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Performing Audiological Fitness for Duty Assessments for Jobs with Essential Hearing-Critical Tasks

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BACKGROUND

The first article in this series described a new way of characterizing real-world noise environments in terms of their potential impact on an individual's ability to perform essential hearing-critical (HC) job tasks (Soli et al, 2018a). The current article describes how this information can be used by audiologists in the clinic to perform objective, evidence-based hearing screening of individuals seeking jobs with essential HC tasks. The steps necessary to define the screening criteria are analogous in some ways to the steps used to define pure tone threshold levels (dB HL), but use recorded speech material. The rationale and calculations that characterize real-world noise environments, like the rationale and calculations that define dB HL measures, are detailed, but in both cases the assessment process is relatively simple and straightforward.

The impact of real-world noise environments on speech communication can be expressed in terms of the likelihood of effective speech communication using different levels of vocal effort and different communication distances (Soli et al, 2018a). These likelihoods are calculated using the Extended Speech Intelligibility Index (ESII) (e.g., Rhebergen, 2006), which enables estimates of speech intelligibility in nonstationary real-world noise environments to be obtained. We assume that effective speech communication can occur during time intervals when the value of the ESII is large enough for speech to be intelligible. This value is referred to as the criterion ESII for individuals with normal functional hearing ability. The ESII is measured over 4 seconds, the shortest time period during which a brief two-way communication might occur. The proportion of 4-sec intervals in real-world noise environments with ESII values exceeding the criterion value defines the likelihood of effective speech communication for individuals with normal functional hearing ability, and provides a reference value for each noise environment, as shown for a sample of 24 noise environments in Figures 3-5 in Soli et al (2018a). The method for using these criterion ESII values for screening is described below.

MEASURING FUNCTIONAL HEARING ABILITY WITH SPEECH RECOGNITION THRESHOLDS USING THE HEARING IN NOISE TEST

For occupational hearing screening, the individual's functional hearing ability is assessed by measuring their speech reception thresholds (SRTs) in noise with the Hearing In Noise Test (HINT) (Nilsson et al., 1994). The individual's SRTs are then compared to the average SRTs obtained by individuals with normal functional hearing ability, as found in the HINT norms (Vermiglio, 2008). Table 1 shows the normative SRTs in columns 2-4 of the row labeled "Normal." The column headings indicate the spatial location of the masking noise source, Front (NF), Right (NR), and Left (NL), for each test condition. The speech source is fixed in the Front location for all measurements. Note that the norms include evidence of spatial release from masking (SRM), in that the average NR and NL SRTs are 7.5 dB lower (more negative, or better) that the NF SRT. It is important to include the benefits of SRM in estimating the likelihood of effective speech communication, given its significant impact in noisy environments. The Composite SRT is defined as follows.

$SRT_{Comp} = (2*SRT_{NF} + SRT_{NR} + SRT_{NL})/4$

The Composite SRT provides an overall measure of speech recognition in noise that equally weights conditions with and without the effects of SRM. In this case, the Composite SRT of -2.4 was calculated as follows: (2*-2.6 -10.1 -10.1)/4 = -6.4.

Individual	HINT SRTs (dB SNR)					ESIIs	Likelihoods	
	Front	Right	Left	Composite	Δ SRT		Absolute	Proportional
Normal	-2.6	-10.1	-10.1	-6.4	0.0	0.30	0.90	—
A	-1.2	-8.0	-7.0	-4.4	2.0	0.36	0.84	0.93
B	1.2	-5.0	-7.0	-2.4	4.0	0.42	0.70	0.78

Table 1. An Example of HINT SRTS, SRT Elevations Above the Normative Value, ESII Values, Absolute Likelihoods and Proportional Likelihoods for Hypothetical Individuals A and B.

Hypothetical HINT SRTs for Individuals A and B are also shown in Table 1. Both individuals exhibit elevated (less negative) Composite SRTs. The amount by which the Composite SRTs are elevated over the normative values is given in the column labeled "? SRT." Individual A exhibits a 2.0 dB elevation, and Individual B exhibits a 4.0 dB elevation. Note that many different patterns of individual SRTs can produce the same Composite SRT.

HINT SRTs can be measured under headphones or in the sound field. The acoustic effects of spatial separation of the speech and noise sources for headphone tests are simulated by processing the headphone signals using head-related transfer functions (HRTFs). The validity of this simulation has been demonstrated numerous times (e.g., Soli & Wong, 2008). The complete HINT protocol, including Quiet SRTs, can be completed in less than 20 minutes with the use of the recommended automated testing software.

EXPRESSING FUNCTIONAL HEARING ABILITY WITH ESII VALUES

If the individual's Composite SRT is equal to or better than the average normal Composite SRT (?6.4 dB), the individual has met the screening criteria. Composite SRTs that are elevated above the normal value need to be converted to ESII values. This is done by multiplying the amount by which the Composite SRT exceeds the normative SRT by 0.03, the amount the ESII increases per dB, and then adding the result to the Criterion ESII value. As shown in Table 1, for an individual with an SRT at the normative value, the ESII value is the Criterion ESII, 0.30. For Individual A, whose Composite SRT is 2 dB higher than the normative value, the ESII value is 0.36 (2*0.03 + 0.30), and for Individual B the ESII value is 0.42 (4*0.03 + 0.30) as shown in column 7 of Table 1. These are the estimated ESII values necessary for Individuals A and B to communicate effectively in the real-world noise environment.

DETERMINING THE LIKELIHOOD OF EFFECTIVE SPEECH COMMUNICATION

The final step in the screening process is to determine the absolute and proportional likelihoods of effective speech communication associated with these ESII values. The cumulative proportions of 4-sec intervals exceeding ESII values increasing from 0.00 to 1.00 in 0.03 steps have been tabulated for normal, raised, loud, and shouted levels of vocal effort and for communication distances of 0.5, 1.0, 5.0 and 10.0 m. These values for public safety, law enforcement, and corrections personnel are publicly available online (http://links.lww.com/EANDH/A405) in 24 tables. The tables contain absolute likelihoods for each ESII value.

Absolute likelihoods were established for each ESII value assuming raised vocal effort (68 dB SPL) and a communication distance of 0.5 m, and are shown in column 8 of Table 1. The absolute likelihood for an individual with normal functional hearing ability is 0.90, indicating that this individual can communicate effectively 90% of the time. The absolute likelihoods for Individuals A and B, 0.84 and 0.70, indicate that these individuals can communicate effectively 84% and 70% of the time, respectively.

Finally, the absolute likelihoods for Individuals A and B are expressed as proportional likelihoods, as shown in column 9 of Table 1. These values are the ratio of the individual’s absolute likelihood to the absolute likelihood for an individual with normal functional hearing ability. For example, the proportional likelihood for Individual A is 0.93 (0.84/0.90), which means that Individual A can communicate 93% as effectively as an individual with normal functional hearing. Likewise, the proportional likelihood for Individual B is 0.78 (0.70/0.90), or 78% as effectively as an individual with normal functional hearing. Proportional likelihoods are used for screening because they take into direct consideration that in some noisy real-world environments even individuals with normal functional hearing have limited ability to communicate effectively, resulting in low absolute likelihoods for everyone. It is more appropriate to consider the individual’s likelihood in relation to that of an individual with normal functional hearing ability.

In most cases, the government agencies for whom the hearing screening studies were performed have defined the screening criterion to be a proportional likelihood of approximately 80%. In other words, individuals are assumed to be able to perform essential HC job tasks safely and effectively in relevant real-world noise environments if their likelihood of effective speech communication is 80% or more than that of an individual with normal functional hearing ability. In this example, Individual A would meet the screening criteria, but Individual B would not. Choice of the value for the screening criterion is based on the agencies’ considerations regarding safety and other factors related to the jobs that include essential HC job tasks, which are not audiological considerations.

Note that it is not necessary for the audiologist to perform these calculations; although their purpose and meaning should be understood. Simple tables for different levels of vocal effort and communication distances showing ESII values as well as the absolute and relative likelihoods of effective communication for any Composite SRT greater than the normative value can be made for this purpose and posted online.

SUMMARY OF THE OCCUPATIONAL HEARING SCREENING PROCESS

Although the rationale and calculations necessary to obtain objective, evidence-based occupational hearing screening may seem complicated and lengthy, the screening process itself is straightforward, consisting of the following steps:

1. Measure HINT SRTs (less than 20 min)

    - Quiet
    - Noise Front, SRT_{NF}
    - Noise Right, SRT_{NR}
    - Noise Left, SRT_{NL}
2. Calculate the Composite SRT using SRTComp = (2*SRTNF + SRTNR + SRTNL)/4
3. Look up the Proportional Likelihood associated with the Composite SRT
4. Compare the obtained Proportional Likelihood with the screening criterion

Note that this process does not address the use of auditory prostheses such as hearing aids. The process is designed to evaluate individuals either with our without hearing prostheses in the same manner to determine whether they meet the screening criterion. Individuals tested with or without prostheses who do not meet the screening criterion are considered no differently from an audiological perspective. However, individuals with auditory prostheses who meet the screening criterion may be subject to further considerations related to whether auditory prostheses are a reasonable accommodation. Such considerations may occur for individuals who must wear protective headgear and/or ear level communication systems that may be incompatible with auditory prostheses. Again, these considerations relate to specific job requirements and are not audiological, placing them beyond the scope of these articles.

VALIDATION OF THE SCREENING MODEL

For the validity of the screening model to be established, it is necessary to determine how accurately speech intelligibility and SRTs can be predicted for individuals with normal and impaired functional hearing ability using SII calculations. A total of six studies have addressed this issue. Rhebergen and colleagues conducted several studies showing that SRTs for individuals with normal hearing are accurately predicted in a wide range of real-world fluctuating noise environments, and that the ESII value at the SRTs consistently averaged 0.34 (e.g., Rhebergen et al, 2006; Rhebergen et al, 2008), the same as the SII value at the SRT in stationary noise (Houtgast & Festen, 2008).

Soli et al (2018b) reported two studies in which intelligibility scores were predicted from ESII values and compared with measured scores for subjects with normal and mild-moderate hearing loss. Intelligibility predictions were highly accurate (0.78 ? r^2 ? 0.94). Finally, Laroche et al (2014) found that intelligibility scores predicted from ESII values and measured scores obtained in a variety of real-world noise environments also correlated highly (r^2 = 0.91) when the noise contained no linguistic content. As the amount of linguistic content increased, correlations decreased to approximately 0.80, a phenomenon referred to as informational masking (e.g. Brungart et al, 2001). The consistency with which SRTs and intelligibility scores are predicted from ESII values, as seen in these studies, provides solid validation of the screening model.

APPLICATION OF THE SCREENING MODEL

An example of the use of measures of functional hearing ability for occupational hearing screening is found in an article describing the Royal Canadian Mounted Police’s (RCMP) experience with these measures (Vaillancourt et al, 2011). The RCMP is a police force that operates throughout Canada at national, federal, provincial, and municipal levels. Traditionally, the RCMP has used pure tone screening to characterize hearing by classifying individuals in one of five categories: H1-H5. Individuals classified as H3 have limited duty assignments, and individuals classified as H4 or H5 are assigned administrative roles. The distinction between categories H3 and H4 is perhaps most important because individuals classified as H3 are thought to have adequate hearing to perform limited duty assignments in the field, while individuals classified as H4 receive administrative and desk jobs. H3 and H4 classifications can substantially impact an officer's career and promotion opportunities. Individuals with thresholds in their better ear up to 30 dB HL between 0.5 and 2.0 kHz receive an H3 classification, and individuals with thresholds in their better ear up to 50 dB HL at these frequencies receive an H4 classification.

RCMP officers with H4 classifications were evaluated using the functional hearing protocol described above to determine their Composite SRTs. Of the 57 officers evaluated, 37 officers met the screening criteria for Composite SRTs , and of those 28 also met the additional sound localization criteria and thus received H3 re-classifications. This result demonstrates clearly that pure tone thresholds did not accurately predict functional hearing ability, as determined from measures of speech intelligibility. In other words, approximately half the officers with the same H4 audiometrically-based classification exhibited adequate functional hearing ability and approximately half did not. Those officers who received H3 re-classifications were no longer assigned only administrative roles and were given limited duty assignments in the field.

The RCMP screening criterion for Composite SRTs was based on the 5th percentile of the norm distribution (Vermiglio, 2008) rather than on a 0.80 proportional ESII value. The proportional ESII value corresponding to this criterion is 0.85, a slightly stricter screening level.

An article in the RCMP magazine, *Frontline*, reported that these results had a "tremendous impact" on those individuals who would be able to work on limited duty assignments in the field (Greco, 2012). The article also reported that these individuals "are happy that they get to continue to do police work with some limitations, instead of working in an administrative position." The benefits to the RCMP were also noted, stating that these individuals were often highly experienced, and thus "keeping them active in police work means they continue to serve in roles that maximize their contributions."

This case study example demonstrates that appropriate evidence-based functional hearing screening can benefit the individual, the organization, and the public. The RCMP has regarded it as "a win-win situation for everyone."

CONCLUSIONS

In this paper, and in the published companion paper, we describe the process by which we believe the audiological function of employees in critical employment positions, such as police officers, fire fighters, correctional officers, etc. can be evaluated functionally to determine whether they are "fit for duty" based on their functional hearing ability. The procedure is efficient (performed within 20 min) and involves obtaining SRTs using the HINT test. It can be used without and with auditory prostheses to document aided auditory performance for those employees in need of such devices. This procedure provides objective evidence of the ability to understand speech, which is the most important functional hearing ability for performance of hearing-critical job tasks, and has significantly greater validity than the use of pure tone threshold measures for this purpose.

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