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Speech Intelligibility and Hearing Protector Selection

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14. ABSTRACT
This report provides a summary of speech intelligibility research and offers guidelines for selecting hearing protection based on speech intelligibility. MIL-STD-1472G (11Jan2012) Department of Defense Design Criteria Standard Human Engineering provides the basis for the guidelines using the Modified Rhyme Test and the Articulation Index.

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Introduction

In an effort to alleviate the harmful effects of noise on hearing, hearing protection devices (HPDs) are commonly used to reduce sound exposure. Passive linear HPDs attenuate necessary sounds, such as speech and warning signals, at the same rate as the unwanted sounds. Active HPDs and Tactical Communications and Protective Systems (TCAPS) are designed to attenuate unwanted sounds, such as weapons fire, while allowing situational awareness to be maintained. The use of TCAPS is growing but standard passive HPDs are the primary focus of this report. However, the recommendations should be applicable to all HPDs, including TCAPS.

Commonly, attenuation and comfort are the major criteria used in selecting an HPD for a given noise environment (Oregon OSHA, 2014). However, the proper selection of HPDs is important not only to prevent hearing loss, but also to minimize the loss of necessary information. The goal of this report is to recommend a speech intelligibility based criteria for hearing protector selection, which will take into account the noise environment and the hearing acuity and needed vocabulary of the wearer. For example, if a potentially large vocabulary must be communicated, then a higher level of speech intelligibility will be required versus a limited or closed set vocabulary.

Importance of the problem

The discrimination of speech is one of the most important functions of the human auditory system (Suter, 1989a). Therefore, speech interference is a particularly bothersome effect of a noisy environment. However, at high noise levels, problems with speech communication are not the only concern. Exposure to loud noise for short periods of time can cause the ear to desensitize (Rossing, 1990; Kryter, 1985; Chung, 1983). This desensitization is usually most prominent in frequencies around 4000 Hz. As long as the exposure is short or limited and the noise level is not too intense, the hearing threshold will eventually return to its original level. The time it takes for hearing to return to pre-exposure threshold level can vary from a few hours to several weeks (Miller, 1974). This is known as temporary threshold shift (TTS). If, however, the stimulus continues or is frequently repeated, a permanent threshold shift (PTS) can occur.

Noise induced hearing loss (NIHL) is the most common type of acquired hearing impairment other hearing loss due to aging, or presbycusis (Royster, 1996; Mills, 1992). NIHL is often characterized by a ringing in the ears, known as tinnitus, and by difficulty understanding speech (Axelsson and Barrenas, 1992). Tinnitus and noise induced hearing loss are the two most prevalent disabilities for individuals that have served in the military (Department of Veterans Affairs, 2012). Additionally, noise induced hearing loss is detrimental to military readiness, soldier effectiveness, and unit morale. Susceptibility to NIHL can vary substantially from individual to individual but it is usually preventable.

When exposure to excessive sound levels cannot be avoided, the use of personal HPDs can reduce the sound level entering the middle ear to a level which will not cause NIHL (Berger, 1988). However, care must be taken to ensure that the HPD does not reduce the sound level too much (Abel et al., 1982). Providing an HPD with too much attenuation is known as overprotection, and in certain conditions where situational awareness is paramount, overprotection can be just as hazardous as the providing of too little attenuation, or under-protection (Michael, 1991).

An HPD with a high level of attenuation can greatly reduce the risk to the hearing mechanism but the decreased situational awareness could increase the risk of accident or injury by creating an inability to hear important speech or warning signals. The reduction of speech intelligibility due to wearing HPDs primarily occurs in listeners with impaired hearing (Lindemann, 1976; Bauman and Marston, 1986; Chung and Gannon, 1979; Abel et al., 1982), but the effect can be seen at low and moderate noise levels even with normal hearing listeners because of the reduced audibility of important consonant speech cues (Suter, 1989).

Background

Noise, defined by Kryter (1994) as an "audible acoustic energy (or sound) that is unwanted because it has adverse auditory and nonauditory physiological or psychological effects on people," is prevalent in many military operations. As stated previously, noise induced hearing injuries, including tinnitus, are currently the two most prevalent service connected disabilities. The technical term for NIHL is noise induced permanent threshold shift (NIPTS) (Royster, 1996). The amount of NIPTS experienced by a given individual is dependent upon that person's unique susceptibility as well as the nature of the noise, including the overall sound pressure level, frequency spectrum, and length of exposure (Ashkinaze and Kramer, 1991). There are two types of NIPTS: acoustic trauma and gradually developing, or chronic, noise induced hearing loss.

Acoustic trauma refers to permanent cochlear damage resulting immediately from a single exposure to very high sound pressure levels. These injuries often occur following explosions, gunfire, or other blast-related events. In contrast to acoustic trauma, which is sudden and associated with a particular noise event, chronic NIHL develops gradually over months and years of repeated exposure. Noise levels below those necessary to cause acoustic trauma can cause dysfunction of the sensory hair cells in the inner ear if the noise exposure is repeated often enough or continued for a long enough time (Royster, 1996).

Chronic NIHL typically first affects the hearing thresholds in the high frequency region, usually 3000 to 6000 Hz. If noise exposures continue, the loss will increase at the higher frequencies and spread to the lower frequencies (National Institute of Health [NIH], 2014). A plot of the threshold level at each frequency is called an audiogram. The classical example of chronic NIHL results in an audiogram with a high frequency notch. The notch is centered around 4000 Hz, with better thresholds at adjacent frequencies as in Figure 1.

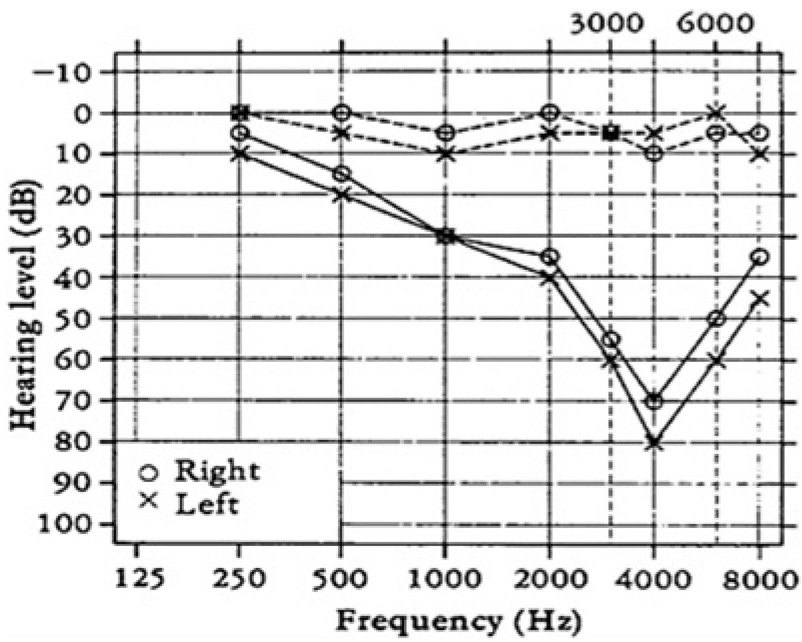

Figure 1. Example of a chronic NIHL audiogram. Note the notch at 4000 Hz.

Several factors contribute to the development of a high frequency notch from exposure to broadband noise. First, the shape of the outer ear, or pinna, and the resonances of the ear canal amplify the amount of energy reaching the cochlea in the region of 2000 to 4000 Hz. Second, the acoustic reflex of the middle ear reduces the amount of energy at and below 500 Hz that reaches the cochlea. Finally, in most cases, the frequency maximally damaged by noise is about one-half octave to one octave above the maximum exposure frequency. For broadband noise and average anatomy, the noise is filtered by the ear to produce maximum levels at about 3000 Hz, adding a half octave places the maximum loss around 4500 Hz (Royster, 1996).

NIHL symptoms

Because it begins slowly, and is typically limited to high frequencies, affected individuals may not realize they are suffering from a progressive hearing loss until speech understanding begins to deteriorate, especially in a noisy environment, or until an audiogram is measured. However, there are several symptoms that accompany NIPTS. These symptoms are tinnitus, recruitment, and distortion.

Tinnitus is a persistent ringing or noisy sound in the ear that is often very disturbing and bothersome to individuals suffering from this condition. Although it is occasionally experienced in mild forms by people with normal hearing, it is associated in its acute forms with sensorineural hearing loss, including NIHL.

Recruitment is an abnormal growth of loudness as a function of intensity. This abnormal loudness growth has been shown to be a symptom of most hearing losses that are caused by damage to the sensory cells of the inner ear and is more likely demonstrated in the higher frequencies than in the lower frequencies (Martin, 1997). Subjects with recruitment may not be able to hear very faint sounds, but sounds of high intensity are just as loud as for a normal hearing listener. However, due to distortion, sounds that are easily audible may not be easily intelligible (Moore, 1989).

Plomp (1978) divides hearing loss into two classes: Class A, for attenuation, and Class D, for distortion. Individuals with a Class D hearing loss often complain, “I can hear you speaking, but I can’t understand what you are saying.” Class A listeners have a difficult time hearing at low speech and noise levels, but their hearing acuity approaches that of listeners with normal hearing at high speech levels, even in noisy environments. Individuals of Class D have minor difficulties in low noise, but have a great deal of difficulty communicating in high levels of speech and noise. Many hearing losses are a combination of both Class A and Class D impairments. Plomp went on to find that most hearing impaired listeners appear to need a more favorable speech-to-noise ratio than do normal listeners. A person with a hearing impairment that is purely of Class D needs a ratio that is 10 dB more favorable than that required by normal listeners.

Masking

Masking is the upward shift in hearing threshold of a sound due to the presence of noise or another sound (Sonn, 1969). Masking can be most easily understood by considering the way pure tones excite the basilar membrane. High frequency tones excite the basilar membrane near the oval window, while tones of low-frequency cause maximum excitation near the apical end. Pure tone excitation creates a tail on the membrane, which extends toward the high frequency end as shown in Figure 2. Therefore, a tone of higher frequency is easier to mask than one of lower frequency. As the intensity of the masking tone, or masker, increases, more of its tail is of sufficient amplitude to mask higher frequency tones (Rossing, 1990). The degree to which the upward spread of masking affects the speech discrimination ability of the hearing impaired varies greatly and is not closely linked to the degree of hearing loss (Martin and Pickett, 1970).

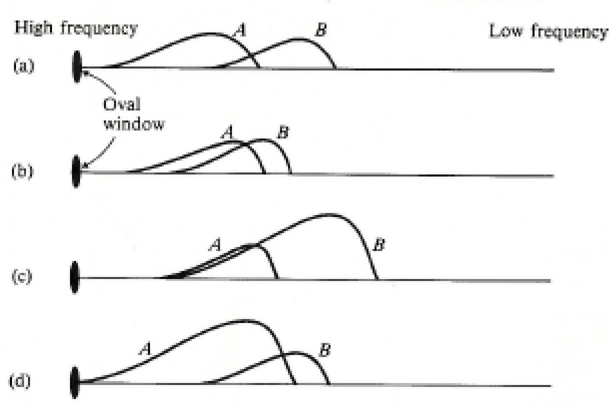

Figure 2. Simplified response of the basilar membrane for two pure tones A and B. (a) Little masking occurs since excitations barely overlap. (b) Overlap occurs; tone B masks tone A more than tone A masks tone B. (c) The more intense tone B almost completely masks the higher frequency tone A. (d) The more intense tone A does not completely mask the lower frequency tone B. (From Rossing, 1990)

The acoustic waveform of a speech signal contains information that is highly redundant (Matthei and Roeper, 1983). Noise, which is found in most environments that communication takes place, has the effect of reducing this naturally occurring redundancy. When the listener suffers from a hearing loss, the redundancy is reduced further. Depending on the degree of hearing loss and the level of the competing noise, the communication may be perceived correctly, partly, completely misunderstood, or not perceived at all. The consequences of missed communication can range from being mildly annoying to being catastrophic (Suter, 1989b).

Speech sounds are called phonemes. These phonemes can be divided into two groups, vowels and consonants. Vowel sounds tend to have a high energy concentration that is located in the mid-frequency range of about 300 to 3000 Hz, whereas consonants tend to be of high frequency, 2500 to 6000 Hz in the case of some fricatives and have a low concentration of energy (Kent and Read, 2002). Thus the acoustical characteristics of consonants, high frequency and low energy, causes them to be easily missed by those individuals with NIHL. Because consonants also contribute most of the intelligibility to speech, NIHL is very effective in degrading speech discrimination ability (Suter, 1989b).

Since it is the higher frequencies of hearing that are most adversely affected by NIHL, the higher order auditory system receives a signal that has been effectively low-pass filtered. Levitt (1982) showed that for an individual with a mild hearing impairment most of the lower energy consonants will be just audible or completely inaudible. This effect is maximized when these phonemes occur in the final position of a word where the intensity will be lower. This missed information greatly reduces speech understanding.

Hearing Protection Devices (HPDs)

The best way to avoid the adverse effects of NIHL is to shun exposure to loud noise. Unfortunately, this is not possible in many Military Occupational Specialties (MOSs). The use of HPDs can reduce the intensity of sound reaching the tympanic membrane, or eardrum, to a level that will not damage the auditory system. The most commonly used types of HPDs are: earmuffs, which seal against the head and around the ear; earplugs, which seal against the walls of the ear canal; and semi-aural devices, which form a seal at the entrance of the external ear canal. These types of devices can be active, usually meaning there is electronic circuitry involved, or passive.

Earmuff type hearing protectors usually consist of a hard plastic cup that surrounds the ear. The cup is lined with acoustic material and foam, fluid, or gel filled pads form the interface between the cup and the head of the wearer (Berger, 1988). The amount of attenuation that earmuffs provide is dependent upon factors such as the size of the cup surrounding the ear, the material composition of the cup, the type of acoustic material found inside the cup, and the efficacy of the seal the cup makes with the head.

An advantage of an earmuff type HPD is the attenuation is usually more consistent among wearers than are earplugs or semi-aural devices. Also, earmuffs are easily fitted to heads of most individuals and are hard to misplace. However, earmuffs may be uncomfortable in hot environments. Other disadvantages of earmuffs include the possible loss of attenuation due to wearing eyeglasses or earrings and the increased cost of earmuffs over most earplugs and semi-aural devices (Berger, 1980; Michael, 1991).

Earplug type HPDs come in a variety of shapes and sizes, and are usually made from materials that will retain size and flexibility over long periods of time (Michael, 1991). There are several types of earplugs including pre-molded, formable, and custom-molded (Wilson, 1989), all of which are designed to fit inside the ear-canal. Since ear canals vary widely in shape and size, care must be taken to insure that the plug forms a tight seal in the ear canal. The lack of an adequate seal will compromise the effectiveness of the plug, and could put the hearing of the wearer at risk (Berger, 1980).

Semi-aural devices, which provide a compromise between earplugs and earmuffs, usually consist of a pair of soft cones attached to a lightweight headband. The cones make a direct seal at the ear canal entrance and are easily removed and replaced. The attenuation of semi-aural devices varies depending on the material composition and shape of the cones, but the devices that partially enter the ear canal provide the best performance (Berger, 1988).

An advantage of insert-type HPDs, which includes both earplugs and semi-aural devices, is they are small which makes them easy to carry. Also, head protection, eyeglasses, and earrings do not interfere with performance. Further, inserts do not restrict the movement of the head when space is limited. However, it takes more time and effort to properly fit insert-type HPDs compared to earmuffs. Also, dirt may be inserted into the ear canal if earplugs are applied with soiled hands (Michael, 1991).

One of the primary concerns regarding the use of hearing protectors is the effect on verbal communication. Many would-be hearing protector users fear the noise reduction due to the HPD will block out sounds and voices, which are essential for job performance or mission completion (Sataloff et al., 2006). This seems like a reasonable objection, but research has demonstrated proof to the contrary. The wearing of hearing protectors in noise exceeding 85 dB has actually been shown to improve speech intelligibility, compared to the speech intelligibility in the same conditions without hearing protection, for listeners with normal hearing (Kryter, 1946; Lindemann, 1976; Chung and Gannon, 1979).

Passive HPDs attenuate noise and desired signals equally with respect to frequency. This means that at any one frequency the signal to noise ratio under the protector will be the same as the signal to noise ratio in the environment, since both signal and noise are attenuated the same amount. However, the attenuation of hearing protectors is frequency dependent. Generally, the high frequencies are attenuated more than the low frequencies, so that the spectrum of the sound reaching the ear will be distorted compared to the sound environment. Since most of the energy in an acoustic speech signal is concentrated at or below 2 kHz, hearing protectors will attenuate high frequency noise and seem to “let the speech through.” This effect is predominant in a noise environment with a large high frequency energy concentration (Berger, 1988).

Usually, the primary cause for the improvement in speech intelligibility that HPDs offer people with normal hearing in high levels of noise is due to the overall reduction in the sound level that reaches the ear. The HPD reduces the sound to a level that allows the inner ear to function without distortion. This distortion-free operation is certain only at levels well below 90 dB(A) (Lawrence and Yantis, 1956). Berger (1988) likens this effect to the wearing of sunglasses on a very bright day. He states that “since the total illumination of the scene is reduced, the eye is allowed to function more effectively and in a more relaxed manner.” The HPD is effectively reducing the “acoustical glare” of high level sounds.

People with impaired hearing do not experience the same increase in speech intelligibility that individuals with normal hearing experience. Lindemann (1976) showed that the wearing of HPDs had a detrimental effect on speech intelligibility in high levels of noise for listeners with NIHL. The results of Chung and Gannon (1979) showed a similar result. While listeners with normal hearing showed improved intelligibility scores while wearing HPDs, the hearing impaired listeners performed more poorly with HPDs than without. The selection of HPDs is therefore important in keeping the loss of speech intelligibility for hearing impaired listeners to a minimum.

The wearing of HPDs does not only affect the listener of speech communication in a noisy environment, HPDs can also affect the speaker. Tufts and Frank (2003) found that talkers produced lower overall speech levels, lower speech to noise ratios, lower Speech Intelligibility Index (SII) values, and less high frequency speech energy when wearing earplugs than when talking with open ears. The changes in speech patterns can increase the challenges of communicating in a noisy environment.

For communication ability to be a consideration in the selection process, the selection cannot be based on a single number descriptor such as the Noise Reduction Rating (NRR) due to the lack of precision inherent in such ratings (Michael, 1991). In order to be valid, the selection process must take into account the frequency spectrum of the noise environment and the attenuation response of the HPD at the octave bands of interest, not just a single number attenuation descriptor.

Speech intelligibility experiments

Several methods have been developed to test for the intelligibility of speech. These methods include testing with nonsense syllables, digits, monosyllabic words, and sentences. Tests can use either an open response set, in which the listener must choose an answer from an infinite number of possibilities, or a closed response set, in which the listener must select the appropriate response from a known group (Martin, 1997).

The use of phonetically balanced (PB) word lists, which consist of words that contain all the phonetic elements of connected English discourse in their normal proportion to one another, are common in intelligibility testing.

A relatively new speech intelligibility test, the Callsign Acquisition Test (CAT), has been developed by the U.S. Army Research Laboratory for military applications to supplement the existing battery of speech tests (Blue, Ntuen, and Letowski, 2004). This test was developed because typical military communications use limited vocabulary with recurrent use of numbers and codes. Military communications are also relatively short and words can be hard to decipher based on the message context (Blue-Terry and Letowski, 2011). The CAT has yet to be standardized for use.

Another nonstandardized speech intelligibility test relevant to military environments is the Coordinate Response Measure (CRM), developed by the U.S. Air Force Research Laboratory (Bolia, Nelson, Ericson, and Simpson, 2000). The phrases in the CRM are comprised of a call sign and a color-number combination, all contained in a carrier phrase. Possible dependent measures include the percentage of correct call sign detections and the percentage of correctly identified color-number combinations. The CRM is particularly useful in evaluating speech intelligibility over multi-channel systems.

Speech intelligibility can also be evaluated by making use of what is known as a rhyme test. One such test is the Modified Rhyme Test (MRT). The MRT consists of six equivalent word lists that are phonetically balanced. The words of each list are monosyllabic and are generally of the form consonant-vowel-consonant (CVC). The lists were generated to form 50 related ensembles, each ensemble consisting of 6 words. The vowel in each ensemble is fixed and the words vary in either the initial or the final phoneme. For each stimulus word the listener must select a response from six alternatives, making the MRT a closed response set test (House et al., 1965).

Rhyme tests have several advantages over tests using PB lists. Rhyme tests are generally easier to administer and score, the data is typically easier to analyze, and the listeners usually do not need to undergo training to take the test (Kryter and Whitman, 1965). MIL-STD-1472G (11Jan2012) Department of Defense Design Criteria Standard Human Engineering, which establishes general human engineering criteria for design and development of military systems, equipment, and facilities, recommends using the MRT as the experimental method "when information concerning the speech intelligibility of a system is required."

Speech intelligibility calculations

The Articulation Index (AI) is a measure, between zero and one, of the amount of acoustic information that is available at the ear of the listener. The AI was originally developed in 1947 by French and Steinberg as an index to the intelligibility of speech and is based on physical measurements of the spectra of speech, thresholds of audibility, and competing noise in the operational environment.

According to the AI concept, speech intelligibility is proportional to the average of weighted differences in decibels (dB) between the masking level of noise and the long-term root-mean-square (rms) level of the speech signal, plus the level of the speech peaks above the long-term rms level, in each of a number of relatively narrow frequency bands (Kryter, 1994; DePaolis, 1992; French and Steinberg, 1947). In other words, the AI reflects and measures the degree of separation between speech and noise (Psychology Dictionary, 2015). In the calculation of AI, the thresholds of audibility and the masking level of the noise are used interchangeably. In 1969, the technique was standardized by the American National Standards Institute in American National Standard Methods for Calculation of the Articulation Index (ANSI S3.5-1969).

In the 1997 ANSI S3.5 standard, "American National Standard Methods for Calculation of the Speech Intelligibility Index," the SII essentially replaced the AI. The Foreword of the standard states, "The most important changes in the present version of the Standard relate to the need to provide a general framework into which various methods for determining the input variables of the Speech Intelligibility Index model (e.g., the equivalent speech spectrum level, the equivalent noise spectrum level, and the equivalent hearing threshold level) can be incorporated." ANSI S3.5-1997 was reaffirmed in 2012.

As with the AI, for a given speech-in-noise condition, the SII is calculated from the speech spectrum, the noise spectrum, and the listener's hearing threshold. Both speech and noise signal are filtered into frequency bands. Within each frequency band the factor audibility is derived from the signal-to-noise ratio (SNR) in that band indicating the degree to which the speech is audible. Since not all frequency bands contain an equal amount of speech information (i.e., are not equally important for intelligibility), bands are weighted by the so-called band-importance function. The band-importance function indicates to which degree each frequency band contributes to intelligibility. The function depends on the type of speech material involved (e.g., single words or sentences), and other factors. Finally, the SII is determined by accumulation of the audibility across the different frequency bands, weighted by the band-importance function. The resulting SII is a number between zero and unity. The SII can be seen as the proportion of the total speech information available to the listener. An SII of zero indicates that no speech information is available to the listener; an SII of unity indicates that all speech information is available. Model parameters have been chosen such that the SII is highly correlated to intelligibility (ANSI, 2012; Rhebergen and Versfeld, 2005).

Proposed guidelines

MIL-STD-1472G (11Jan2012) Department of Defense Design Criteria Standard Human Engineering, which establishes general human engineering criteria for design and development of military systems, equipment, and facilities states, "When information concerning the speech intelligibility of a system is required, two recommended methods are available." These methods are the MRT and the AI. The MRT is used to measure speech intelligibility and the AI is used as a predictive estimator. As stated previously, the AI has essentially been replaced by the SII.

The SII is "highly correlated with the intelligibility of speech under a variety of adverse listening conditions, such as noise masking, filtering, and reverberation" (ANSI S3.5-1997 R2002). The input variables include the equivalent speech spectrum level, the equivalent noise spectrum level, and the equivalent hearing threshold level. Therefore, the SII can be calculated for an individual based on his or her audiogram and type of hearing protection worn.

The table below shows guidelines for acceptable MRT and AI (SII) scores from MIL-STD-1472G. An MRT score of 75 percent or higher or an SII score of 0.3 or higher should be the target for listeners wearing HPDs. If a large vocabulary must be communicated, an MRT score of 80 percent or higher or a SII score of 0.4 or higher should be targeted. When selecting hearing protectors, it is important that the attenuation provided is sufficient, so the noise hazard is eliminated, but not so much so that the wearer feels isolated, which results from too much attenuation or over-protection. Over-protection will result in an unnecessary lowering of speech intelligibility and situational awareness.

TABLE XX. Intelligibility criteria for voice communication systems.

Communication requirement	Score	
	MRT	AI [1/]
Exceptionally high intelligibility	97%	0.7
Normal acceptable intelligibility	91%	0.5
Minimally acceptable intelligibility for mechanized equipment user(s)	80%	0.4
Minimally acceptable intelligibility	75%	0.3

NOTE:
[1/] The Articulation Index (AI) shall not be used to measure intelligibility of synthetic speech because some key acoustic features are not present in non-human "speech". Instead, intelligibility of synthetic speech shall be measured using representative panels of talkers and listeners (see MRT).

Guidelines from MIL-STD-1472G (Table XX.)

Conclusion and recommendations

Noise induced hearing injuries, including tinnitus, are currently the two most prevalent service connected disabilities. The proper selection of HPDs is important not only to prevent hearing injury but also to minimize the loss of necessary information.

When experimentally measuring speech intelligibility, it is recommended that the MRT be used. The MRT is a closed response set test in which the listener must select a response from six alternatives. Depending on how the test is administered, the six alternatives may appear on a computer monitor (or tablet) or on paper. After listening to the presented sentence, the task of the subject is to identify the stimulus word in the sentence. The fraction of the words correctly identified by the subject is the measure of the intelligibility of speech over the system. The system may consist of the air and the room or outdoors in face-to-face communications. The procedure for administering the MRT is described in ANSI/ASA S3.2-2009, "American National Standard Method for Measuring the Intelligibility of Speech over Communication Systems."

When using the MRT to experimentally select a hearing protector, it would be ideal to conduct the test in the actual noise environment in which the hearing protector will be worn. When this is not possible, a high-fidelity recording of the noise environment should be used. However, care should be taken to ensure the recording is played back at the proper sound level. The hearing protectors to be tested should be chosen based on the ability to provide adequate protection in the environment in which they are needed. At the conclusion of the experiment it can be determined if any of the selected devices meet the criteria of MIL-STD-1472G which are summarized in Table XX, and the selection of the appropriate device or devices can be made.

The AI is a measure, between zero and one, of the amount of acoustic information that is available at the ear of the listener. The index is based on physical measurements of the spectra of speech, thresholds of audibility, and competing noise in the operational environment.

In the 1997 ANSI S3.5 standard, “American National Standard Methods for Calculation of the Speech Intelligibility Index,” the SII essentially replaced the AI. Therefore, when calculations are needed to estimate the effect of HPDs on speech intelligibility, it is recommended that the SII be used. It should be noted that SII should **not** be used as a substitute for determining speech intelligibility as described in ANSI/ASA S3.2-2009, “American National Standard Method for Measuring the Intelligibility of Speech over Communication Systems” (ANSI S3.5-1997 R2002).

When using the SII as a basis for the selection of hearing protection it is important that the background noise level used in the calculation is accurate in terms of level and spectral content. It is also important that accurate attenuation values for the protector are used. These values are usually found on the hearing protector packaging received from the manufacturer. If several devices are under consideration, the calculation should be run on each device to determine which meets the desired criterion.

Aligning with MIL-STD-1472G in recommending acceptable intelligibility scores, an MRT score of 75 percent or higher or an SII score of 0.3 or higher should be the target for listeners wearing HPDs. If a large vocabulary must be communicated, an MRT score of 80 percent or higher or a SII score of 0.4 or higher should be targeted.

The maximization of speech intelligibility while wearing hearing protectors often improves safety and efficiency. Providing a hearing protector with too much attenuation could lead to accidents and the rejection of the protector in situations where communication is necessary. The adoption of a selection criterion could allow for the protection of the hearing mechanism, while still allowing for the perception of speech and warning signals.

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