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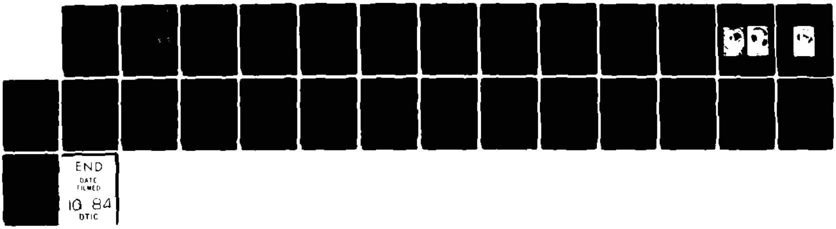

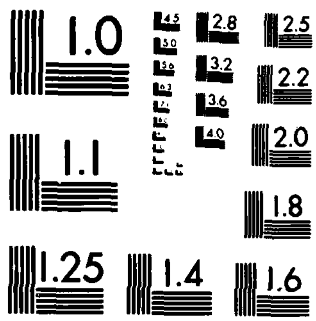

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HEARING PROTECTION AND SPEECH INTELLIGIBILITY OF TWO NONSTANDARD INFLIGHT COMMUNICATION HEADSETS

ANN M. PROHASKA
CHARLES W. NIXON

JULY 1984

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AIR FORCE AEROSPACE MEDICAL RESEARCH LABORATORY
AEROSPACE MEDICAL DIVISION
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FOR THE COMMANDER

Henning E. von Gierke

HENNING E. VON GIERKE, Dr Ing
Director
Biodynamics and Bioengineering Division
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This study evaluated the hearing protection and voice communications effectiveness of two standard earmuff hearing protectors modified to function as voice communications headsets. Both modified units contained the AF standard H-143 inflight receivers and the M-87 noise cancelling boom microphone. Hearing protection and voice communication performance of the modified units were compared to those of the H-157 headset at four intensity levels of a noise spectrum that was generally flat from 63 Hz to 5000 Hz (80, 95, 105, 115 dB 20μPa). The results showed that the H-157 headset provided more hearing protection than either of the modified headsets, especially in the higher frequencies. The modified headsets provided better speech intelligibility than the H-157 headset. Wearability problems were noted with the modified headsets which may become a problem in the operational situation.

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BACKGROUND

The inflight noise environs of operational aircraft threaten the performance of aircrew members with the potential for adverse effects on the hearing function and on voice communications effectiveness. The inflight voice communications headset, H-157, was designed and incorporated into AF aircraft almost three decades ago. Design specifications were based on measurements of the actual inflight noise at the crew member locations in the classes of non-tactical aircraft in the inventory at that time. Since these communication units were incorporated into the Air Force inventory several new aircraft have been developed and deployed. Although the H-157 headset was proven satisfactory for the moderately intense inflight noise environments of that time, its hearing protection and voice communications performance in other aircraft have been described as marginal in anecdotal reports.

The Digital Audio Distribution System (DADS) development program that is in progress will provide a new tri-service aircraft intercommunication system. Among the elements of this DADS program is the requirement for developing new terminal equipment, specifically new headset and helmet type systems, that will provide the personal equipment performance essential to crewmember effectiveness with the digital communications links. One task will be to replace the H-157 inflight headset with a new headset system that will provide enhanced hearing protection and voice communications capabilities.

There is no formal program to develop an improved communications headset for use until the DADS unit is available for situations in which the performance of the H-157 headset is reported to be marginal. Consequently, personnel sometimes modify available equipment in an effort to obtain improved audio communications performance for their individual situations. These non-standard communication units may appear in a variety of forms and configurations and must be individually investigated to determine their effectiveness. These modified or altered units are not approved for Air Force use by virtue of the investigation even though improved performance may be demonstrated. Authority to approve the use of such equipment in Air Force environments does not reside in the Air Force Aerospace Medical Research Laboratory.

This memorandum describes the laboratory investigation of two standard earmuff hearing protectors that were modified to function as voice communication headsets intended to provide improved performance over the standard H-157 headset. The units were modified by an Air National Guard Unit and submitted to Mr. Kenneth Troup, ASD/AESO, Life Support SPO for investigation and assessment. An investigation of the hearing protection and voice communications effectiveness in noise of these units was conducted in the Bioacoustics Branch (BBA) of the Air Force Aerospace Medical Research Laboratory (AFAMRL).

APPROACH

The modified communications units were investigated in two separate facilities in AFAMRL/BBA; one dedicated to the measurement of hearing protection performance and the other to the measurement of speech intelligibility in emulated operational noise environments. The H-157 headset was also measured under identical conditions to serve as the baseline or control unit. The hearing protection characteristics were measured in accordance with American National Standards Institute procedures and speech intelligibility was measured using a standardized test of intelligibility, the Modified Rhyme Test. Human volunteers were trained to perform these tasks and participated as experimental subjects in defining the performance characteristics of the units. Performance results of the two modified units were compared to those of the H-157 headset to determine their relative effectiveness and suitability for use in Air Force environments.

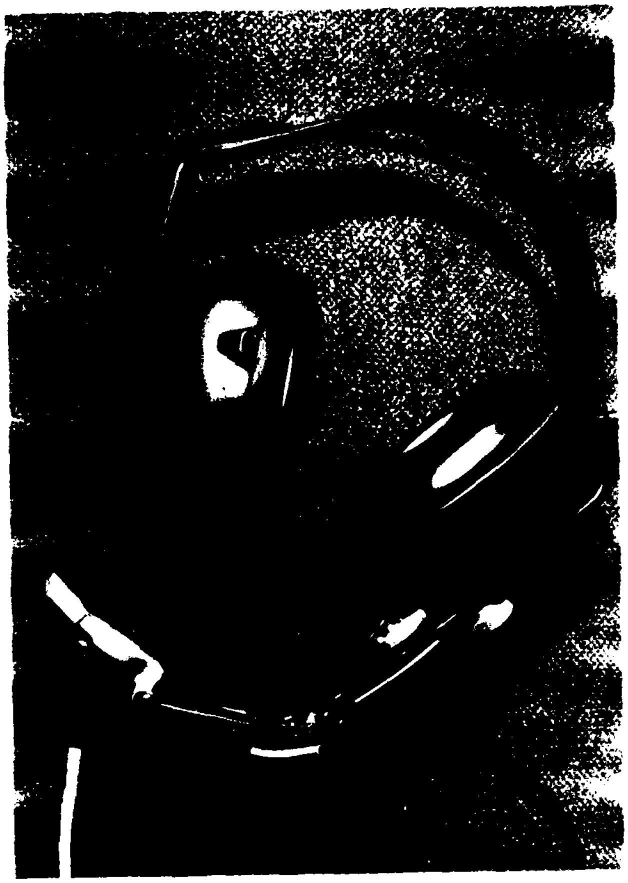
COMMUNICATION HEADSETS

The communications headset configurations under investigation and the standard Air Force H-157 headset are shown in Figures 1(a), 1(b) and 1(c). The black earcups-plastic headband unit is a Willson 365 earmuff and the large gray earcups-wire headband unit is a David Clark 117 earmuff. Both of these units were designed as earmuff hearing protectors without a voice communications capability, and their reported attenuation characteristics are typical of good earmuffs. The modification or alteration of each earmuff consisted of adding the terminal equipment of the standard Air Force intercommunication system which were the standard M-87 microphone and H-143 receivers and the associated brackets and wiring harnesses. Consequently, the three headsets had the same physical and functional features that included circumaural earcups mounted on a headband, H-143 altitude compensated receivers inside the earcups and the M-87 noise cancelling microphone mounted on a boom.

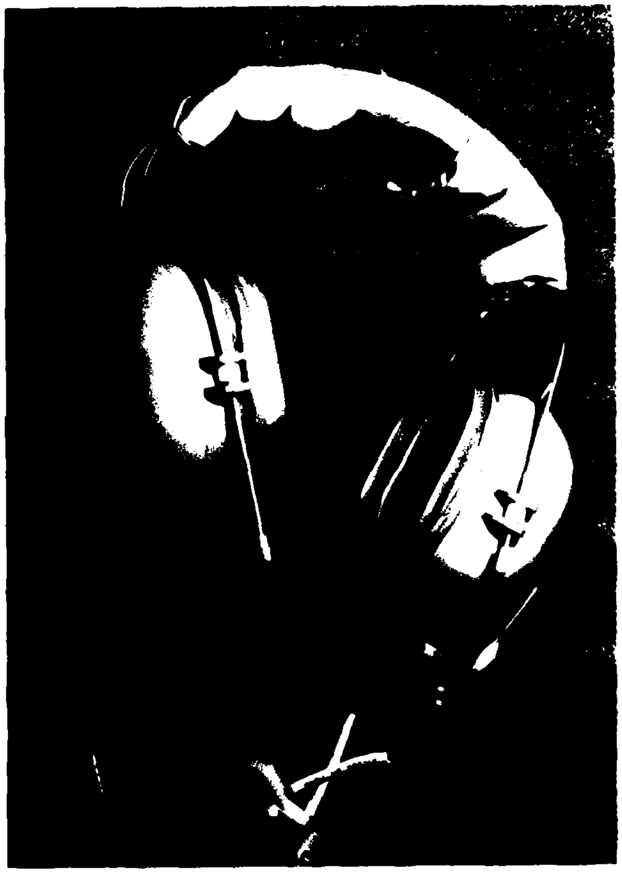
The unaltered noise excluding earmuffs provide more hearing protection than the H-157 headset. It would seem reasonable to expect that the addition of

FIGURE 1

COMMUNICATIONS HEADSETS. 1(a) - MODIFIED WILLSON 365 EARMUFF. 1(b) - MODIFIED DAVID CLARK 117 EARMUFF. 1(c) - STANDARD AIR FORCE H-157 COMMUNICATIONS HEADSET



1(a)



1(b)

1(c)

the microphone, receivers and hardware to these good noise excluding units would provide better protection and voice communication than with the H-157 headset. However, the addition of the communication components affects the integrity of the earmuff by altering, in a way that cannot be precisely estimated, characteristics that affect the attenuation performance such as overall weight, volume displacement inside the earcups and attachments such as the brackets and wiring harnesses. Consequently, the performance of earmuff hearing protectors into which communications components have been integrated, cannot be accurately predicted and must be individually measured to determine their usefulness in operational environments.

PROCEDURES

a. *Facilities and Equipment*

The experiments were conducted in two research facilities at the AFAMRL/BBA, the hearing protection measurement system and the voice communication research system.

Hearing Protection Measurement System. The hearing protection measurement facility is an electroacoustic system designed to measure hearing threshold levels for one-third octave bands of noise in compliance with the American National Standards Institute, Method for the Measurement of the Real-Ear Protection at Threshold of Hearing Protectors and the Physical Attenuation of Earmuffs, ANSI S3.19, 1974. The system is housed in a semi-reverberant chamber and maintained in a ready condition so that experiments may be initiated as required. It is operated on a periodic basis to determine the noise excluding characteristics of a wide variety of personal equipments requiring non-routine measurements. Results are used for various reasons including the estimation of permissible noise exposures of personnel wearing these devices in operational noise situations.

Voice Communication Research and Evaluation System (VOCRES). The voice communication research facility contains the standard AIC-25 Air Force intercommunications and A-14 respiration systems at each of ten (10) stations. This facility simultaneously measures the responses of ten human subjects and it emulates the operator, system and environmental variables important to audio communications. The facility is operated daily throughout the year to investigate the full spectrum of audio communications systems and equipment in terms of problems, applications and enhancements.

The voice communication research facility is housed in a specially designed acoustic reverberation chamber intended to disrupt the formation of standing waves and maximize the uniformity of the level of noise distributed throughout the room. A programmable high intensity sound system allows almost any desired noise environment within the human audio frequency range to be generated inside the chamber. This allows the accurate reproduction in the laboratory of ambient and environmental noise conditions of specific Air Force operational situations for realistic research on audio communications.

The noise spectrum in which this investigation was conducted was generally flat from 63 Hz to 5000 Hz. The one-third octave band levels of the noise are shown in Table 1 for an overall sound pressure level of 95 dB. Word

TABLE 1

ONE-THIRD OCTAVE BAND LEVELS (dB) OF THE 95 dB (OASPL)
NOISE CONDITION IN WHICH INTELLIGIBILITY WAS MEASURED

ONE-THIRD OCTAVE BAND CENTER FREQUENCY (Hz)	SOUND PRESSURE LEVEL (dB)	ONE-THIRD OCTAVE BAND CENTER FREQUENCY (Hz)	SOUND PRESSURE LEVEL (dB)
40 Hz	71.1	1 kHz	81.1
50 Hz	75.0	1.25 kHz	80.9
63 Hz	81.1	1.6 kHz	81.9
80 Hz	82.4	2.0 kHz	82.4
100 Hz	82.3	2.5 kHz	79.2
125 Hz	82.4	3.15 kHz	81.0
160 Hz	83.1	4.0 kHz	79.6
200 Hz	83.2	5.0 kHz	80.8
250 Hz	82.7	6.3 kHz	77.1
315 Hz	83.1	8.0 kHz	74.6
400 Hz	79.8	10.0 kHz	74.2
500 Hz	81.3	12.5 kHz	71.9
630 Hz	80.9	16.0 kHz	62.7
800 Hz	79.7		

OVERALL SOUND PRESSURE LEVEL: 95 dB

intelligibility measurements were made in this noise at the four different overall sound pressure levels of 80 dB, 95 dB, 105 dB and 115 dB.

b. Human Volunteers

Human volunteers for these studies were selected from a pool of subjects trained in both the hearing protection and audio communications experimental procedures. The subject pool is comprised of volunteer college students, housewives, and individuals with a second part-time job, as well as others. All subjects have normal hearing (ANSI 1969) and a general mid-american speech dialect. Subjects with non-normal hearing or strong speech accents or dialects may be recruited for special studies but are not retained in the standard subject pool. Volunteers receive monetary compensation for their participation.

EVALUATION

a. Hearing Protection

The hearing protection evaluation procedure involved the measurement of the "open ear" hearing threshold levels of the subjects for pulsed one-third octave bands of noise with the center frequencies of 125, 250, 500, 1000, 2000, 3000, 4000, 6000 and 8000 Hz in a semi-reverberant test room. One of the three communication headsets included in the study was put on by the subject and the hearing threshold levels were measured again at the same test signals. The difference between the open ear hearing threshold levels and those measured with the headset being worn were defined as the attenuation or amount of protection provided by the headset. During each test session the seven volunteers repeated the open ear measurements and the headset measurements three times at each test signal. The overall headset attenuation value at each signal was the arithmetic average of the differences between the 21 open ear and 21 headset values. The hearing threshold level measurements were recorded and tabulated manually.

Seven normal hearing young adults volunteered as subjects for these measurements. Each of the seven volunteers wore the three headset units in all experimental conditions thereby serving as their own controls. The headset units were donned by the subjects according to instructions provided by the experimenter prior to the headset measurements. When the experimenter observed that a headset was not properly fit, the subject was instructed to readjust the headset. Subjects readjusted the headsets as many times as necessary to obtain a good fit and then the measurements were accomplished.

This evaluation was conducted in compliance with the American National Standards Institute, Method For The Measurement Of Real-Ear Protection at Threshold and Physical Attenuation of Earmuffs except that seven (7) instead of ten (10) volunteer subjects participated in the study.

b. Speech Intelligibility

The VOCRES consists of ten communications stations equipped with the standard AF intercommunications and respiration systems, however, only four stations were utilized for this study. Each of four talkers (2 female and 2 male) wearing the H-157 communications headset presented lists of fifty monosyllabic test words from the standardized Modified Rhyme Test (MRT) to 3 listeners (1 wearing the H-157, 1 wearing the black earcups-plastic headband unit and 1 wearing the gray earcups-wire headband unit). The word lists are generally equivalent in intelligibility and are relatively easy to administer and score. There is very little training required with this test and it is the test of choice when evaluating military voice communications systems.

The intelligibility of each of the three headsets was investigated at four levels of the general noise spectrum (80 dB, 95 dB, 105 dB and 115 dB re 20 uPa) shown in Table 1. The criterion measure was percent correct response of the words in a 50-word list of the Modified Rhyme Test corrected for guessing. The intelligibility scores were tabulated and processed to provide data on the performance of each headset.

RESULTS

a. Hearing Protection

The hearing protection performance of the three communication headsets is presented in Table 2 in terms of the mean attenuation and standard deviation for each test signal. In Table 3, the same data are presented as mean minus two standard deviations data as used by the Air Force in estimating the amount of hearing protection to be expected by over 95% of the wearers when the devices in the field are worn in the same manner as during the laboratory investigation. The Noise Reduction Rating (NRR), is a single number descriptor of hearing protector effectiveness and (shown in Table 3) was calculated in accordance with guidelines from the US Environmental

TABLE 2

MEAN AND STANDARD DEVIATION HEARING PROTECTION VALUES
OF THE COMMUNICATIONS HEADSETS AS A FUNCTION OF TEST FREQUENCY

		Frequency (Hz)								
		125	250	500	1000	2000	3000	4000	6000	8000
H-157	Mean Attenuation	8	11	21	26	24	25	31	29	25
	Standard Deviation	1	1	3	3	2	3	2	3	2
Black	Mean Attenuation	8	10	21	24	24	27	31	32	30
	Standard Deviation	1	1	3	5	5	4	3	5	3
Gray	Mean Attenuation	9	12	22	20	19	22	26	30	25
	Standard Deviation	3	2	2	4	4	5	3	8	5

TABLE 3

MEAN HEARING PROTECTION VALUES MINUS TWO STANDARD DEVIATIONS (dB)
FOR THE COMMUNICATIONS HEADSETS

	Frequency Hz)									
	125	250	500	1000	2000	3000	4000	6000	8000	NRR
H-157	6	9	15	20	20	19	27	23	21	16.2
Black	6	8	15	14	14	19	25	22	24	13.3
Gray	3	8	18	12	11	10	20	14	15	10.4

Protection Agency. Standard deviations associated with the attenuation values may be an indication of how well the device fits the population. Generally, the smaller the standard deviation the better is the estimation of the fit and of the amount of attenuation of the device. The NRR is a single number performance rating for a hearing protector and it's value is subtracted from the A-weighted sound pressure level of a noise environment to determine the level under the hearing protector.

The data in Table 2 suggest that the black-plastic and gray-wire headsets provide approximately the same amount of protection as that provided by the H-157 headset. However, the standard deviations for the H-157 headset are smaller than the other headsets. As a consequence, the mean minus two standard deviation data and the NRR data indicate that the H-157 sound protection is better than that of both the other units. Allowable daily noise exposures are defined using Table 5, page 20, in Air Force Regulation 161-35, Hazardous Noise Exposure. Calculations of allowable noise exposures are adjusted to account for the amount of protection provided by the headset used by the exposed person. The allowable daily noise exposure using the gray-wire headset would be less than with the H-157 headset, especially in the higher frequencies. The limiting values for the black-plastic headset would be only slightly less than the H-157 headset.

b. Speech Intelligibility

The word intelligibility scores are summarized for each headset in Figure 2 and Table 4 in terms of the criterion measure, average percent correct response. The primary effect was the noise condition where intelligibility decreased from about 98% for the ambient condition to 68% to 74% for the maximum noise condition of 115 dB. These differences between means of the noise conditions were found to be statistically significant only between the 115 dB and the other three conditions; differences between ambient, 95 dB and 105 dB were not significant. The statistical significance was evaluated using Critical Ratios and the rule of thumb that a critical ratio of 2.0 or larger is statistically significant.

Generally, the results indicated that the two modified headsets provided better intelligibility than did the standard H-157 headset. The greatest difference was observed at the 115 dB noise condition. The H-157 was designed for use in moderate noise environments that do not exceed about 110 dB, consequently its performance is still consistent with its design goals because audio communications that exceed the 85% range as measured by the communications research system have been fully acceptable in the operational environment. Both the black-plastic and gray-wire headsets provided intelligibility that was the same as the H-157 under the ambient condition but better under the three higher level noise conditions. The gray-wire unit provided slightly better performance than the black-plastic headset at both 95 dB and 105 dB. The mean intelligibility scores collapsed across noise conditions were 89% for both modified headsets and 86% for the H-157.

The word intelligibility data for the three headsets are different for the noise conditions, however, the magnitudes of the differences appear to be insufficiently large to be statistically significant because of the very small sample size used in the data collection. Only four talkers and three listeners were utilized in the measurement phase of word intelligibility

TABLE 4

SPEECH INTELLIGIBILITY OF THE COMMUNICATIONS HEADSET
AS A FUNCTION OF NOISE CONDITION

NOISE LEVEL	CORRECT %		
	H-157	Black Plastic	Gray Wire
Amb	97.4	98.2	98.1
95	91.1	92.1	94.6
105	86.8	91.4	88.7
115	68.1	75.8	74.1

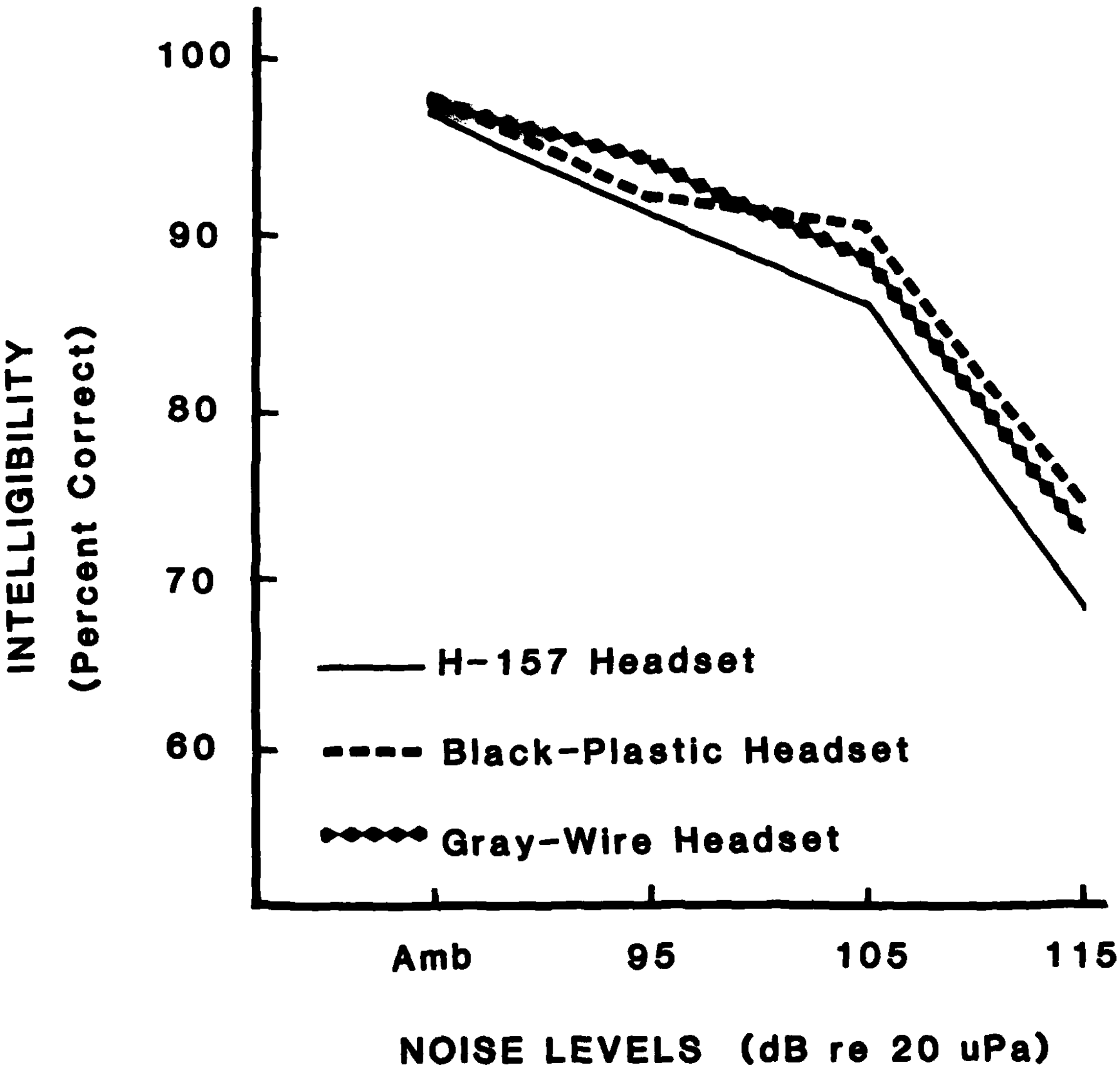

100
90
80
70
60
INTELLIGIBILITY
(Percent Correct)
H-157 Headset
Black-Plastic Headset
Gray-Wire Headset
Amb
95
105
115
NOISE LEVELS (dB re 20 uPa)

Figure 2

performance, as a consequence the data should be used for estimation purposes only because they are not sufficient to allow the results to be generalized to a larger population.

COMMENTS ON WEARABILITY

During investigations of hearing protection and word intelligibility performance in AFAMRL/BBA both experimenters and trained volunteers observe and report on various wearability factors of the personal equipment. No negative comments were received on discomfort features of any of the three headset devices. The black-plastic headset microphone mounting bracket created a problem by interfering with the ability to fully adjust the earcups of the headset. The gray-wire headband caused problems that resulted in difficulties in adjustment of the headset and also in slipping out of place again after an adjustment. The microphone hardware attachment assembly came apart frequently and easily making the unit unusable until it had been reattached. These wearability problems are minor inconveniences in the laboratory situation, but become major problems in the operational situation where the first priority is mission accomplishment.

CONCLUSIONS

The investigation of the hearing protection and speech intelligibility characteristics of the test headsets reveals that:

a. The H-157 headset provided slightly more attenuation than the black-plastic headset and considerably more than the gray-wire headset. particularly in the high frequency region.

b. Both the black-plastic and gray-wire headsets provided better word intelligibility than the H-157 headset. The black-plastic unit provided the best intelligibility in noise levels of 105 dB and 115 dB whereas the gray-wire headset provided the best intelligibility in the 95 dB noise.

c. The modified headsets provide better speech intelligibility and worse hearing protection in noise than the H-157 headset. Care must be taken when using these modified devices in high level and/or long duration noises to ensure that the amount of attenuation is adequate to prevent any adverse effects of noise exposure on hearing.

NOTE: Authority for Air Force personnel to use non-standard hearing protection and voice communications equipment in operational noise environments does not reside with the authors or in this laboratory.

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