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US Army Research Laboratory

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Human Research and Engineering Directorate, ARL

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14. ABSTRACT

Three communication-system configurations were evaluated for speech intelligibility (SI) when used with the Joint Service Aircrew Mask for Strategic Aircraft and the Intercommunication Unit in high (85 and 95 dBA) background noise. Each communication system was used with foam earplugs or additional over-the-ear hearing protection and worn in combination with the protective hood. The goal of this evaluation was to compare communication-system configurations at high noise levels and to determine if the MIL-STD-1472G specifications for minimally acceptable speech intelligibility were being met (SI score ≥ 75%). The average SI scores for one system exceeded the minimally acceptable requirement, with average scores of 96% and 93% in 85 dBA and 95 dBA, respectively. Results are discussed and recommendations are provided.

15. SUBJECT TERMS

speech intelligibility, protective mask, high noise, modified rhyme test, earplugs

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1. Introduction

The interior of aircraft, as well as proximity to aircraft or other military machinery, are often high-noise environments. High noise leads to 2 main challenges: 1) hearing protection and 2) effective speech communication. Additionally, the use of personal protective equipment, such as full-face respirators and associated protective ensembles, can add to the challenges of effective speech communication and effective use of hearing protection devices.

To address these challenges, a variety of communication systems and associated hearing protection devices can be implemented. The present evaluation examined 3 communication-system–hearing-protection configurations used with the Joint Service Aircrew Mask for Strategic Aircraft (JSAM SA) protective ensemble, under 2 levels of high noise, to assess the intelligibility of transmitted speech.

The JSAM SA is designed to integrate with applicable aircraft and aircrew systems, including but not limited to aircraft-mounted oxygen systems, portable aircrew systems, seating and restraint systems, Aviation Night-Vision Imaging System, and service survival vests. The JSAM SA is also designed to integrate with communication systems such as the Intercommunication Unit (ICU) Model 6015-1 or equivalent intercom unit. The ICU provides an integrated microphone capability without voice distortion that operates without breaking the seal of the mask. The ICU can be operated with various headsets or in-the-ear communication devices, and users may or may not simultaneously wear additional hearing protection. Insert hearing protection (e.g., foam earplugs) can be worn with headsets, while a headset itself can serve as additional hearing protection for an in-the-ear communication device. Because there are a variety of possible configurations of communications equipment that may be used with the JSAM SA, it is important to assess the speech intelligibility (SI) of different configurations under high levels of noise that users are likely to encounter.

To examine the performance of different configurations under high-noise conditions, SI measurements were conducted with 3 communication systems, all used with additional hearing protection, under 2 high-noise conditions (85- and 95-dBA pink noise[*]). This was done to determine if the JSAM SA performance specification's requirements (Joint Program Manager–Protection 2015) for SI were met in these configurations. The communication systems tested were the David Clark H10-76, the Bose AHX-20, and the Communication Enhancement and

[*] Noise whose intensity is inversely proportional to frequency over a specified range, to give constant energy per octave (as defined in *McGraw-Hill Dictionary of Scientific and Technical Terms,* 6th ed.).

Protection System (CEPS). 3M Co. E-A-R Classic foam earplugs have been approved for use in most legacy aircraft to improve noise attenuation and were used along with the H10-76 and AHX-20 headsets in this evaluation. The CEPS is an in-the-ear communication system and cannot simultaneously be worn with foam earplugs. To provide additional hearing protection for the CEPS, a David Clark H10-76 headset was worn on top but was not used to send communicative signals. In all conditions, the JSAM SA respirator was used with a production-representative XM69 mask, with the ICU in hardwire mode, and was worn with a protective hood.

The US Army Research Laboratory's (ARL's) Human Research and Engineering Directorate (HRED) at Aberdeen Proving Ground (APG), Maryland, completed the SI testing at the request of the JSAM SA Product Manager (PM). Modified rhyme testing was performed on the JSAM SA flight mask with these various communication and noise-level configurations, following the PM's test plan (Coyne et al. 2015). Approval of the test plan was obtained from the ARL Human Use Committee prior to the start of testing.

The Modified Rhyme Test (MRT) was completed at ARL–HRED's Environment for Auditory Research (EAR) facility in December 2015. MRT is a standardized word test recommended by the American National Standards Institute and Acoustical Society of America (ANSI/ASA 2009) for measuring the intelligibility of speech over communication systems.

2. Objective

The objective was to measure the SI of the JSAM SA–hood–ICU system under 2 noise levels and 3 typical configurations of communication and hearing-protection equipment. The goal was to determine if the US Department of Defense's specifications (MIL-STD-1472G 2012) for minimally acceptable speech intelligibility were being met (SI score $\geq$ 75%) under the tested noise conditions and to compare performance of the different communication-system configurations.

3. Methods

3.1 Equipment

3.1.1 Individual Protective Equipment

The full JSAM SA system, including mask, hood, and hose, were worn by the test participants (TPs) in all test conditions. The JSAM SA, shown in Fig. 1, is a respirator that provides individual aircrew members with "above the shoulder" head, eye, respiratory, and percutaneous protection against chemical and biological (CB) warfare agents. The JSAM SA integrates with the Joint Protective Aircrew Ensemble (JPACE) and the US Air Force (USAF) CWU-66/P "below the neck" CB-protective ensembles. The JSAM SA respirator was used with a production-representative XM69 mask.

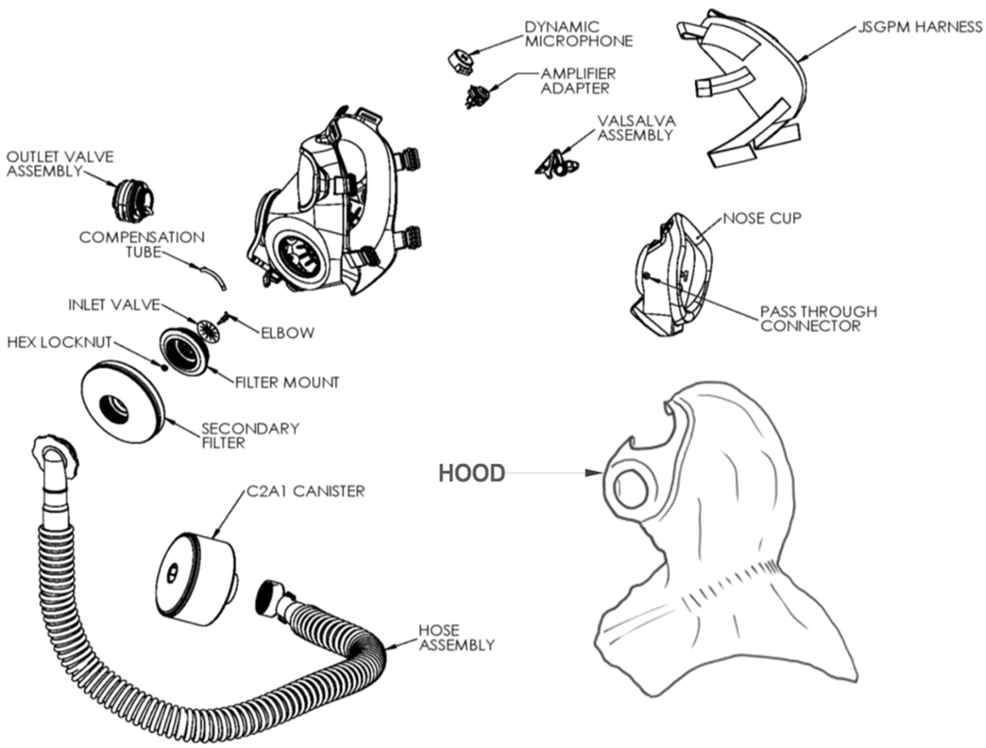

Fig. 1 Components of the CB-protective JSAM SA ensemble

3.1.2 Communication Devices

All TPs used the ICU, in hardwire mode, in all trials. While on the ground and not connected to aircraft communications systems, the ICU is used to enable communication while wearing the JSAM SA. Although the ICU can be operated in 3 modes (hardwire, talk/listen, and listen only; see Fig. 2), the test was conducted with the ICU in hardwire mode. Hardwire mode is intended to be used in high-noise environments. In the hardwire mode, 2 users plug into either side of the ICU. Sound is picked up via the microphones inside each mask and transmitted to each user's headset or CEPS.

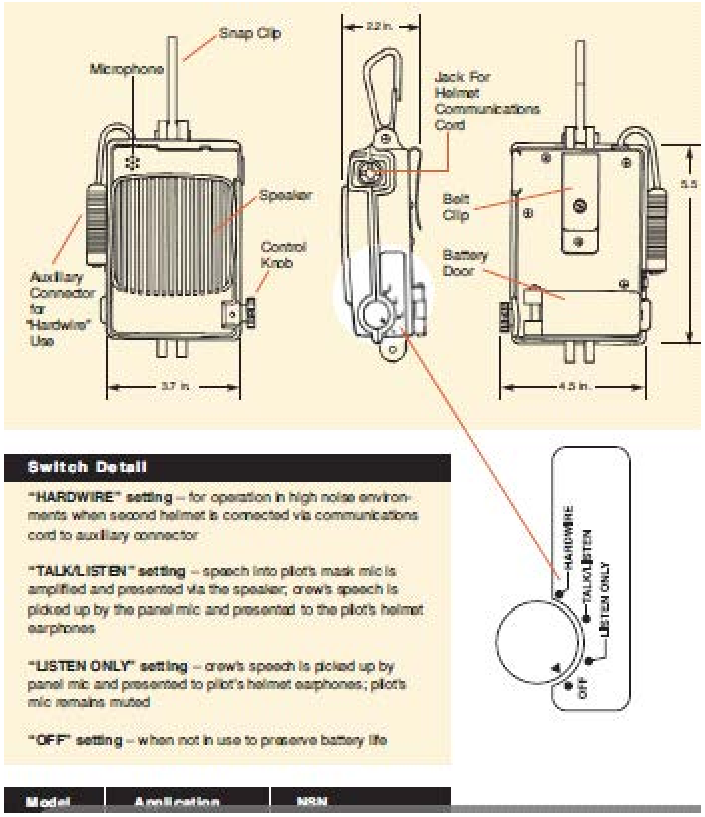

Fig. 2 ICU and (inset) switch settings for 3 communication modes

Communication headsets plug into the ICU and rest on top of the hood and mask assembly. They function both to attenuate environmental noise and to allow the user to hear communication from the other user. The sound passes through the hood material to the ears. Two legacy headset models were examined (Fig. 3a): David Clark H10-76 and Bose AHX-20. The H10-76 headset is a common headset used by USAF E-3C aircraft crews. The AHX-20 headset is used by US Navy P-8A aircraft crews. In-the-ear communication systems, such as the CEPS, plug into the ICU and terminate under the hood in soft foam inserts in the users' ear canals. This functions both to attenuate environmental noise and to allow the user to hear communication. One model of in-the-ear communication system was examined (Fig. 3b), the CEPS.

Fig. 3 a) Headsets, left to right: H10-76 and AHX-20; b) components of the in-the-ear CEPS

In noisy conditions, users often employ additional hearing protection devices (HPDs) for more sound attenuation. Our current investigation was to specifically test communications configurations under conditions where additional hearing protection is used. When wearing a headset, in-the-ear hearing protection such as foam earplugs may be worn under the hood fabric and under the communication headset's ear cups. The 3M Co. E-A-R Classic foam earplugs (shown in Fig. 4) have been approved for use in most aircraft and were used for this investigation. The JSAM SA and both legacy headsets were assessed while users wore foam earplugs under the JSAM SA hood. When wearing in-the-ear communications systems, additional sound attenuation can be provided by wearing an unplugged headset on top. The David Clark H10-76 (Fig. 3a) was used for this purpose with the CEPS in this investigation.

Fig. 4 3M Co. E-A-R Classic foam earplugs

3.1.3 Evaluation Environment

The evaluation was conducted in the Distance Hall of HRED's EAR facility (Fig. 5) at APG, Maryland. The Distance Hall is an acoustically treated space that meets Noise Criteria 15 (NC-15) specifications for a very low ambient noise floor. TPs were seated at the center of the room and surrounded by 8 Genelec 8030A loudspeakers. Pink noise was generated in MATLAB and played simultaneously through all 8 loudspeakers to yield 85 dBA or 95 dBA at the listener's head position, as measured without the TPs present. The noise level remained within 3 dBA of the target noise level when the TPs were present.

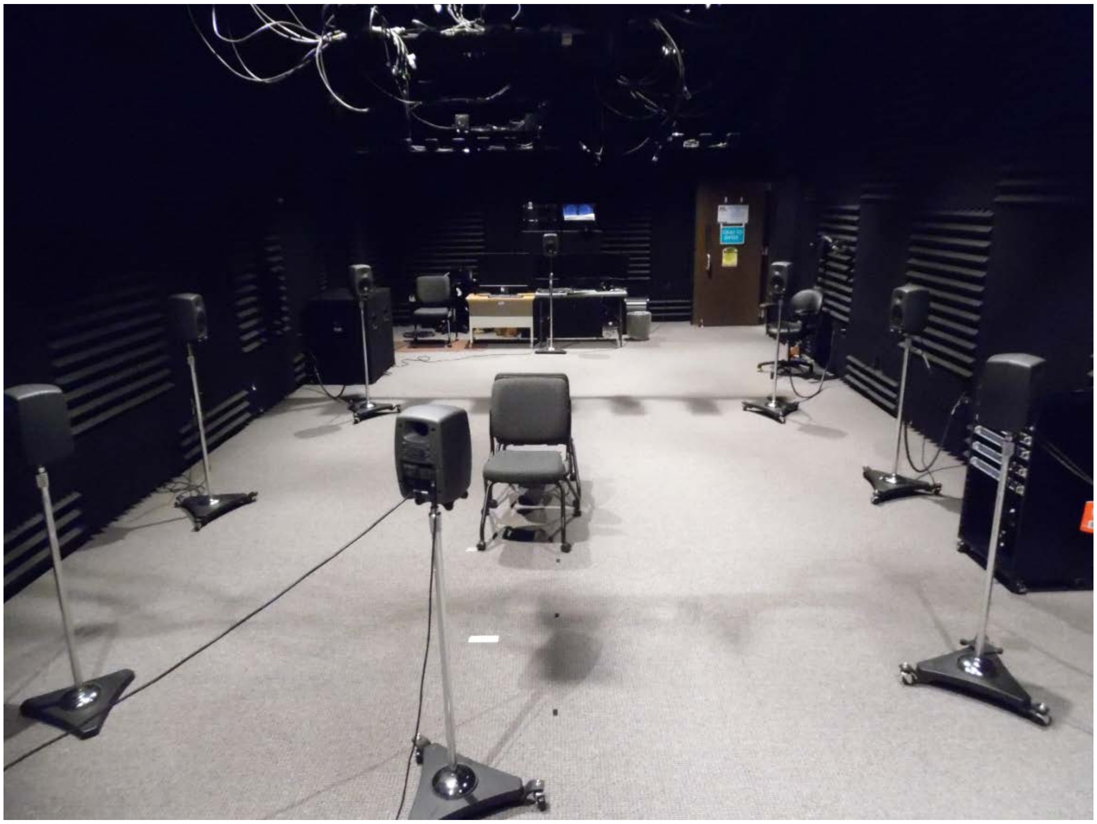

Fig. 5 ARL–HRED indoor EAR facility used to measure speech intelligibility performance

3.2 Test Participants

Eight TPs (4 male, 4 female) between the ages of 23 and 44 took part in this test. They were recruited from the military and civilian populations at APG and comprised 3 Airmen and 5 military-employed civilians. All 8 TPs had pure-tone hearing thresholds between –10 and 20 dB hearing level (HL) in both ears at all audiometric test frequencies: 125, 250, 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz. All TPs were native speakers of American English with no strong regional accents or dialects. No TPs had any signs of or reported any history of otologic problems.

3.3 Test Design

The goal of this evaluation was to investigate SI while TPs wore the JSAM SA using a hardwired ICU and 3 communication systems, each under 2 different background noise levels.

Six test configurations (shown in Table 1) were examined using a 3 × 2 design with 3 communication systems—David Clark H10-76, Bose AHX-20 with active noise reduction (ANR) on, and CEPS—and 2 background noise conditions: 85 dBA and

95 dBA. As per the PM's test plan, TPs were assigned to talker–listener pairs (one female–female pair, one male–male pair, one female–male pair, and one male–female pair). One talker–listener pair participated in the test at a time. To avoid fatigue, TPs alternated talking and listening roles at each trial. Each TP served as a talker for all 6 test configurations and served as a listener for all 6 test configurations, for a total of 12 trials for each TP. Configuration test order was counterbalanced, with the exception that all earplug trials were clustered (to avoid participants' discomfort of repeatedly removing hoods to remove and insert earplugs). A separate randomized word list was used for each trial, with no list ever used twice for the same talker–listener pair. Refer to Appendix A for the test-order matrix.

Table 1 Configuration matrix

Configuration no.	Communication system	Noise level (dBA)	Additional HPD
1	David Clark H10-76	85	Foam earplugs
2	Bose AHX-20 (ANR on)	85	Foam earplugs
3	David Clark H10-76	95	Foam earplugs
4	Bose AHX-20 (ANR on)	95	Foam earplugs
5	CEPS	85	H10-76 unplugged
6	CEPS	95	H10-76 unplugged

3.4 Procedure

Each TP first received a hearing screening to ensure he or she qualified for the test. ARL's Institutional Review Board ruled this evaluation did not constitute human research; thus, formal volunteer agreement affidavits were not required. Instead, the equipment test procedure was explained to each TP verbally. The TPs were informed they could quit the evaluation at any time with no penalties. After TPs gave verbal consent, they were sized and fitted for the JSAM SA by an expert member of the PM team. Once the TPs were fitted, they were trained in the donning and doffing of the mask. Aircrew-equipment experts were available to help assist in proper JSAM SA donning, doffing, and reconfiguration for the duration of test.

A brief training session familiarized TPs with all test materials and procedures, including proper speaking techniques. TPs were asked to read a sample list of MRT phrases and were guided on speaking rate and pronunciation. TPs practiced until they had proper cadence and pronunciation while maintaining a consistent voice level of 75–85 dBA without the mask (as per PM's test plan). The voice level was measured by a calibrated microphone connected to a visual-feedback sound level meter using the A-weighted, fast-response setting. The 75–85 dBA range without the mask (at a standard distance of 1 m) was found to be equivalent to 75–85 dBA with the mask at a distance of approximately 2 inches; so, participants were instructed to put on their masks, place their mask mouthpiece 2 inches from the calibrated microphone, and practice vocal effort levels until the desired voice level was reached (as indicated by the visual feedback, visible to TPs). TPs were then instructed to use the same level of vocal effort during the trials.

For the trials, TPs (talkers and listeners) inserted foam earplugs or CEPS (as appropriate for the trial) and then donned the full JSAM SA system. Talker–listener pairs were then seated back-to-back with the ICU hardwired at a maximum distance of 3 ft (shown in Figs. 6 and 7). The ICU was worn on one TP’s vest or was placed on a chair beside them (Figs. 8 and 9). The appropriate headset model was then placed on the TP pair’s heads. Both members of the pair used the same communication system at the same time. Each TP was handed a pen and a clipboard containing talker word lists and listener answer sheets.

Fig. 6 Front view of TP configuration

Fig. 7 Side view of TP configuration

Fig. 8 ICU worn on the vest

Fig. 9 ICU placed on the chair

Pink noise was then turned on in the background (85 dBA or 95 dBA, as appropriate for the trial), and the sound levels were confirmed using a calibrated sound level meter held at the position of the listener's head. When the TPs signaled they were ready, the test began. Within a test configuration, each partner served as a talker for one word list and as a listener for another word list. The talker read aloud 50 stimulus words to the listener, with each stimulus word spoken within the carrier phrase "Mark the ________ again." Talkers used preprinted randomized lists of MRT words (refer to Appendix B) to read during each trial. Listeners were presented with 6 possible answers for each stimulus word (refer to Appendix C) and were instructed to select on the preprinted sheet the word they perceived to be spoken by the talkers. Once the list was completed, the members of the pair switched roles. Using the next sheets on their clipboards, the new talker read a new MRT list and the new listener marked his/her answers on a fresh answer sheet.

After 4 trials in one communication system, TPs performed 4 trials in the next system and then 4 trials in the next. Between the CEPS and headset trials, TPs removed their JSAM SA hoods and masks, replaced their CEPS ear inserts with foam ear plugs (or vice versa, as appropriate for the trial), re-donned the JSAM system, and performed the remaining trials. TPs were allowed to take breaks whenever they wished during the evaluation. Completed word lists and answer sheets were collected after every trial.

In 3 instances, TPs accidentally saw a word list too early or experienced an equipment malfunction at the beginning of a trial. In those cases, the trial was started over and performed using a new randomized MRT word list, and the data from the false-start trial were excluded from the analysis.

3.5 Data Analysis

The MRT answer sheets filled out by the listeners were scored by comparison with the associated MRT word lists. The number of responses correct, incorrect, and omitted were tallied.

SI scores were then computed as percent correct, adjusted for guessing. The following equation was used to adjust for guessing:

$$Score = 2(R - \frac{W}{n-1}) \quad , \tag{1}$$

where

Score = Percent correct (adjusted for guessing)

R = Number correct

W = Number incorrect

n = 6 (number of choices available to listener per MRT item).

As per the PM's test plan, averages of adjusted MRT scores were calculated. Averages (arithmetic means) were calculated for each configuration, each communication system, and each background noise condition.

A series of paired-samples t-tests were used to compare conditions. To compare the communication systems, first the differences between paired system configurations were calculated and subjected to a Shapiro–Wilk test of normality. None of the distributions significantly differed from normal, so parametric statistics were used. Paired-samples t-tests were conducted using all data and also within each background noise condition separately.

4. Results

All MRT data presented in this report have been adjusted for guessing, as described in Section 3.5. MRT scores (adjusted for guessing) ranged from 28 to 100 (mean = 71.4, standard deviation = 21.9).

Average scores are presented in Table 2 for each communication system and background noise level. TPs were wearing the XM-69–JSAM SA mask system in every condition. Under both of the noise conditions investigated here, the CEPS's average score exceeded 75%. Under the 85 dBA condition, the David Clark H10-76's average score came close to 75%.

Table 2 SI test results (average adjusted MRT scores) for all configurations

Configurations	MRT score in 85 dBA	MRT score in 95 dBA	Average MRT score
David Clark H10-76 with foam earplugs	74.2 (N = 8)	51.4 (N = 8)	62.8 (N = 16)
Bose AHX-20 with foam earplugs	68.5 (N = 8)	45.4 (N = 8)	57.0 (N = 16)
CEPS w/David Clark H10-76 as added hearing protection	95.8 (N = 8)	93.1 (N = 8)	94.5 (N = 16)
All of the communication systems	79.5 (N = 24)	63.3 (N = 24)	71.4 (N = 48)

Note: N is the number of data points in each condition.

Paired-samples t-tests revealed significant SI differences among communication systems. In both 85- and 95-dBA background noise, the CEPS system yielded the highest MRT scores, significantly higher than both the H10-76 and the AHX-20. (In 85 dBA, CEPS versus H10-76: t(7) = 6.42, $p < 0.001$, and CEPS versus AHX-20: t(7) = 9.08, $p < 0.001$. In 95 dBA, CEPS versus H10-76: t(7) = 6.80, $p < 0.001$, and CEPS versus AHX-20: t(7) = 9.14, $p < 0.001$.) The CEPS outscored the other systems whether or not the noise levels were pooled for analysis (with pooled data, CEPS versus H10-76: t(15) = 7.43, $p < 0.001$, and CEPS versus AHX-20: t(15) = 9.56, $p < 0.001$).

The H10-76 significantly scored higher than the AHX-20 when both noise levels were pooled (H10-76 versus AHX-20: t(15) = 2.15, $p = 0.048$), but average numeric differences were small—approximately 5%–6%—and the difference was not statistically significant when the noise levels were examined separately.

Average scores for the 6 configurations, along with confidence intervals, are shown in Fig. 10.

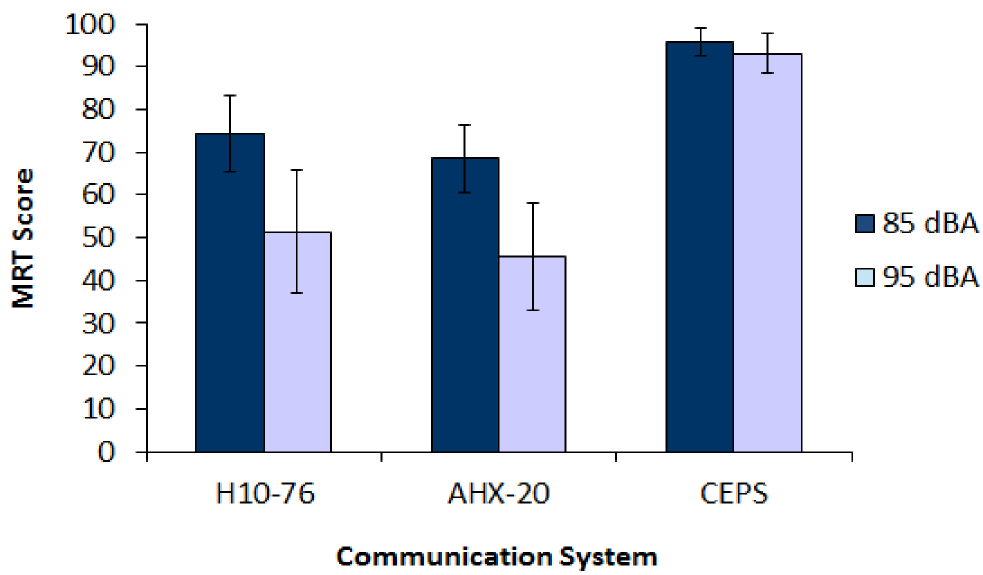

Fig. 10 Average MRT scores for each configuration, +/– 95% confidence interval

5. Discussion

Military environments are often high-noise environments. Being inside or near military aircraft, ground vehicles, or other machinery can pose a communication challenge and a risk of hearing damage. When communications equipment and additional hearing protection are used in high-noise settings, it is important to understand how well the equipment can deliver intelligible speech communication under those conditions.

Communication systems are required in military aircraft, both to reduce noise exposure and to provide communication capabilities. These systems may take the form of the traditional legacy headset, an over-the-ear device that sits outside the JSAM SA hood. These systems may also take the form of in-the-ear devices that rest in the ear canal under the JSAM SA hood. In high-noise environments, additional hearing protection is often desired and may take the form of foam earplugs (if used with an over-the-ear headset communication system) or may take the form of a headset (if used with in-the-ear communication systems). The question this investigation aimed to answer: How well do these added-HPD configurations transmit speech under high-noise conditions?

The current investigation explored SI in a high-noise environment with concomitant use of additional hearing protection. Three communication systems were investigated. Under the test conditions, the CEPS far outperformed the other systems that were investigated. The SI differences were substantial. In 85 dBA, TPs scored on average 22 percentage points higher with CEPS than with H10-76 and 27 percentage points higher with CEPS than with AHX-20. The differences were even greater in 95 dBA. In 95 dBA, TPs scored on average 42 percentage points higher with CEPS than with H10-76 and 48 percentage points higher with CEPS than with AHX-20. These differences are large and represent much stronger SI with CEPS than with the alternatives examined here under these test conditions. A plausible reason for this difference is the relative location of the added HPDs with respect to the incoming speech sounds. In the CEPS configuration, the added HPD rests outside the ears, with the speech sounds being delivered directly to the protected ear canals by the CEPS. In the H10-76 and AHX-20 conditions, the added HPD rests inside the ear canals, with the speech sounds being delivered externally from the circumaural headsets. In the H10-76 and AHX-20 configurations, the speech sounds must travel past the in-the-ear foam earplugs, which likely attenuates the signal. However, without experimental testing it would not be known whether the design specifications and typical use of the headset configurations could overcome this disadvantage. Our results suggest they do not: The CEPS configuration yielded the highest SI under our test conditions. The CEPS scores were also high in absolute terms—over 95% and 93% in 85 and 95 dBA, respectively. For high-noise conditions in which additional HPDs are required, we would thus recommend using the CEPS or a similar in-the-ear system if feasible.

6. Conclusions

This evaluation assessed SI performance of the JSAM SA ensemble in operationally representative configurations using legacy headsets and CEPS devices in a high-noise environment. A comparison of 3 communication systems in 2 different noise levels was conducted using the MRT. Measurements were collected on the JSAM SA system worn with communication systems, additional hearing protection, and the ICU, in 85- and 95-dBA background noise. The aim was to determine if JSAM SA Performance Specification requirements were met and to compare communication systems. The MRT results showed substantial differences among communication systems, with the CEPS system yielding significantly higher SI scores than the other tested systems. This was true under both noise conditions. Average SI scores met MIL-STD-1472G specifications for minimally acceptable SI (SI score of 75%) only with the CEPS. However, the H10-76 came close under the 85-dBA condition.

7. References

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Appendix A. Test-Order Matrix

This appendix appears in its original form, without editorial change.

Trial no.	Comms system	Hearing protection	Noise level	Talker	Listener	Word list
		Group 5				
1	HX-20, ANR on	Foam earplugs	85	I	J	15
2	HX-20, ANR on	Foam earplugs	85	J	I	16
3	HX-20, ANR on	Foam earplugs	95	I	J	17
4	HX-20, ANR on	Foam earplugs	95	J	I	18
5	H10-76	Foam earplugs	85	I	J	19
6	H10-76	Foam earplugs	85	J	I	20
7	H10-76	Foam earplugs	95	I	J	21
8	H10-76	Foam earplugs	95	J	I	22
9	CEPS	H10-76 headset	85	I	J	23
10	CEPS	H10-76 headset	85	J	I	24
11	CEPS	H10-76 headset	95	I	J	25
12	CEPS	H10-76 headset	95	J	I	26
		Group 6				
13	H10-76	Foam earplugs	95	K	L	16
14	H10-76	Foam earplugs	95	L	K	17
15	H10-76	Foam earplugs	85	K	L	15
16	H10-76	Foam earplugs	85	L	K	18
17	HX-20, ANR on	Foam earplugs	95	K	L	23
18	HX-20, ANR on	Foam earplugs	95	L	K	25
19	HX-20, ANR on	Foam earplugs	85	K	L	24
20	HX-20, ANR on	Foam earplugs	85	L	K	26
21	CEPS	H10-76 headset	95	K	L	22
22	CEPS	H10-76 headset	95	L	K	21
23	CEPS	H10-76 headset	85	K	L	20
24	CEPS	H10-76 headset	85	L	K	19
		Group 7				
25	CEPS	H10-76 headset	85	M	N	17
26	CEPS	H10-76 headset	85	N	M	18
27	CEPS	H10-76 headset	95	M	N	16
28	CEPS	H10-76 headset	95	N	M	15
29	HX-20, ANR on	Foam earplugs	85	M	N	23
30	HX-20, ANR on	Foam earplugs	85	N	M	25
31	HX-20, ANR on	Foam earplugs	95	M	N	19
32	HX-20, ANR on	Foam earplugs	95	N	M	22
33	H10-76	Foam earplugs	85	M	N	21
34	H10-76	Foam earplugs	85	N	M	26
35	H10-76	Foam earplugs	95	M	N	20
36	H10-76	Foam earplugs	95	N	M	24
		Group 8				
37	CEPS	H10-76 headset	95	O	P	23
38	CEPS	H10-76 headset	95	P	O	17
39	CEPS	H10-76 headset	85	O	P	22
40	CEPS	H10-76 headset	85	P	O	15
41	H10-76	Foam earplugs	95	O	P	26
42	H10-76	Foam earplugs	95	P	O	25

Trial no.	Comms system	Hearing protection	Noise level	Talker	Listener	Word list
43	H10-76	Foam earplugs	85	O	P	24
44	H10-76	Foam earplugs	85	P	O	16
45	HX-20, ANR on	Foam earplugs	95	O	P	20
46	HX-20, ANR on	Foam earplugs	95	P	O	21
47	HX-20, ANR on	foam earplugs	85	O	P	18
48	HX-20, ANR on	Foam earplugs	85	P	O	19

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Appendix B. Modified Rhyme Test (MRT) Answer Sheet for Listener

This appendix appears in its original form, without editorial change.

Start Time ___________ Subject ID ___________

Device Type _________ **Listener MRT Answer Sheet** List Number ___________

Earplugs Yes / No Today's Date _________

1	bat	bad	back	bass	ban	bath
2	bean	beach	beat	beam	bead	beak
3	bub	bus	but	buff	buck	bug
4	came	cape	cane	cake	cave	case
5	cut	cub	cuff	cup	cud	cuss
6	dig	dip	did	dim	dill	din
7	duck	dud	dung	dub	dug	dun
8	fill	fig	fin	fizz	fib	fit
9	hear	heath	heal	heave	heat	heap
10	kick	king	kid	kit	kin	kill
11	late	lake	lay	lace	lane	lame
12	map	mat	math	man	mass	mad
13	page	pane	pace	pay	pale	pave
14	pass	pat	pack	pad	path	pan
15	peace	peas	peak	peal	peat	peach
16	pill	pick	pip	pig	pin	pit
17	pun	puff	pup	puck	pus	pub
18	rave	rake	race	rate	raze	ray
19	sake	sale	save	sane	safe	same
20	sad	sass	sag	sack	sap	sat
21	seep	seen	seethe	seed	seem	seek
22	sing	sit	sin	sip	sick	sill
23	sud	sum	sub	sun	sup	sung
24	tab	tan	tam	tang	tack	tap
25	teach	tier	tease	teal	team	teak
26	led	shed	red	bed	fed	wed
27	sold	told	hold	fold	gold	cold
28	dig	wig	big	rig	pig	fig
29	kick	lick	sick	pick	wick	tick
30	book	took	shook	cook	hook	look
31	hark	dark	mark	lark	park	bark
32	gale	male	tale	bale	sale	pale
33	peel	reel	feel	heel	keel	eel
34	will	hill	kill	till	fill	bill
35	foil	coil	boil	oil	toil	soil
36	fame	same	came	name	tame	game
37	ten	pen	den	hen	then	men
38	pin	sin	tin	win	din	fin
39	sun	nun	gun	fun	bun	run
40	rang	fang	gang	bang	sang	hang
41	tent	bent	went	dent	rent	sent
42	sip	rip	tip	dip	hip	lip
43	top	hop	pop	cop	mop	shop
44	meat	feat	heat	seat	beat	neat
45	kit	bit	fit	sit	wit	hit
46	hot	got	not	pot	lot	tot
47	nest	vest	west	test	best	rest
48	bust	just	rust	must	gust	dust
49	raw	paw	law	jaw	thaw	saw
50	way	may	say	gay	day	pay

Appendix C. Example of Modified Rhyme Test (MRT) Phrase List for Talker

This appendix appears in its original form, without editorial change.

Start Time __________ **LIST 1** Talker ID ___________

Device Type ________ List Number ___1___

Earplugs _Yes / No_ Today's Date _________

Talker MRT Phrase List

1. Mark the bad again.
2. Mark the bean again.
3. Mark the bus again.
4. Mark the cake again.
5. Mark the cuff again.
6. Mark the did again.
7. Mark the duck again.
8. Mark the fit again.
9. Mark the heal again.
10. Mark the king again.
11. Mark the lake again.
12. Mark the mass again.
13. Mark the pane again.
14. Mark the pack again.
15. Mark the peak again.
16. Mark the pip again.
17. Mark the pub again.
18. Mark the raze again.
19. Mark the sale again.
20. Mark the sat again.
21. Mark the seed again.
22. Mark the sick again.
23. Mark the sum again.
24. Mark the tan again.
25. Mark the teak again.
26. Mark the shed again.
27. Mark the gold again.
28. Mark the dig again.
29. Mark the sick again.
30. Mark the shook again.
31. Mark the dark again.
32. Mark the gale again.
33. Mark the reel again.
34. Mark the bill again.
35. Mark the toil again.
36. Mark the name again.
37. Mark the pen again.
38. Mark the fin again.
39. Mark the gun again.
40. Mark the rang again.
41. Mark the went again.
42. Mark the lip again.
43. Mark the mop again.
44. Mark the meat again.
45. Mark the sit again.
46. Mark the got again.
47. Mark the test again.
48. Mark the dust again.
49. Mark the jaw again.
50. Mark the pay again.

List of Symbols, Abbreviations, and Acronyms

ANR	active noise reduction
APG	Aberdeen Proving Ground
ARL	US Army Research Laboratory
CB	chemical and biological
CEPS	Communication Enhancement and Protection System
Comms	Communications
dBA	decibels (A-weighted)
EAR	Environment for Auditory Research
HL	hearing level
HPD	hearing protection device
HRED	Human Research and Engineering Directorate
ICU	Intercommunication Unit
JPACE	Joint Protective Aircrew Ensemble
JSAM SA	Joint Service Aircrew Mask for Strategic Aircraft
MRT	Modified Rhyme Test
PM	Product Manager
SI	speech intelligibility
TP	test participant
USAF	US Air Force

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