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Speech Intelligibility with Helicopter Noise: Tests of Three Helmet-Mounted Communication Systems (Reprint)

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Aircrew Protection Division

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13. ABSTRACT <i>(Maximum 200 words)</i> Military aviator helmet communications systems are designed to enhance speech intelligibility (SI) in background noise and reduce exposure to harmful levels of noise. Some aviators, over the course of their aviation career, develop noise-induced hearing loss that may affect their ability to perform required tasks. New technology can improve SI in noise for aviators with normal hearing as well as those with hearing loss. SI in noise scores were obtained from 40 rotary-wing aviators (20 with normal hearing and 20 with hearing-loss waivers). There were three communications systems evaluated: a standard SPH-4B, an SPH-4B aviator helmet modified with communications earplug (CEP), and an SPH-4B modified with active noise reduction (ANR). Subjects' SI was better in noise with newer technologies than with the standard issue aviator helmet. A significant number of aviators on waivers for hearing loss performed within the range of their normal hearing counterparts when wearing the newer technology. The rank order of perceived speech clarity was 1) CEP, 2) ANR, and 3) unmodified SPH-4B. To insure optimum SI in noise for rotary-wing aviators, consideration should be given to retrofitting existing aviator helmets with new technology, and incorporating such advances in communication systems of the future. Review of standards for determining fitness to fly is needed.			
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Speech Intelligibility With Helicopter Noise: Tests of Three Helmet-Mounted Communication Systems

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Background: Military aviator helmet communications systems are designed to enhance speech intelligibility (SI) in background noise and reduce exposure to harmful levels of noise. Some aviators, over the course of their aviation career, develop noise-induced hearing loss that may affect their ability to perform required tasks. New technology can improve SI in noise for aviators with normal hearing as well as those with hearing loss. **Methods:** SI in noise scores were obtained from 40 rotary-wing aviators (20 with normal hearing and 20 with hearing-loss waivers). There were three communications systems evaluated: a standard SPH-4B, an SPH-4B aviator helmet modified with communications earplug (CEP), and an SPH-4B modified with active noise reduction (ANR). **Results:** Subjects' SI was better in noise with newer technologies than with the standard issue aviator helmet. A significant number of aviators on waivers for hearing loss performed within the range of their normal hearing counterparts when wearing the newer technology. The rank order of perceived speech clarity was 1) CEP, 2) ANR, and 3) unmodified SPH-4B. **Conclusions:** To insure optimum SI in noise for rotary-wing aviators, consideration should be given to retrofitting existing aviator helmets with new technology, and incorporating such advances in communication systems of the future. Review of standards for determining fitness to fly is needed.

Keywords: Speech intelligibility in noise, aviator helmet, fitness to fly.

NOISE LEVELS IN U.S. Army helicopters exceed safe limits in accordance with Department of Defense Instruction 6055.12 (5). The rotary-wing flying environment is noisy, and intercommunications systems introduce acoustic distortion. As a result, many aviators have a hearing loss. In some cases, the ability of the helmet alone to protect the hearing of the aviator is marginal. Using combination or double protection, by wearing earplugs in addition to the aviator helmet, can compound the problem, particularly in cases where intercommunications systems (ICS) are not capable of producing the speech levels needed to overcome the earplug sound attenuation (9).

Voice communications are critical to the successful completion of the aviator's mission. The aviator must be able to understand complex messages quickly and completely in order to maintain complete control of the aircraft and gain every advantage over opposing forces. Poor communications may compromise the mission and result in the loss of life and property. There is evidence that high noise levels, degraded communication signal, and sensorineural hearing loss combine to impair speech intelligibility (SI) (1). Those with hearing

loss may be at especially increased risk for aircraft mishap due to degraded SI.

The noise spectrum within military helicopter crew compartments is predominantly low frequency with peak levels occurring near the blade passing frequency. Noise sources in addition to the blades include engines, blowers, transmissions, vibration, and turbulence caused by the movement of the helicopter through the atmosphere. Since helicopter noise levels normally exceed 85 dBA, hearing protection is required. Military aviator helmets, among other functions, address this safety issue by providing noise attenuation for the crewmembers. To facilitate internal communication, all aircrew on rotary-winged aircraft use electrically augmented communication systems for crew coordination.

The effectiveness of hearing protective devices with communication capability is generally determined via sound attenuation measures using standard laboratory techniques. Results from laboratory evaluations are subsequently applied through mathematical models to estimate the expected performance in a user's particular noise environment. This approach uses noise level values from measurements that were made in the operational environment to demonstrate the effectiveness of the hearing protector. New technology is now available that may enhance hearing in noise over communications systems currently in use in Army aviation. Comparison of existing and new technologies is a logical step in evaluating optimum listening conditions and hearing protection for aviators.

Factors Affecting SI

Hearing protector effectiveness may be compromised by any of several factors: improper fit for the individ-

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TABLE I. CLASS II HEARING STANDARDS IN DB HL FOR ARMY AVIATORS.

Frequency (Hz)	500	1000	2000	3000	4000	6000
Better ear	25	25	25	35	65	75
Worse ear	25	35	35	45	65	75

ject provided written, informed consent before participating.

Subjects were screened by otoscopic examination, middle ear function test (tympanometry), and hearing health intake history. Selection criteria for the normal hearing aviators (control group) were limited to audiometric thresholds no greater than Army Class II hearing standards for aviators (2). Subjects in the waiver (experimental) group were defined as those aviators exhibiting a sensorineural hearing loss that exceeded Army Class II standards as presented in Table I, and who were on waived status.

Audiometry

Behavioral audiometric thresholds were obtained pre- and postnoise exposure using a modified Houghson-Westlake descending method at 0.125, 0.250, 0.500, 1, 2, 3, 4, 6, and 8 KHz. Testing was conducted in a sound-treated booth by a certified audiologist using a GSI-10 audiometer (Grason-Stadler, Madison, WI).

Establishing Speech Presentation Levels

Speech signal levels were determined by measuring frequency responses for each of the three devices, analyzed into one-third octave band levels, at dBA and dB linear levels using a Fast Fourier Transform Analyzer (Model 2630, Tektronix® Inc., Beaverton, OR) (9). Pre-recorded speech (W-22, 50-word lists) was presented through each device under test and measured in quiet. Word lists were presented in rapid succession while measuring the equivalent continuous sound level of the sound signal produced by the device under test. The results of this measurement were used to determine the attenuator settings required for the 85 dBA and 95 dBA speech presentation levels (9).

SI in Background Noise

Participants were trained in proper fitting techniques for each of the devices under investigation by a technician experienced in hearing protector fitting procedures. After training, participants were responsible for donning and doffing each helmet under test. The technician monitored the fit of each device and provided additional training as necessary.

A speech reception threshold level was determined for each device for each subject using a list of 36 W-1 spondaic words (11) prior to the SI test series. Speech reception threshold is defined as the level at which the listener achieves a 50% correct response (14). Speech materials used to determine SI consisted of four pre-recorded lists (W-22) with four orderings of each list. The words were presented to the listener at a rate of 12 per minute. The recordings for all speech materials

were commercially available products from Auditec® of St. Louis, MO. Each list consisted of 50 monosyllabic words. Monosyllabic words were chosen in order to tax the listener and to provide a highly sensitive measure of intelligibility for each device.

Subsequently, each participant was given an SI pre-test to screen out subjects who had difficulty performing the SI task. Subjects were fully familiarized with the four word lists used in the SI measurements. The order of tests was randomized using a Latin squares design to minimize any learning effects (13). Subjects were then seated in a reverberant chamber using noise levels which simulated a UH-60 helicopter during cruise at 120 kn. Mozo and Murphy (9) described the details of the setup for this study. Overall levels of the noise were adjusted to 105 dBA (re 20 µPa).

Subjects were asked to listen to the words presented and record their answers on a numbered sheet. SI tests were scored as percent correct for each device and test condition. Total test time was approximately 5 h divided into two test sessions. There were six conditions for SI testing for each subject. The speech stimuli were presented at fixed levels of 85 dBA and 95 dBA for each of the three helmet configurations. The SI for constant speech level input of 85 dBA and 95 dBA was used to determine the relative merit of the devices at levels near the acceptable sound pressure level input limit. These levels were derived from research by Camp, Mozo, and Patterson (3). Their research revealed that CH-47 Chinook helicopter noise under SPH-4 helmets averaged 85 dBA (ICS off) and 95 dBA (ICS on). Noise levels in a CH-47 helicopter at some locations within the aircraft exceed those of the UH-60. The rationale for using the data from Camp, Mozo, and Patterson was to provide a worst-case scenario. Given the method for deriving speech presentation levels for this study, it might prove more realistic to think of these levels in terms of time-weighted average. Time-weighted average is a calculation of variable noise exposure doses over a given time to which an individual is subjected compared with the allowable duration and level of noise for that period of time. In this study, subjects were not exposed to a steady-state level of speech stimulus of 95 dBA.

RESULTS

Audiometry

Postexposure audiometric configurations for the two test groups are presented in Table II. Mean thresholds and standard deviations for both groups reflect little difference between ears (pre- and postnoise exposure), therefore, right and left ear data were collapsed. Normal hearing aviator thresholds averaged below 20 dB

TABLE II. MEAN POST-NOISE/SPEECH EXPOSURE AUDIOMETRIC DATA IN DBHL.

	Frequency (Hz)								
	125	250	500	1000	2000	3000	4000	6000	8000
Normal	3	3	4	5	4	12	19	19	19
Waivered	7	8	11	13	18	46	60	63	60

TABLE IV. PERCENT OF AVIATORS IN THIS STUDY THAT FELL INTO THE "EXCEPTIONALLY-HIGH TO NORMAL" CATEGORIES RE MILITARY STANDARD 1472D BY GROUP.

	85 dBA		95 dBA	
	Normal	Waivered	Normal	Waivered
ANR	55	40	90	80
CEP	90	65	95	85
SPH-4B	0	5	70	40

Military Standard 1472D (8) indicates that monosyllabic word tests should be used to assess SI in communications systems when a high degree of sensitivity and accuracy are needed. It would seem tenable, therefore, to consider where the SI scores for both subject groups in this study fell in relation to these criteria. The categories of "exceptionally high" and "normal" intelligibility as defined in Military Standard 1472D (8) have been arbitrarily grouped together in Table IV.

The findings from Table IV reveal a pattern of better performance when ANR and CEP systems deliver the speech signal than when speech is presented through the unmodified SPH-4B system. For instance, at 85 dBA, when the CEP was worn, 65% of waived aviators and 90% of normals fell within the exceptionally high-normal category. Whereas at the same level of speech signal, when the unmodified SPH-4B was worn, only 5% of waived and none of the normal hearing aviators fell into the exceptionally high-normal category. It may seem counterintuitive that normals would perform worse than those with a waiver for hearing loss. However, 5% in this small sample represents only one subject and, therefore, is probably just a variation due to chance. These findings confirm earlier observations and provide compelling evidence to support retro-fitting of existing Army aviator helmets with CEP or ANR technology.

CONCLUSIONS

The results of this study show that ANR and CEP technology enhance voice communications for the aviator in noise when compared with the basic issue SPH-4B helmet. In summary: 1) normals scored higher than waived subjects on all devices; 2) both ANR and CEP communications devices improved SI in both waived and normal groups when compared with the unmodified SPH-4B; 3) many waived aviators were able to perform within the normal range of performance in the SI tests when new technology was used; 4) at low levels of speech input both ANR and CEP outperformed the standard helmet when speech was presented at 95 dBA; 5) the change in SI scores was less dramatic for the CEP between 85 dBA and 95 dBA than for ANR or the unmodified SPH-4B (probably because the CEP performance had already reached asymptote at 85 dBA); and 6) the CEP was perceived to have the greatest clarity of speech by a ratio of 3:1 over ANR and the unmodified SPH-4B. Due to similarities in attenuation and communications system characteristics for the SPH-4B and HGU-56/P, findings from this study suggest both helmets can be significantly improved by incorporating ANR or CEP technology.

Based on the results of this study, a large proportion of waived aviators can be expected to understand speech in background noise as well as their normal hearing counterparts, provided their communications system is modified with ANR or CEP technology. The results of this study are compelling and should serve as impetus for changes in the existing communications system configuration and future aviator helmet design in the rotary-wing environment. Proactive decision-makers may wish to compare the CEP and ANR. Issues that might be considered are: attenuation, effects of ancillary equipment (eyeglasses, protective mask), perceived background noise, VC setting, comfort, weight, impact protection, compatibility with existing aircraft communications systems, cost, installation, power requirements, and aircraft modifications when contemplating upgrading systems. There are significant differences that merit a detailed comparison (10).

While this study did not determine the best criteria for determining fitness to fly, it has highlighted the need to do so. It is worth noting that the SI in noise of a significant number of waived aviators can be improved with new technology, resulting in near-normal performance. This may be an appropriate time to revisit fitness to fly standards, particularly the criteria for determining waived status. It is conceivable that in the future, flight surgeons will place aviators with a hearing loss on waived status on condition that their helmets are equipped with ANR or CEP technology.

The point at which SI degradation affects flight safety has not been studied. Therefore, research is needed to assist the aviation medical community in developing criteria to determine fitness to fly for both aviators with normal hearing and those with hearing loss. It is foreseeable that speech in noise tests such as the Hearing In Noise Test (12), SPeech Recognition In Noise Test (4), or the Speech In Noise Test (6), along with other conventional tests, could be used in the future as a test battery to assist flight surgeons in determining the eligibility of aviators to continue flying.

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