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Visual Performance Effects and User Acceptance of the M43A1 Aviation Protective Mask Frontserts

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The initial M43 aviation protective mask was fielded without provisions for optical corrective devices. Contact lenses, an interim solution, were not entirely acceptable since a small segment of the population could not be fitted adequately with contacts. This study evaluated visual performance effects and user acceptance of the M43A1 mask with frontsert correction modifications. The subjects were 30 U.S. Army aviators (28 men and 2 women). Objective data from flight simulation evaluations suggested there were no significant differences between flight performance with and without the mask, despite refractive status. Subjective data from static and flight evaluations reflected positive user acceptance of the new mask and frontserts. Problems may exist in smaller cockpits (OH-58A/C, D), but evidence suggested that this may have been an artifact resulting from testing the mask while wearing protective body armor. Within the range of flight conditions and profiles examined, the M43A1 frontsert system meets U.S. Army aviation needs for optical correction when mission requirements dictate flying with chemical-biological protective masks.

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Background: The initial M43 aviation protective mask was fielded without provisions for optical corrective devices. Contact lenses, an interim solution, were not entirely acceptable since a small segment of the population could not be fitted adequately with contacts. This study evaluated visual performance affects and user acceptance of the M43A1 mask with frontsert correction modifications. ***Methods:*** The investigation was divided into three phases: 1) a helicopter simulator evaluation designed to experimentally test the suitability of the M43A1 frontserts, both in single vision and bifocal forms, for use in the aviation environment; 2) a static cockpit evaluation, designed to identify aircraft-specific problems with the frontsert system; and 3) an inflight evaluation to examine the stability and usability of the frontserts under actual flight conditions. The subjects were 30 U.S. Army aviators (28 men and 2 women). ***Results:*** Objective data from flight simulation evaluations suggested there were no significant differences between flight performance with and without the mask, despite refractive status. Subjective data from static and flight evaluations reflected positive user acceptance of the new mask and frontserts. Problems may exist in smaller cockpits (OH-58 A/C, D), but evidence suggested that this may have been an artifact resulting from testing the mask while wearing protective body armor. ***Conclusions:*** Within the range of flight conditions and profiles examined, the M43A1 frontsert system meets U.S. Army aviation needs for optical correction when mission requirements dictate flying with chemical-biological protective masks.

THE M43 AVIATION protective mask (**Fig. 1**), designed specifically for use in the Army's AH-64 attack helicopter, has received considerable attention at the U.S. Army Aeromedical Research Laboratory (USAARL), Fort Rucker, AL (2,3,13,17,24). Much of this research was initiated because the original M43 mask was fielded without provisions for optical corrective devices. The capability of providing optical correction is crucial for chemical-biological aviation protective masks, as 22% of active duty Army aviators, 27% of reserve aviators, and 32% of national guard aviators require some form of optical correction (19).

One such research project, an evaluation of the M43 protective mask corrective frontserts, found that the frontserts produced visual performances comparable to spectacles in visual acuity, stereopsis, and phoria (2). These researchers noted a reduction in field-of-view, but attributed this loss to the mask rather than to the frontsert correction. In an evaluation of glue-on corrections for the M43 protective mask, other researchers noted that visual performances in the areas of visual acuity, stereopsis, and phoria were similar to those obtained when the subjects wore their usual correction (3). However, this approach had optical problems due to the thickness of the lenses. A third approach, contact lenses, also has been evaluated with the M43 mask (13). These investigators found that extended-wear, soft contact lenses provided acceptable visual performance when worn with this mask. However, one-third of aviators requiring refractive error correction could not be adequately fit with presently approved contact lenses due to presbyopia or astigmatism (12).

Evaluations of approaches for providing optical correction for other protective masks have emphasized fields-of-view, stability of the correction, both under operational conditions and in the face of donning and doffing, and the strength of the lens holders (7,10,15). However, little effort has been devoted to clarifying the effect of these forms of correction on visual performance while piloting aircraft. Consequently, the Army's program manager for aviation life support equipment (PM-ALSE) requested support from USAARL in evaluating the performance effects and user acceptance of the modified M43A1 protective mask frontserts for use in all Army aircraft. As bifocal frontserts are under development for this mask, their evaluation was a major focus of this effort. Thus, this investigation had characteristics of both a research project and a test and evaluation project.

Besides visual concerns, several evaluations also have noted a variety of human factors problems with M43-series protective masks. These difficulties included hot spots, incompatibilities with cockpit systems, and interference between the mask, survival vest, and armor that restricted free head movement (5,18). These findings prompted us to include the survival vest in all portions of this study along with armor in the static evaluations. In addition, McLean (personal communication, Decem-

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Fig. 1. The M43A1 is a close fitting mask for use in aviation that protects the face, eyes, and respiratory system of the user from chemically, biologically, and radiologically toxic environments. Whereas there is insufficient eye relief behind the lenses to accommodate correction devices, this study examined the performance effects and user acceptance of corrective frontserts in the Army aviation environment.

ber 1993) has found evidence of potential incompatibilities with the aviation night vision system (ANVIS), which led us to include the use of ANVIS in this evaluation.

This study was divided into three phases. Phase one, a simulator evaluation, was designed to provide an objective experimental verification of the suitability of the M43A1 frontserts, both in single vision and bifocal forms, for use in the aviation environment. Phase two, a ground static evaluation, was designed to identify any aircraft-specific problems with the frontsert system. Phase three was an in-flight evaluation of these forms of correction that examined the stability and usability of the M43A1 frontserts under actual flight conditions. All phases were approved in advance by USAARL's Human Use and Scientific Review Committees and were monitored while in progress by an aviation research psychologist, a flight surgeon, and USAARL's Flight Safety Office.

METHODS

Subjects

There were 30 volunteer aviators who were recruited to serve as subjects (28 men and 2 women; ages 20–47 yr). Informed consent was obtained from each subject. The subjects recruited included 10 aviators not requiring correction, 10 aviators requiring single vision correction, and 10 aviators requiring bifocal correction. Where possible, subjects were requested to participate in multiple phases of the experiment; however, all subjects did not participate in every phase of the experiment (**Table I**).

TABLE I. SUBJECT PARTICIPATION WITHIN EACH PHASE OF THE EVALUATION.*

Group	Simulator	Static†	Flight
Normal Vision	1,3,4,5,6,8,9,10	2,3,7,8,9,10	1,3,4,5,8
Single Vision	1,2,3,4,5,7,9,10	4,6,7,8,9,10	4,5,7,9,10
Bifocal Vision	1,2,3,5,6,7,8,10	1,2,4,6,8,9	1,3,6,7,9

* Identical numbers within each group indicate that that person participated in multiple phases of the evaluation.
† For the purposes of counterbalancing the order of aircrew position in the static evaluation (see text), subjects with the static evaluation numbers referenced above were assigned new numbers (1–6, respectively).

The simulator phase included 24 aviators (22 men and 2 women), 8 from each correction group. The static evaluation phase used 18 aviators (17 men and 1 woman). Whereas the M43A1 is intended to be used in all Army aircraft except the AH-64, the 18 aviators in the static phase included 3 aviators rated in each of the following aircraft: UH-1, UH-60, AH-1, CH-47, OH-58A/C, and OH-58D. Each group of three aviators included one aviator not requiring correction, one aviator requiring single vision correction, and one aviator requiring bifocal correction. The flight phase included 15 aviators (13 men and 2 women), 5 from each correction group. All subjects were given a vision examination by a USAARL optometrist to verify any necessary correction and to fabricate the required optical correction frontserts. The ranges of correction are shown in **Table II**.

Previous research has shown that frontserts produce visual performances comparable to spectacles in visual acuity, stereopsis, and phoria (2). Subjective reports of visual performance with the frontserts in this experiment were equal to or exceeded those obtained when the subjects wore their usual correction. Whenever the improvements were determined to be due to the recency of the exam, those aviators were provided with an updated spectacle prescription to replace their older correction for normal flying. All subjects had a current DA Form 4186 certifying them as fit for flying duty and were screened for participation in the study by a USAARL flight surgeon.

The size of these samples was resource constrained by the available number of aviators requiring bifocal correction. Previous simulator experiments have employed larger numbers of aviators while measuring the dependent variables similar to those proposed for this experiment (1,20,22). However, given the results of this prior research, a power analysis for the simulator phase found that a sample size of eight per group and alpha equal to 0.05, would yield a beta of approximately 0.2, with power equal to 0.8 for an effect size of 1 SD. This analysis suggested that we should have had an 80% probability of correctly identifying a difference between means 1 SD in size. The sample size for the static phase (N = 18) was

TABLE II. RANGE OF VISUAL CORRECTIONS.

Correction Group	Mean	Standard Deviation	Min (most minus)	Max (most plus)
Single Vision				
Sphere (right/left)	−0.75/−0.70	0.58/0.59	−1.75/−1.50	0.00/+0.25
Cylinder (right/left)	−0.43/−0.38	0.66/0.50	−1.75/−1.75	0.00/0.00
Bifocal Vision				
Sphere (right/left)	−1.00/−0.97	1.10/1.03	−2.25/−2.00	+0.75/+0.50
Cylinder (right/left)	−0.50/−0.28	0.31/0.23	−1.00/−0.75	0.00/0.00
Bifocal segment add	+1.14	0.22		+1.00 to +1.50

based on the requirement to have one aviator use each type of correction in each aircraft. Only 15 aviators were necessary to provide a satisfactory estimate of the stability and usability of frontserts for the in-flight evaluations. Experiments at USAARL have found that groups of this size are satisfactory for evaluation of protective mask performance (10,17).

Instrumentation

Phase one of the experiment was conducted in the USAARL NUH-60 flight simulator. The simulator was "on motion" for all flights during this experiment. Air temperature during flights was maintained between 68–72°F, and relative humidity was maintained between 38–60%. Subjects were provided with an M43A1 protective mask with blower, and with suitable frontsert correction devices, if required. The mask blowers were secured to an approved mounting assembly point on the SRU-21/P survival vest. The masks were fitted under the supervision of qualified personnel trained to fit the M43A1 according to specifications (23). ANVIS was adjusted as outlined in Loro (14). Unless directed to wear the protective mask, frontserts, and/or ANVIS, subjects wore their usual flight ensemble. During the static evaluation phase, subjects wore the M43A1 protective masks and frontserts (if required), fragmentation protective body armor (NSN 8470-122-1299), and the SRU-21/P survival vest, in addition to their usual flight ensemble. The masks were fitted as above, and ANVIS tubes were fitted with daylight training filters. Except for the M43A1 protective mask and frontserts (if required), subjects wore their usual flight ensemble during the flight phase. USAARL's JUH-1 aircraft was employed as the flight test bed for this phase of the experiment. This allowed more flexible subject scheduling, as all rotary-wing pilots are initially qualified in the UH-1 aircraft.

Procedures

Simulator phase: Subjects were provided with an initial briefing, during which time they provided informed consent to participate in the experiment. Subjects then were examined by a USAARL optometrist to verify their correction and by the medical monitor to verify their fitness for flying duty. The subjects were recalled when their frontserts were ready, and their near and far acuities were reverified. Subjects were then briefed on the mission profile to be flown. The standardized profile required approximately 1 h to complete and is summarized in **Table III.** Note that the flight profile included both day and ANVIS maneuvers, as well as IFR and VFR segments.

Following the briefing, the subjects entered the simulator and completed one rehearsal flight while wearing their usual correction, if they required correction. The rehearsal flight was required to familiarize subjects with the mission profile and to establish their initial baseline performance in the simulator. For the experimental sessions, subjects following a predetermined counterbalanced order, flew the profile twice again within a single session—once with the mask and appropriate correction, and once while wearing their usual correction (if necessary) without the mask. Objective performance data, the degree to which the subjects maintained the required standards for each maneuver (Table III), were sampled one time per second during each flight by a VAX 780 and stored for subsequent analysis. Additionally, after each flight, subjects completed a questionnaire that addressed simulator sickness symptoms (6,11), and the NASA Task Load Index (TLX) (8). The former addressed 16 symptoms related to motion sickness such as stomach awareness, blurred vision, sweating, dizziness, etc. Subjects rated the extent to which they experienced these symptoms from 1 (none) to 4 (severe). A single score was obtained for each flight by calculating the mean of all symptoms reported. The TLX recorded subjective task-load experienced within six domains (mental, physical, temporal, performance, effort, and frustration), along a continuum ranging from 1 (low) to 10 (high). In keeping with the suggestion of previous research (9,16), each subscale of the NASA TLX was weighted equally. In addition, at the end of the simulator session, a debriefing allowed subjects to make any supplementary comments regarding the mask. The entire test session lasted approximately 3 h. After completing their simulator flights, the subjects were advised to refrain from actual flight until the next duty day, in keeping with current guidelines and to allow the dissipation of any possible symptoms of simulator sickness (4).

Static phase: In the static phase, subjects were asked to examine a series of areas inside and outside the cockpit in the aircraft for which they were rated. These tasks were performed while wearing the M43A1 protective mask with frontserts in addition to body armor, the survival vest, and their usual flight uniform. At no time during this phase did they fly the aircraft. On the flight line, the subjects donned the body armor, the survival vest, and the mask with frontserts, if required. Once in the aircraft, they systematically examined and rated the

TABLE III. NUH-60 FLIGHT SIMULATION MISSION PROFILE.

Maneuver	Standard to Maintain
Low hover	Maintain heading 330°, altitude 10 ft above ground level (AGL).
Low hover turn	Turn from 330° to 150° while holding altitude of 10 ft AGL.
High hover	Maintain heading 330°, altitude 40 ft.
High hover turn	Turn from 330° to 150°, while holding altitude of 40 ft above ground level.
Terrain flight 1	Maintain heading within ± 2°, 30 ft above the highest obstacle (AHO); arrive at checkpoint in 2 min.
Terrain flight 2	Maintain heading within ± 2°, 30 ft AHO; arrive at checkpoint in 5 min.
Instrument approach	Establish heading 240°, airspeed 120 knots, altitude 2000 ft MSL; maintain the parameters given by instructor and Approach Plate
NVG landing	Maintain airspeed until approach; approach to LZ, intercept; touch down in Y zero ground speed.
NVG formation departure	Maintain 3 rotor disk separation and 30° left angle off leadship; depart ground simultaneously with lead ship (staggered left); maintain leadship's altitude and airspeed.
NVG formation	Maintain 3 rotor disk separation behind leadship (trail); maintain leadship's altitude and airspeed.
NVG formation landing	Maintain 3 rotor disk separation behind leadship (trail); touch down simultaneously with leadship.
NVG terrain 1	Maintain heading within ± 2°, 30 ft AHO; arrive at checkpoint in 2 min.
NVG terrain 2	Maintain heading within ± 2°, 30 ft AHO; arrive at checkpoint in 5 min.

ease of viewing of areas in the aircraft environment and completed an aircraft-specific rating questionnaire for both pilot seats. Even numbered subjects evaluated the left or the front seat position first, while odd numbered subjects evaluated the right or rear seat position first (see footnote to Table I). The questionnaire was read to them by the experimenter who sat in the other available seat. After the evaluation, subjects were debriefed and asked to write any additional comments regarding the mask. This evaluation lasted roughly 1 h.

Flight phase: In the flight portion, subjects were asked to fly the JUH-1 aircraft through a sequence of maneuvers typical of normal missions for that aircraft while wearing the M43A1 with frontserts in addition to their usual flight uniform. As in the first two phases, subjects were provided with an initial briefing during which they were asked to give informed consent to participate in the experiment. Subjects were then briefed on the mission scenario to be flown. The components of the mission were selected from Aircrew Training Manuals for the aircraft (21). The required tasks are summarized in **Table IV.**

All flights were accomplished under daylight visual flight rules conditions (ceiling 2000 ft MSL, visibility 3 mi) and under the supervision of a safety pilot. The safety pilot was a current instructor pilot in the UH-1 and had no other duties on these flights beyond observing and supervising the subject pilots. In flight, the subjects focused on flying the aircraft and no data collection was performed. Following the flight, subjects completed a flight questionnaire, the NASA TLX, and were debriefed. The total experimental session lasted less than 2 h.

RESULTS

Simulator Phase

The objective performance data taken from the NUH-60 simulator are presented in **Fig. 2.** Each score was a composite taken from the various components required to perform the maneuver [i.e., hover score = (altitude score + heading score)/2]. The magnitude of the score (% of 100) represented the degree to which the subject maintained the required standard. A visual examination of the figures reveals that, in general, within each group, the mask's effect on flight performance was the same. Despite whether or not the aviators required correction, their flight performance in the mask reflected only a slight decrement as compared to their initial baseline flight and their flight without the mask.

The composite maneuver scores taken from each flight were subjected to a 3(correction group) × 13(maneuver) × 2(flight condition) repeated measures analysis of covariance (ANCOVA). Because random assignment into groups was not possible, subjects initial baseline performance was used as the covariate to adjust for any naturally occurring differences due to ability or experience. This analysis revealed a significant main effect for maneuver [$F(12,272) = 7.91$, $p < 0.0001$]. A Tukey's HSD

TABLE IV. IN-FLIGHT EVALUATION TASKS FROM THE UH-1 AIRCREW TRAINING MANUAL.

Task	Description
1007	Perform before starting engine checks
1014	Maintain airspace surveillance
1016	Perform hover power check
1017	Perform hover flight
1018	Perform VMC takeoff
1022	Perform traffic pattern flight
1023	Perform fuel management procedures
1025	Navigate by pilotage and dead reckoning
1028	Perform VMC approach
1031	Perform confined area operations
1032	Perform slope operations
1036	Perform hover OGE check
1079	Perform radio communications procedures

(honest significant difference) comparison revealed that, in general, subjects performed the 10-ft hover and 10-ft hover-turn significantly better than all other maneuvers, and the scores for the formation/ANVIS maneuvers were performed significantly worse than all other maneuvers. No main effects for group [F(2,272) = 1.24, p < 0.2895] or condition [F(1,272) = 3.71, p < 0.0551] were found. In addition, all remaining two- and three-way interactions were non-significant [G × M, F(24,272) = 0.90, p < 0.6028; G × C, F(2,272) = 0.57, p < 0.9447; M × C, F(12,272) = 1.37, p < 0.1810; and G × M × C, F(24,272) = 1.01, p < 0.4477].

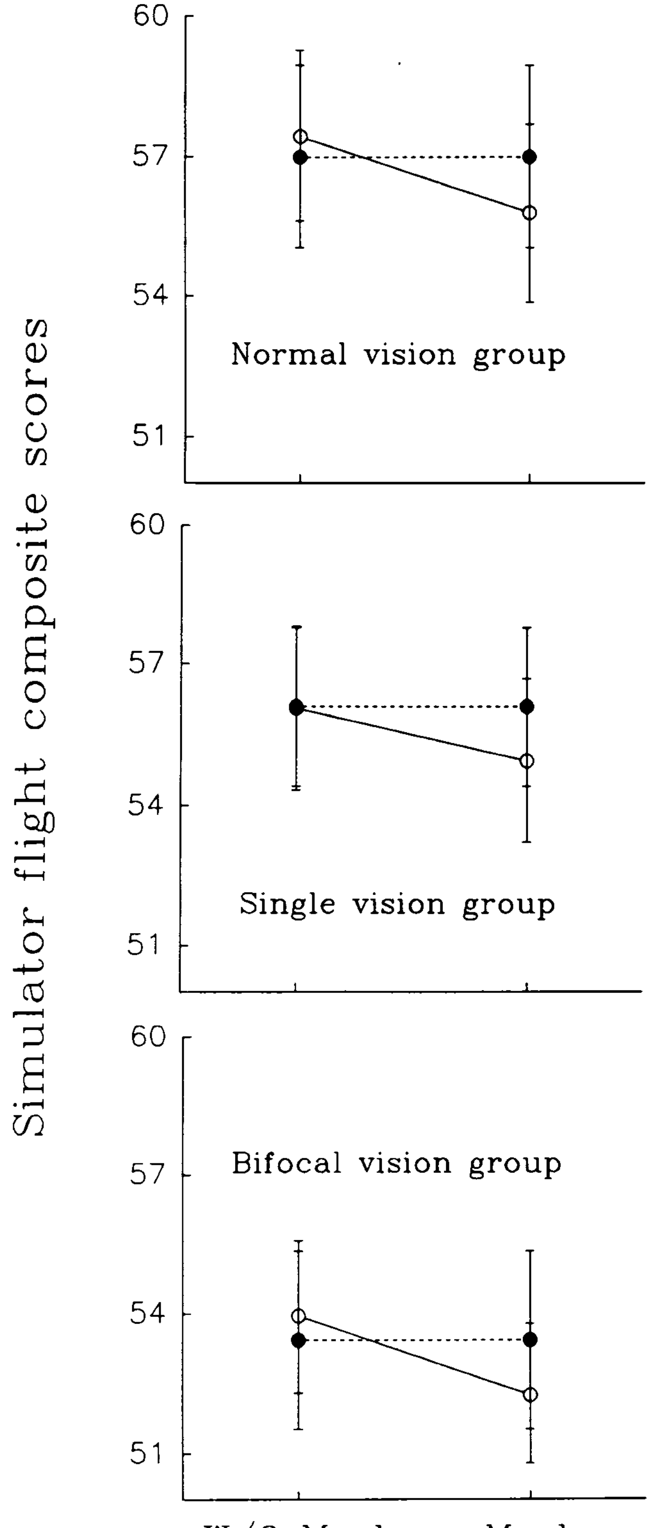

Fig. 2. Objective performance data taken from the NUH-60 flight simulator both with and without the mask (○), as compared to initial baseline performance (●).

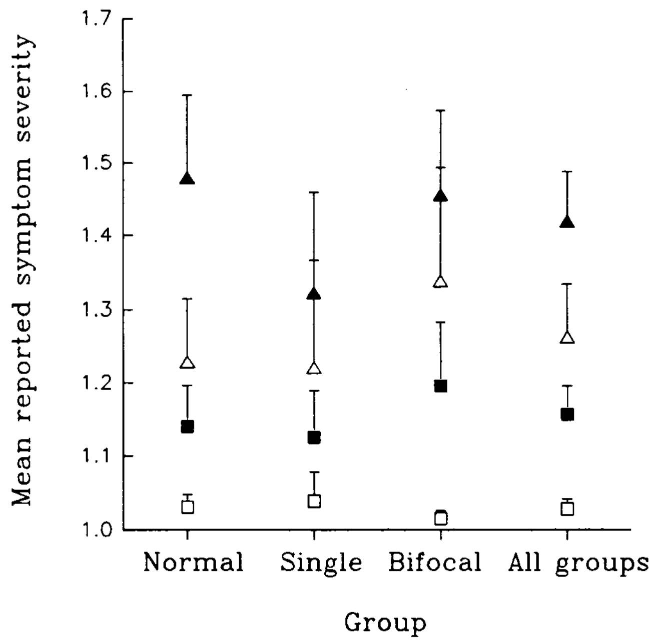

Fig. 3. Mean subjective response data taken from the symptomology questionnaire. 16 individual symptoms were rated according to the following scale: 1 = None, 2 = Slight, 3 = Moderate, and 4 = Severe. Higher mean scores indicate greater severity of motion-related symptoms experienced during each of the experimental flight conditions in the NUH-60 flight simulator (□ preflight baseline, ■ practice trial, △ no mask trial, and ▲ mask trial).

Subjective response data taken from the symptomology questionnaire were analyzed using a 3(group) × 3(condition) ANCOVA similar to the one described above. A mean symptom score was obtained from each flight, and scores were adjusted using the covariate preflight reports of symptoms as baseline. These data, shown in **Fig. 3**, revealed a significant main effect for condition [F(2,42) = 11.72, p < 0.0001]. No significant main effect was found for the group factor [F(2,20) = 0.35, p < 0.7108] or the group × condition interaction [F(4,42) = 0.46, p < 0.7650]. A Tukey's HSD comparison showed that for the condition main effect, discomfort symptoms reported after the mask flight were significantly greater than after the practice and no-mask flights.

In keeping with the suggestion of previous research (9,16), each subscale of the NASA TLX was weighted equally. Subjects rated taskload for six subscales (mental, physical, temporal, performance, effort, and frustration), along a continuum ranging from 1 (low) to 10 (high). Lower ratings suggested reduced taskload demand in that domain. The exception to this was the performance subscale where low ratings suggested better subjective performance and high ratings reflected worse. Therefore, for all subscales, ratings below the midpoint value of 5.5 were interpreted as relatively positive. The mean task ratings for each of the three groups are presented in

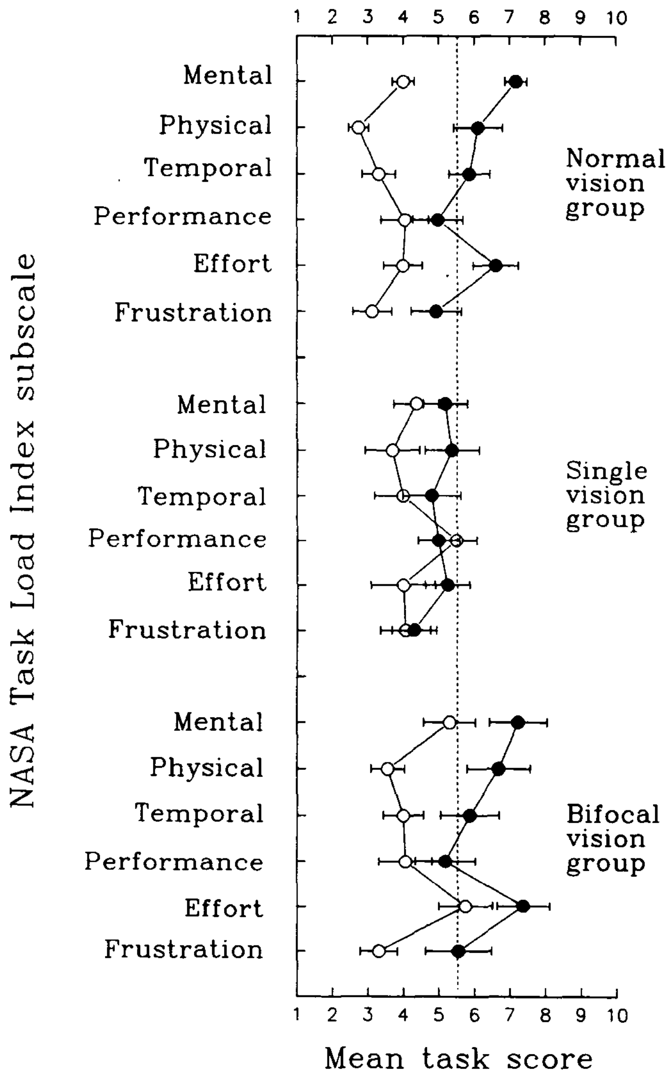

Fig. 4. Mean task scores for each subscale of the NASA Task Load Index during simulator flights with (●) and without (○) the mask.

Fig. 4. In general, subjective taskload for each subscale increased during the mask flights. Further, this effect was greater for the normal and bifocal groups than for the single vision group.

A 3(group) × 6(task) × 2(condition) repeated measures analysis of variance (ANOVA) was applied to the data. This revealed significant main effects for task [$F(5,126) = 2.36$, $p < 0.0437$] and condition [$F(1,126) = 113.81$, $p < 0.0001$]. In addition, the two-way interactions for group × condition and task × condition were significant [$F(2,126) = 10.14$, $p < 0.0001$; and $F(5,126) = 3.40$, $p < 0.0065$ respectively]. All remaining effects were nonsignificant [G, $F(2,126) = 2.41$, $p < 0.0939$; G × T, $F(10,126) = 0.63$, $p < 0.7823$; and G × T × C, $F(10,126) = 0.32$, $p < 0.9746$]. A Tukey's HSD comparison showed that for the condition main effect, the flights with the mask resulted in significantly greater reports of subjective taskload than the flights without the mask. Results for the task main effect showed that taskload reports for the mental and effort subscales were significantly greater than for the frustration subscale. Also, the results for the two-way interaction between group and condition confirmed that the normal and bifocal vision groups reported significant differences in taskload for the two conditions, whereas the single vision group did not. For the task by condition interaction, the Tukey comparison showed that between conditions all taskload subscales, except the performance subscale, were reported to be significantly greater for the flight condition with the mask.

Static Phase

The only data collected during the static phase came from the aircraft-specific surveys and were subjective in nature (Fig. 5). The ratings for most aircraft (UH-60, UH-1, AH-1, and CH-47) revealed positive user acceptance of the mask and frontsert systems. In contrast, it appeared that there were problems with the two smallest aircraft (OH-58A/C, and OH-58D).

Based on our observations and comments made during the evaluations, we suspected that these problems may have been artifacts that resulted from testing the mask with the wearing of protective body armor. To confirm these suspicions, we asked three aviators, one from each of the three smallest aircraft (AH-1, OH-58A/C, and OH-58D), to repeat their static evaluation. This time, they were asked not to wear the protective body armor. All three were blind as to the purpose of the reevaluation. The two evaluations for each aircraft were subjected to a dependent samples *t*-test. As suspected, the results suggested a significant increase in user acceptance of the mask and frontsert system for the evaluations without body armor [means with/without armor:

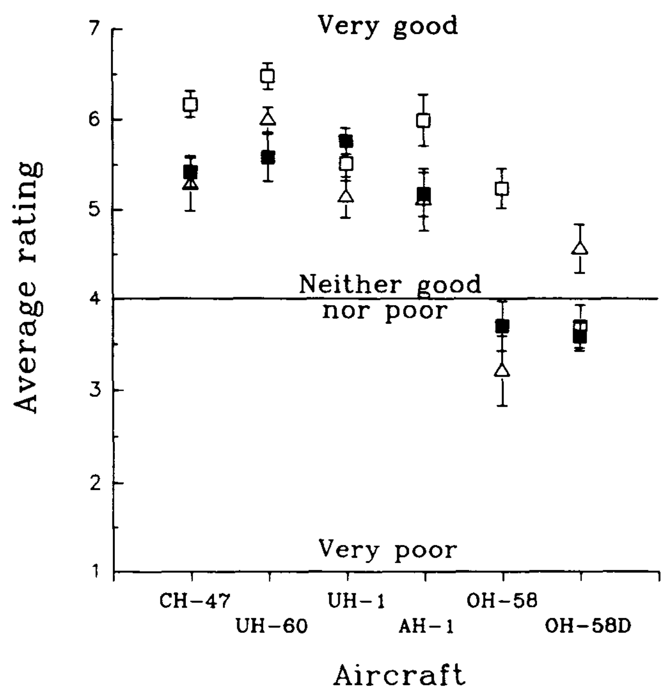

Fig. 5. Average ratings for ease-of-viewing 30+ areas inside and outside each aircraft, as well as compatibility of the mask with aircraft specific systems. The rating scale ranged from 1 (very poor/very difficult) to 7 (very good/very easy). A rating of 4, the midpoint, indicated that the item was neither difficult nor easy. Mean values above 4 were interpreted as reflecting positive user acceptance in that aircraft, and scores below 4 indicated negative user acceptance. Correction group: □ normal vision, ■ single vision, and △ bifocal vision.

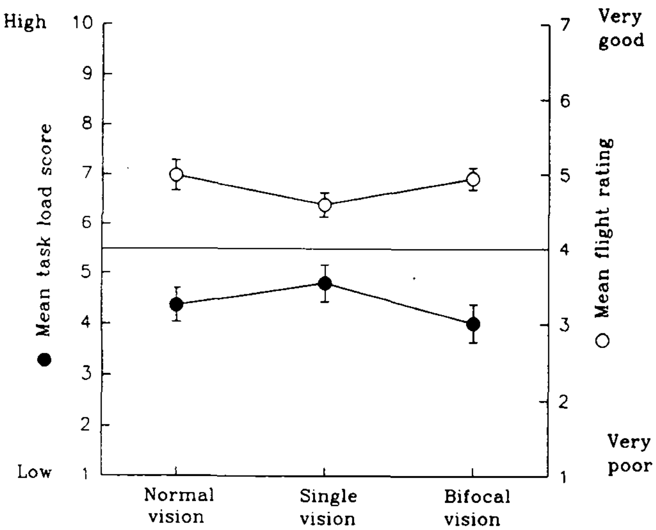

Fig. 6. Data collected during the flight phase taken from the NASA Task Load Index (● left ordinate—same as Fig. 4) and the UH-1 flight survey form (○ right ordinate—same as Fig. 5).

AH-1, 5.11 ± .350/5.89 ± .252, $t(34) = 3.616$, $p < 0.0010$; OH-58A/C, 3.21 ± .378/4.61 ± .311, $t(32) = 6.546$, $p < 0.0001$; OH-58D, 3.70 ± .236/5.15 ± .231, $t(32) = 5.034$, $p < 0.0001$].

Flight Phase

The data collected during the flight phase from the NASA TLX and the UH-1 flight survey form are shown in Fig. 6. As was done in the simulator evaluation, each subscale of the TLX was equally weighted in determining the final scale score. Means for all tasks fell below the 5.5 midpoint value (see simulator phase above). The data were subjected to a two-way 3(group) × 6(task) ANOVA. No significant main effects nor interaction effects were found [group, $F(2, 72) = 1.23$, $p < 0.2975$; task, $F(5, 72) = 2.25$, $p < 0.0586$; and group × task, $F(10, 72) = 0.63$, $p < 0.7837$]. The UH-1 flight survey was an abbreviated form of the UH-1 static evaluation. Subjects rated ease-of-viewing 18 areas inside and outside the aircraft, compatibility of the mask with aircraft systems, and the stability of the frontserts in flight. Rating scales were identical to the static evaluations above. The mean ratings for each group, indicative of the mask's overall compatibility/suitability under flight conditions, as well as stability of the frontserts in flight, all fell above the midpoint value of 4.

DISCUSSION

The purpose of this experiment was to determine the effects of M43A1 protective mask optical correction frontserts on aviator performance. As this experiment was resource constrained, the investigators chose to emphasize simulator data collection with its high face validity, readily quantifiable performance, and low risk, over the riskier and less quantifiable flight segment and the subjective static evaluation segment.

The objective data from the simulator portion showed that overall, aviators could perform the required maneuvers as well with the mask on as with it off, despite refractive status. However, subjects wearing the mask reported that the taskload was significantly greater, and flying with the mask produced a significant increase in subjective discomfort. That all three groups failed to report significant task differences in performance supports the objective data in that subjects felt they could perform the mission equally as well with or without the mask. This led to the conclusion that, while subjects may not want to fly in a protective mask, when asked to do so, they can overcome the inherent task difficulties and perform their assigned duties. It is possible that these difficulties stemmed from decreases in the field-of-view (FOV) inherent with wearing protective masks. In general, the FOV with the M43A1 mask is reduced approximately 12%, with most of this reduction occurring in the lower nasal quadrant. In contrast, there is very little loss of FOV in the temporal quadrants (approximately 1%). Such decreases resulted in the pilots having to make larger head movements than would have been necessary without the mask, especially when viewing areas inside the aircraft.

The deflated performance scores for the formation/ANVIS maneuvers in the simulator also may be indicative of FOV problems. Ongoing research in this laboratory shows that the design does not allow the eye to get close enough to the ANVIS tubes to achieve a 40° FOV [McLean, personal communication, July 1994]. For a full FOV, the eyes need to be approximately 20 mm from the eyepiece. Measured on a rigid headform, the M43A1 mask increased this distance to approximately 22-28 mm (equivalent to a 38–35° FOV). The addition of frontserts increases this stand-off another 5 mm (allowing a 35–32° FOV). Users of this mask must be made aware of and accept the limitations of using the M43A1 mask and frontserts with ANVIS. However, it should be noted that the current aviation protective mask, the M24, is totally incompatible with ANVIS. Thus, the M43A1, while not allowing for full FOV through ANVIS, offers a substantial improvement over the existing capabilities.

The static evaluation phase of this study was intended only as a first look at compatibility of frontsert correction with each aircraft type in which it is to be used. This enabled the experimenters to identify any aircraft-specific problems with the M43A1 mask or frontsert system. In general, user acceptance of this mask was positive. The only difficulties consistently reported were in viewing areas that were down low between the seats or behind the pilot's head, outside the normal FOV. Some of these problems, those involving rearward vision, could be solved with the addition of rear-view mirrors such as those currently found in the AH-1 and CH-47. Therefore, the main value of the static evaluations may lie in their demonstration of the need for follow-up evaluations in a particular model aircraft. Indeed, our own follow-up investigation for the smaller aircraft cockpits revealed that negative user acceptance was a result of restrictions to head movement imposed by the protective body armor rather than of the mask or frontsert systems. User acceptance in these aircraft was increased significantly when reevaluated without the armor. It is reasonable to presume that the same effect would hold true in larger aircraft cockpits.

The purpose of the flight portion of the project was to identify flight-related problems with the frontsert system, and to verify the stability and usability of the M43A1 frontserts, both in single vision and bifocal forms, under actual flight conditions. The only consistently reported difficulty in the JUH-1 was the pilots' ability to see other crewmembers in the rear area of the aircraft. However, the aviators found the mask and frontsert systems fully compatible/suitable for flight, and there were no differences based on refractive status. Overall, the results from this phase were consistent with reports from the static evaluations and revealed that aviators felt the taskload in flight was not excessive. All this suggests that user acceptance of the mask and corrective lens system should be high.

Provided with all these results, we conclude that aviators wearing only the M43A1 should not experience any performance degradation beyond those typical of training in a mission oriented protective posture (MOPP) around aircraft. Reductions in the FOV may account for the increased workload and slight performance decrements observed in the simulator. However, given the incompatibilities of current aviation masks with ANVIS, MOPP performance with the M43A1 during night operations should improve dramatically. Subjects wearing the M43A1 with frontserts may experience some additional risk in using these items due to a greater loss in FOV, although the data show that any degradations in performance should be minimal. Thus, within the range of flight conditions and profiles examined, the M43A1 frontsert system meets U.S. Army aviation needs for optical correction when mission requirements dictate flying with chemical-biological protective masks.

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Opinions, interpretations, conclusions and recommendations are those of the author and not necessarily endorsed by the U.S. Army.

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