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Changing the Audiological Mindset about Fitness for Duty Assessments for Jobs with Essential Hearing-Critical Tasks

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ABSTRACT
The first part of this two-part article introduces the reader to an objective way of characterizing real-world noise environments in terms of their impact of effective speech communication. This provides a foundation for the objective assessment of functional hearing ability to determine whether this ability is adequate to perform public safety and law enforcement jobs with essential hearing-critical tasks. Understanding how this is done will enable the reader to conduct evidence-based occupational hearing screening of individuals seeking such jobs.

Background

For many years audiological hearing assessment has been an important part of medical screening for individuals seeking public safety and law enforcement jobs. Obviously, hearing impairment that interferes with the ability of individuals in such jobs to perform essential hearing-critical (HC) job tasks can affect their safety, as well as the safety of the public. There are several audiological challenges in identifying the presence of hearing impairment that may cause such risks. Two recently published papers (Soli et al, 2018a, 2018b) have made significant advances toward addressing these challenges which are important for audiologists to understand. These challenges can be summarized as follows.

First, most audiological measures and procedures are diagnostic and are intended to determine the etiology and severity of impairment. However, the question for occupational hearing screening has to do with functional hearing ability and whether the auditory system is impaired to an extent that performance of essential HC job tasks is affected. Unfortunately, diagnostic measures such as pure tone thresholds, which are often used as the “gold standard” criteria for determining fitness for duty (e.g., US Dept. of Homeland Security, 2008) are known to be poor predictors of functional hearing ability (e.g., Tufts et al, 2009)

Second, while it is true that results obtained with audiometric speech tests can be interpreted as measures of functional hearing ability, the relationship between performance on such tests and the ability to perform essential HC job tasks has not been fully determined objectively. This challenge is perhaps the most difficult to address because it requires audiological knowledge in the selection, administration, scoring, and interpretation of the audiological test(s), as well as knowledge of the locations and noise environments where essential HC job tasks are performed. Once these two sources of knowledge have been linked, the opportunity to define and validate this relationship

objectively exists. After validation, those audiologists involved in determining fitness for duty will have objective, evidence-based methods of determining whether an individual's functional hearing ability will or will not enable him or her to perform essential HC tasks.

The ability to perform this type of audiological assessment is very important not only because of its potential impact on public safety but also for legal considerations. Both the US and Canada have legal requirements (e.g., EEOC, 1992; Laroche et al, 2003) that require medical screening and inclusion/exclusion criteria to be job-related and meet bona fide occupational requirements. A validated relationship between audiological screening criteria and specific essential HC job tasks is mandatory to satisfy these legal requirements.

Our two-part article discusses the importance to audiology of a body of research—five large studies—conducted over the last 17 years that has focused on defining the objective relationship between speech recognition measures of functional hearing taken in the clinic or lab, and the ability to perform essential HC job tasks safely and effectively in real-world noise environments. The current articles are a summary of the two earlier cited publications, each with an emphasis on their practical significance for audiologists. Of note, is that our two articles are being published simultaneously in *Audiology Today* and *Canadian Audiologist* because of their significance to audiologists in both countries.

Objectives

The threefold objectives of the five studies were the same: determine appropriate and practical measures of functional hearing that are predictive of the ability to perform essential HC job tasks in real-world noise environments; identify and characterize these real-world noise environments; and develop and validate a model to predict performance of essential HC job tasks based on the selected measures of functional hearing ability. A further goal was to identify a single measure that could be used to screen individuals for a wide range of public safety and law enforcement jobs, thus simplifying the training and instrumentation for audiologists who administer the screening protocol. Ideally, the predictive model will be able to use the screening results together with relevant characteristics of the noise environment(s) to predict whether the individual can adequately perform the essential HC job tasks. This approach enables the model predictions to be uniquely tailored to each individual's audiological findings, together with the information about the specific real-world noise environment(s) where the individual would work.

Procedures and Findings

The five studies were commissioned by public safety and law enforcement agencies in the US and Canada. Two were performed in California for the Peace Officers Standards and Training Commission (Goldberg et al, 2001) and the Corrections Standards Authority (Montgomery et al, 2011). Two were performed in Canada, one for the Canadian Coastguard and the Department of Fisheries and Oceans (Laroche et al, 2005) and the other for the Ontario Ministry of Community Safety and Correctional Services (Laroche et al, 2014). One was performed in a number of cities throughout the US for the Federal Bureau of Investigation (Harkins et al, 2017).

Essential hearing-critical job tasks and required functional hearing abilities

In each study the first step was to identify essential HC job tasks and the functional hearing abilities required for these tasks. Not surprisingly, effective speech communication was identified as the most important functional hearing ability in the vast majority of tasks for all five studies. Next, factors that interfered with effective speech communication and made it more complicated were identified. Again not surprisingly, uncontrolled real-world noise was identified as the most

significant factor; although other factors such as multitasking and absence of redundant sensory information also were noted. Of the noise environments where HC tasks occur, 80% had average noise levels over 70 dB(A), as measured in three of the studies. Figure 1 displays the distribution of noise levels from these recordings.

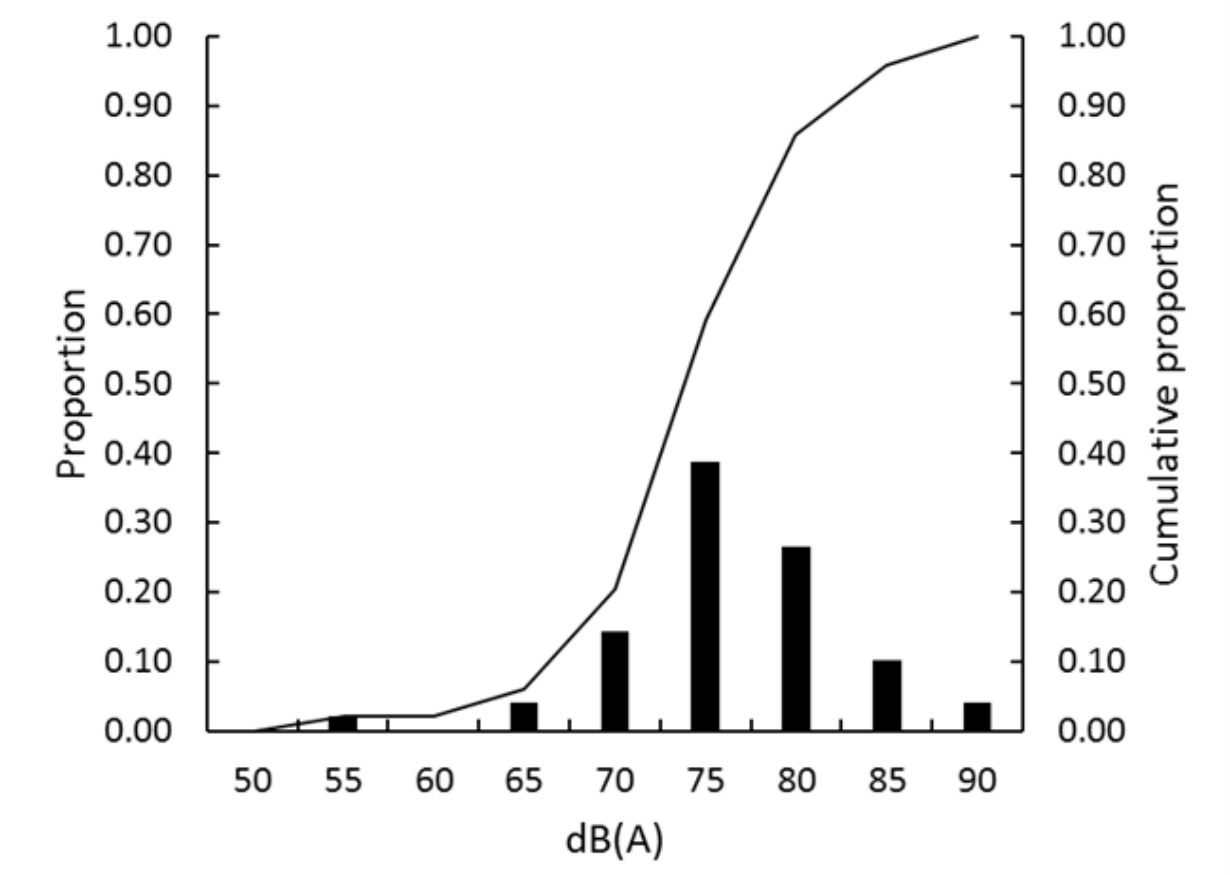

Figure 1. Discrete and cumulative distributions of average dB(A) values measured in 49 noise environments where essential hearing-critical tasks are performed. The values on the left ordinate display the discrete proportions for the bar chart, and the values on the right ordinate display the cumulative proportions. [From Soli et al. (2018a). Evidence-based occupational hearing screening: Modeling the effects of real-world noise environments on the likelihood of effective speech communication, *Ear and Hearing*, 39. 436-448. With permission of Wolters Kluwer Health Inc.]

Measurement of functional hearing ability

The consistent finding that speech communication was the most important functional hearing ability and that noise interference was the most significant complicating factor simplified the selection of a single measure of functional hearing ability that could be used in occupational screening specifically for a wide variety of public safety and law enforcement jobs, namely recognition of speech in noise. However, there are other important functional hearing abilities as well, including detection, recognition, and spatial hearing. An appropriate measure of speech recognition in noise has several potential advantages over measures of other functional hearing abilities. It has high face validity, and robust methods for analysis and characterization of factors affecting speech recognition in noise are standardized (ANSI, 2017). In addition, binaural measures of speech recognition in noise that include conditions with spatial separation of the speech and noise sources tap into several of the other functional hearing abilities, plus such measures assess the ability to process spoken language.

The Hearing In Noise Test (HINT) (Nilsson et al, 1994) was selected as an appropriate measure for occupational hearing screening for several reasons. The HINT has published norms for SRTs

measured both with and without spatial separation of the speech and noise sources. The spatial separation test conditions can be administered with loudspeakers or under headphones by using validated head-related transfer functions (HRTFs). The HINT exists in several languages other than English, including Canadian French, which was a requirement for one of the Canadian studies. Finally, the linguistic properties of the HINT sentence materials are consistent with the requirements in the standard for analysis and characterization of speech recognition in noise (ANSI, 2017).

Prediction of essential hearing-critical job task performance

The Speech Intelligibility Index

The model used to predict effective performance of essential HC job tasks was based on the standardized Speech Intelligibility Index (SII) (ANSI, 2017). Basically, the value of the SII is determined by the amount of speech that is audible in a number of frequency bands, and by the importance of the speech information in each band to the overall intelligibility of the speech. The amount of audible speech in each band is multiplied by the importance of the band, and these values are summed to produce the value of the SII. The amount of audible speech in a band is determined by either the individual's audibility threshold for the band or by the level of noise in the band, whichever is higher. SII values range from 0.00-1.00. The SII at the SRT for meaningful sentences in stationary noise is typically about 0.34 for individuals with normal hearing (e.g., Houtgast & Festen, 2008; Soli et al, 2018a), and the minimum SII for acceptable intelligibility for such sentences in stationary noise is 0.45 (ANSI, 2017).

SII calculations have two important aspects that limit their ability to accurately predict whether an individual's speech recognition ability is adequate to perform essential HC job tasks that require speech communication in real-world noise environments. The SII model assumes that the noise is stationary, which is not true of most real-world noise environments. The model also assumes that speech intelligibility is based entirely on the audibility of speech in each frequency band. In other words, it does not take into consideration impairment of one's ability to process audible speech information, commonly referred to as the distortion component of hearing loss (e.g., Plomp, 1986). There is an ample body of audiological research documenting the effects of distortion loss on speech intelligibility, even in individuals with normal pure-tone thresholds (e.g., Houtgast & Festen, 2008). A means of addressing the first limitation is described in this article, while the means of addressing the second limitation are described in our forthcoming second article.

The Extended Speech Intelligibility Index

Rhebergen and colleagues have developed and validated the Extended Speech Intelligibility Index (ESII) which enables accurate SII calculations to be made with nonstationary real-world noise (Rhebergen et al, 2006, 2008). Briefly, multiple SII calculations are made for sequential "snapshots" of the nonstationary noise and averaged over the time period of interest. The period of time used in the model to predict an individual's ability to perform essential HC job tasks is 4 sec, the time over which a brief two-way communication might occur during performance of the job task.

The distribution of ESII values for all 4-sec intervals in a recording of the real-world noise environment reveals how often these values are large enough for an individual with normal functional hearing ability to achieve acceptable intelligibility and communicate effectively. The criterion ESII value suggested in the standard (ANSI, 2017), 0.45, can be adjusted to account for the benefits of spatial release from masking and the opportunity for repetition that can occur in the performance of HC job tasks. The adjusted criterion value is 0.30. [See Soli et al (2018a) for details on the rationale for this adjusted value.]

Figure 2 displays the cumulative distribution of ESII values for the 4-sec intervals from one of the real-world noise environments, an urban street near a freeway, where essential HC job tasks are performed. These values have been calculated for a communication distance of 1 m using speech levels from the standard for normal, raised, loud, and shouted vocal effort (ANSI, 2017). ESII values larger than the criterion value of 0.30 characterize 4-sec intervals during which effective speech communication can occur. Note that normal vocal effort is never effective, and raised vocal effort is effective less than 5% of the time. Loud vocal effort is effective about 40% of the time, while shouted vocal effort is effective over 95% of the time. In other words, in this particular noise environment individuals with normal functional hearing ability can communicate effective less than half the time at a distance of 1 m with loud vocal effort; although shouting can be effective most of the time.

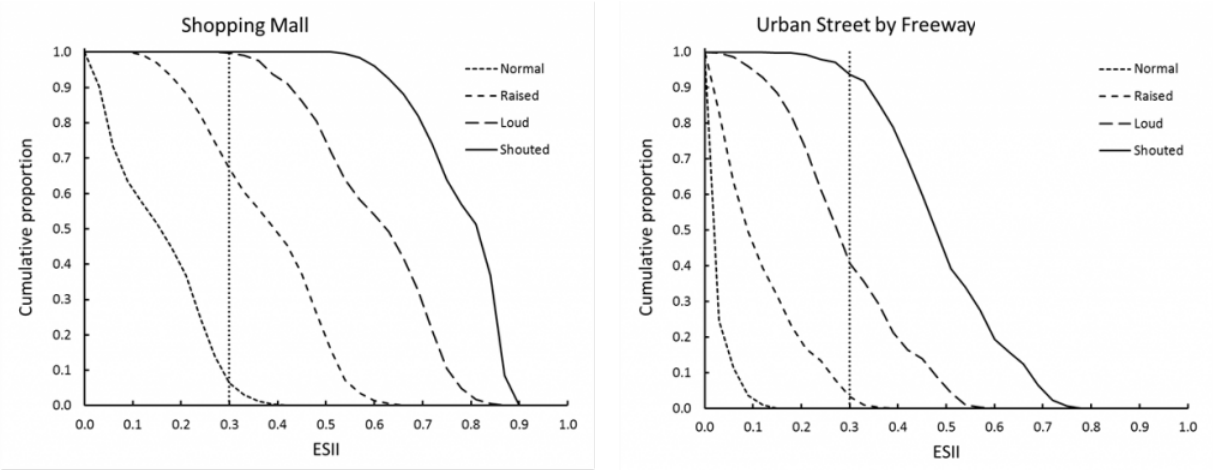

Figure 2. Cumulative distributions of ESII values for 4-sec intervals (average = 79.5 dB(A)) in a specific real-world noise environment. The distributions display the proportion of intervals with ESII values exceeding the values on the abscissa. The vertical dotted line at an ESII value of 0.3 represents the adjusted minimum ESII criterion for effective speech communication. [From Soli et al. (2018a). Evidence-based occupational hearing screening: Modeling the effects of real-world noise environments on the likelihood of effective speech communication, *Ear and Hearing*, 39. 436-448. With permission of Wolters Kluwer Health Inc.]

This characterization of real-world noise environments in terms of their potential impact on effective speech communication for individuals with normal functional hearing is an important step in establishing a valid and evidence-based means of assessing an individual's ability to perform essential HC job tasks in challenging real-world noise environments. Over 260 sound recordings from 24 real-world noise environments where essential HC job tasks are performed have been obtained and analyzed in this manner. The resulting ESII distributions provide a quantitative and objective description of the ability of individuals with normal functional hearing to communicate effectively while performing essential HC job tasks in these environments. These ESII distributions have been posted on the internet and are freely available to use for screening or for other purposes by audiologists and hearing researchers (Soli et al, 2018a).

Our second article will explain how functional hearing screening results for an individual, together with the ESII distributions for the relevant real-world noise environments, can be used to predict whether the individual's functional hearing ability may cause safety risks for the individual and for the public. These predictions, unlike previous methods of occupational hearing screening based on

diagnostic measures of hearing, are evidence-based and objectively link the screening measures to the essential HC job tasks, providing a stronger audiological foundation for important employment decisions.

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