11 ± 0.85	0.89
11. Compatibility with NVGs*	2.31 ± 0.74	2.28 ± 0.72	2.31 ± 0.79	2.30 ± 0.75	0.43
12. Reflections in visor**	2.36 ± 0.80	2.37 ± 0.79	2.33 ± 0.76	2.35 ± 0.78	0.36
13. Lens retention	2.63 ± 0.73	2.63 ± 0.76	2.59 ± 0.81	2.61 ± 0.76	0.81
14. Screw retention	2.66 ± 0.76	2.65 ± 0.82	2.56 ± 0.79	2.62 ± 0.79	0.35

$\bar{x}$ = mean; SD = standard deviation; *incomplete set of data ($N = 26, 45, 46$) for 1, 6, and 12 wk, respectively; **incomplete set of data ($N = 56, 59, 58$) for 1, 6, and 12 wk, respectively.

operational eyewear problems reported in the survey paper by Capó-Aponte et al.:[3] hot spots around the ears with and without the helmet and breakage of ear cup seal. The favorable results for the AFF-OP on reduced hot spots around the ears may be due to the thinner temple profile of the frame. Finally, a recently published tech report did compare noise attention loss using the HGU-4/P and AFF-OP frames (bayonet temples) and demonstrated "very little difference" in noise attenuation performance.[5] However, the testing was performed with a one-size KEMAR Manikin, which does not accurately represent the various head anthropometry seen among humans.

Subjective comments from the aircrew during their flight operations were encouraged throughout the 3-mo testing timeframe. Some subjects noted the "light weight" of the AFF-OP frame provided better comfort around the ears and nose than the current Army-issued aviator frame. Furthermore, comments noting the "rubber tip" of the AFF-OP temple (bayonet style) provided "good stability" and "extra grip," which made the frame feel "more comfortable" around the ears and was small enough that it was comfortable around the ears. Finally, subjects favorably noted the thinner temple or smaller "profile" of the AFF-OP frame had an "improved effect" on the ear cup seal. In contrast, three subjects who preferred the current HGU-4/P frame reported negative comments regarding the AFF-OP frame. One participant preferred the AFF-OP frame during the initial two survey intervals; however, by the 12th wk, the subject felt the temples "stretched out" after repeated usage. Another pilot noted the AFF-OP frame "pinched" heavily and did not "conform" to the shape of his head. Consequently, this led to the pilot often pushing the frame back to his face. Finally, a pilot had difficulty with the comfort cable temple style frame due to feeling "uncomfortable" around his ears. He did return to the lab for adjustments; however, the "discomfort" returned after approximately 2 h of flight.

Two limitations were seen in the present study. First, not all outcome measures in the survey were equally assessed in the three time intervals due to nonapplicability of the measure to some subjects: compatibility with NVGs, compatibility with oxygen masks, and reflections in visors. Second, the relatively short time period tested may not provide a complete assessment to uncover long-term potential problems with the AFF-OP frame.

Finally, it is recommended, as noted by some study subjects, that aircrew should bring their flight helmet to the eye clinic to confirm there are no integration issues with their preferred eyewear. Although both the HGU-4/P and AFF frames have been used by aircrew for many years, there still may be individual compatibility issues (e.g., XXS head/helmet size with an aircrew member who prefers a large spectacle eye size) with integration of their helmet and frame that should be resolved prior to issuing aircrew spectacle frames.

In conclusion, the present study demonstrated strong preference for the AFF-OP over the HGU-4/P eyewear by Army aircrew. Flying in today's operational environment requires optimal operational eyewear. If aircrew do not wear the current Army-issued frame, they may purchase their own frame out of pocket. However, this can lead to utilization of a frame that has not been tested for compatibility and performance with aircrew life support equipment as well as a potential lack of readiness since users will likely purchase only one pair of glasses. We also found no compatibility issues with other aviation systems during laboratory and operational testing, making the AFF-OP eyewear a suitable replacement for the current HGU-4/P frame that could overcome reported safety and operational deficiencies.

ACKNOWLEDGMENTS

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 AFF-OP frame or any other ArtCraft product.

This research was funded by the Military Operational Medicine Research Program of the U.S. Army Medical Research and Materiel Command. It was sponsored in part by the appointment to the Postgraduate Research Participation Program at the U.S. Army Aeromedical Research Laboratory administered by the Oak Ridge Institute of Science and Education through an interagency agreement the U.S. Department of Energy and U.S. Army Medical Research Material Command. Finally, the authors thank the Naval Ophthalmic Support and Training Activity laboratory for supplying the frames and lenses in support of the research.

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