Update on fitness standards for hearing-critical jobs

C. Laroche[1], C. Giguère[1], V. Vaillancourt[1], S. Soli[2]

[1] Audiology & Speech-Language Pathology Program, University of Ottawa, Ottawa, Ontario K1H 8M5, Canada

[2] Department of Human Communication Sciences and Devices, House Ear Institute, LA, CA 90057, USA

INTRODUCTION

Since the last ICBEN meeting in 2008 only a few papers have been published on fitness standards for hearing-critical jobs, mainly in North America (Tufts et al. 2009; Vaillancourt et al. 2011; Corrections Standards Authority 2011). The last two publications report the efforts of two organizations in reviewing their hearing standards previously based solely on the audiogram, a measure of hearing sensitivity in quiet. It is now generally accepted that the audiogram is not sufficient in most cases for predicting auditory performance in workplaces where hearing-critical tasks must be performed efficiently to ensure worker and public safety. This is highlighted in a review by Tufts et al. (2009) on hearing standards for jobs where safety can be compromised (e.g. police officers, firefighters, correctional officers, coast guard officers, etc.).

Hearing standards are often dealt with from a purely medical standpoint, without taking into account workplace requirements. However, Auditory Fitness For Duty (AFFD) refers to the set of functional hearing abilities required for safe and effective job performance. For tasks (e.g. surveillance, rescue operations, piloting, military operations) in which the ability to respond to critical sounds or speech is paramount to successful operations and job safety, hearing loss can at times negatively impact performance to the point of being detrimental to worker and/or public safety. AFFD screening protocols should therefore provide valid assessments of functional hearing abilities that are free of discriminatory practices based solely on hearing loss (Tufts et al. 2009).

In the last few years, at least two organizations have demonstrated efforts in revising their hearing standards. The RCMP (Royal Canadian Mounted Police) has proposed functional criteria for officers wearing hearing aids on the job. As a growing number of officers were recommended the use of hearing aids since their hearing thresholds exceeded previously established audiometrically-based criteria and faced operational restrictions, timely implementation of these criteria was imperative, prior to work done to establish job-specific criteria. Over the last three years, over 80 officers were evaluated on measures of speech recognition in noise and sound localization to determine if they could be reintegrated into their job functions without compromising worker and public safety.

For California correctional officers (Corrections Standards Authority 2011), standards for entry-level employees were established based on a detailed analysis of job requirements performed jointly with Subject Matter Experts (SMEs) and a study of prevailing on-the-job acoustical conditions. The overall approach was similar to that used by Giguère et al. (2008) for Canadian Coast Guard personnel and Department of Fisheries officers, with the exception that hearing screening criteria were established on the basis of the Extended Speech Intelligibility Index (ESII) from Rhebergen et al. (2006).

OVERVIEW OF AFFD

Tufts et al. (2009) provide a comprehensive review of the different issues involved in the establishment of hearing standards. Numerous examples are drawn from the military environment, where adequate functional hearing abilities are an essential requirement (e.g. detection of footsteps, target identification, understanding commands during combat, etc.). Hearing fitness standards are also important and in use in many other civil and governmental organizations. In a detailed table summarizing various hearing standards used in the USA, the authors provide examples from the Federal Mine Health and Safety Series, the Federal Air Traffic Control, and the Michigan State Police, to name a few. Similarly, threshold-based hearing standards are also in effect in Canada for military personnel, police officers and railway workers; however, a few pan-Canadian organizations [Department of Fisheries and Oceans Canada (DFO) and the RCMP)] have adopted screening measures that do not rely solely on the audiogram.

The final decision pertaining to an employee's ability to perform the job in a safe and secure manner should be based on 1) results of AFFD testing, 2) job requirements, 3) amount of on-the-job experience, 4) legal considerations, and 5) the needs of the organization (Tufts et al. 2009). With regards to legal considerations, one can cite an example involving threshold-based DFO standards being successfully challenged in court by an employee with unilateral hearing loss. The Canadian Human Rights Tribunal ruled that the organization should revise their hearing standards. Details of this major revision of standards were presented at the last ICBEN meeting (Laroche et al. 2008) and also published in both Laroche et al. (2003) and Giguère et al. (2008). In establishing new criteria, the job requirements and needs of the organization were taken into account by involving SMEs from the beginning of the project.

In most cases, hearing abilities required for the safe performance of hearing-critical jobs include sound detection, sound recognition, speech perception in noise and sound localization. However, a detailed analysis of the various standards used across the USA (Tufts et al. 2009) and elsewhere reveals that most are still based purely on the audiogram. Unfortunately, except perhaps for sound detection in quiet, the audiogram is generally a poor predictor of hearing abilities required on the job. Accordingly, the development of AFFD protocols that are valid, reliable, and consistently and appropriately implemented is of paramount importance.

A good starting point in the development of such protocols is a thorough job analysis to identify hearing-critical tasks, the importance of such tasks, the environment and conditions in which these tasks must be performed, and the minimal performance level required by the employer. This job analysis must be carried out jointly by SMEs from the organization and specialists in the field of hearing. The former group can describe the conditions in which hearing-critical tasks are performed, while the latter group can help identify the underlying functional hearing abilities required for each task as well as the screening tests that can be used to measure these abilities. Two different approaches to AFFD screening are recommended; real-world simulations and the use of valid screening tests. Real-world simulations involve a substantial amount of time and money on an ongoing basis, but may be required in particular situations. In such cases, one must ensure that realistic on-the-job conditions are provided when administrating the test protocol, and that valid normative data have been established. For the second approach, one must ascertain the predictive validi-

ty of the screening tests and screening criteria for the given workplace, which will require a substantial amount of experimental work upfront.

Tufts et al. (2009) offer some directions for the future. AFFD test protocols cannot be viewed as "one size fits all" and must be job-specific. The authors also emphasize that the "pure-tone audiogram is no longer defensible as the only AFFD test in most cases" (p. 553). In support of this statement they provide an example of soldiers returning from war with traumatic brain injuries due to explosives. Such individuals can present normal audiograms yet complain of difficulties understanding speech in noise.

RCMP STUDY (Vaillancourt et al. 2011)

Over the last few years, the RCMP has been faced with a growing number of police officers requiring the use of hearing aids due to the aging workforce and, possibly, from noise exposure and shooting range training over the course of one's career. Officers are classified into 5 categories of hearing (H1 to H5 with increasing hearing loss) based on their audiogram. When reaching H4, the degree of hearing loss is considered large enough that the officer is assigned to "non-operational" duties and a hearing aid trial is recommended. With hearing aids, reclassification to H2 (fully operational) or H3 (operational with certain restrictions) is possible. In light of the high number of officers with H4 classification or above and the costs of training RCMP officers for pan-Canada duty, the organization is seeking to implement alternative strategies that allow more officers to be reintegrated into the workforce. Vaillancourt et al. (2011) report on the assessment of RCMP officers wearing hearing aids. The purpose of the study was to quantify individual performance in different domains of hearing identified as necessary components of AFFD for this organization, and to document the benefits, if any, of hearing aids for functional hearing. The data were to help RCMP in making more informed decisions regarding AFFD in officers wearing hearing aids.

The proposed new AFFD protocol includes unaided and aided measures of speech recognition in quiet and in noise using the Hearing in Noise Test (HINT) (Nilsson et al. 1994; Soli & Wong 2008), and sound localization in the left/right and front/back horizontal planes. Sixty-four officers with hearing thresholds exceeding hearing class H3, 57 of which owned hearing aids, were identified and selected by the RCMP to take part in the study.

Based on individual test results, 49 % of officers were reclassified from non-operational status to operational with limitations and restrictions on the basis of adequate functional abilities for speech perception and sound localization, either with or without their hearing aids. As the need for pass/fail criteria was urgent to deal with the growing number of police officers required to wear hearing aids, the 5^{th} percentile of performance by normal hearing individuals on measures of speech perception in noise and sound localization was deemed acceptable prior to the establishment of job-specific criteria for the RCMP. A similar approach was used by Goldberg (2001) for the California Commission on Peace Officer Standards and Training. For speech perception in quiet the criterion was set at 40 dBA, ensuring that RCMP members are able to understand various levels of speech, including whispered speech, at typical conversational distances.

Individual data relative to the functional criteria are summarized in Table 1. The Speech reception threshold (SRT) corresponds to the average presentation level of the sentences presented in Quiet, whereas the Noise Composite score [(2×NF + NR + NL)/4] is used to represent overall functional ability for speech perception in noise under binaural listening conditions (NF = Noise Front; NR = Noise Right; NL = Noise Left). The results highlight a key issue for the design and fitting of hearing aids. While they can provide benefits in speech recognition hearing aids can significantly hinder front/back localization abilities, as shown by the following key results:

- 13 out of 17 (76 %) officers who did not meet the speech in quiet criterion passed with hearing aids. Hearing aids are therefore beneficial to improve speech in quiet most of the time.
- 10 out of 30 (33 %) officers who did not meet the noise composite criterion passed with hearing aids, suggesting that research and development are still needed to improve speech perception in noise with hearing aids;
- Only 1 of 21 officers who did not meet the criterion for front/back localization passed aided, highlighting a limited benefit of hearing aids. Of even greater concern, 16 out of 36 (44 %) officers who initially met the criterion for front/back localization failed aided. Because they limit the frequency bandwidth to about 5 kHz, hearing aids seem detrimental for sound localization in the front/back dimension, which relies on high-frequency information above 5 kHz.

Table 1: Summary of unaided vs aided performance in RCMP officers wearing hearing aids (N=57)

Task	Performance measure	Aided outcome	Unaided outcome	
			Pass	Fail
HINT	SRT in Quiet	Pass	40	13
		Fail	0	4
	Noise Composite	Pass	27	10
		Fail	0	20
Localization	# of L/R errors (Behind)	Pass	53	2
		Fail	0	2
	# of F/B errors (Side)	Pass	20	1
		Fail	16	20

Additional analyses also indicated that hearing thresholds were poor predictors of functional abilities for speech in noise (r^2 = 0.26 to 0.33) and sound localization (r^2 = 0.03 to 0.28). Only speech in quiet (r^2 = 0.68 to 0.85) was predicted adequately from threshold data.

Results show that hearing aids can considerably affect front/back localization abilities in some individuals. Moreover, speech understanding in noise and sound localization abilities were poorly predicted from hearing thresholds, demonstrating the need to specifically test these abilities, both unaided and aided, when assessing AFFD. Finally, the authors conclude that further work is needed to develop empirically-based hearing criteria for the RCMP. The current AFFD criteria used are called "interim criteria" as the hearing-critical tasks and the environmental conditions in which these tasks are performed have not yet been identified. Such criteria will need to be validated and refined using an approach similar to that used by the Corrections Standards Authority (2011), as described below.

Finally, as RCMP members were tested using their own hearing aids, fitted and adjusted independently from the study, makes, models, styles and settings covered a wide range, making it difficult to identify the optimal characteristics of hearing aids for the performance of hearing-critical tasks. Further work is needed to identify best practices in hearing aid fittings for optimal functional hearing abilities.

CORRECTIONS STANDARDS AUTHORITY (CSA 2011)

Public protection and safety issues are constant concerns for Correctional Officers who must prevent escape, quell riots, and protect the public and other custody personnel in detention establishments. A Correctional Officer's job requires a high degree of physical and sensory abilities, including hearing. Any hesitation, reluctance, or inability to fully engage in a critical and potentially life-threatening situation caused by inability to hear could trigger a sequence of events that could have significant, even fatal, consequences.

The hearing standard for entry-level California Correctional Officers was last updated in 1992. The recent strategy put in place to develop new screening measures consists of four major elements:

1) Identification of hearing-critical job functions performed by Correctional Officers with the help of SMEs;

2) Determination of functional hearing abilities important in the performance of these functions (e.g., speech comprehension, sound detection and recognition, sound localization);

3) Assessment of the impact of the sound environment, especially background noise levels, on the performance of these functions using a methodology based on the ESII model (Rhebergen et al. 2006); and,

4) Selection of valid and reliable screening tests and protocols to predict the necessary hearing abilities.

Figure 1 shows the components of the complete research and development protocol. Because Correctional Officers must defend themselves while wearing protective headgear and other protective equipment during certain adversarial encounters, such as cell extractions and riots, and this protective headgear may interfere with the use of hearing aids, the screening procedure includes an additional step (see Figure 2) while using such headgear or other protective devices.

The main research findings can be summarized as follows:

- Speech communication is a frequently used and demanding job function in the prison environment.
- More than 28 % of the cues for detecting incidents and emergencies are exclusively based on hearing, and another 23 % involve hearing as a critical component.
- Background noise levels in prison environments where Correctional Officers perform hearing-critical job functions ranged from almost 90 dBA at its loudest to 62 dBA at its softest, with average values between about 70 dBA and 85 dBA.
- The likelihood of effective speech communication in prison noise environments for a person with normal hearing ranges from less than 20 % when normal vo-

cal effort is used up to 100 % when shouting at communication distances of about 1 meter or less.

The study demonstrated that measures of speech recognition in noise are better predictors of functional hearing abilities used by Correctional Officers to perform hearing-critical job functions than traditional measures based on audiometric thresholds. A more appropriate and valid test for evaluating the functional hearing ability of applicants for the Correctional Officer position was found to be the Hearing in Noise Test (HINT) (Nilsson et al. 1994; Vaillancourt et al. 2005). The new standard is based on measures of speech recognition in quiet and in a background noise condition that is representative of the levels found in the Correctional Officer's workplace. The screening criterion in quiet is a speech level of 27 dBA or less. In 75 dBA noise, the screening criterion for speech is 71 dBA or less, corresponding to a signal/noise ratio of -4.0 dB or lower. It is interesting to note that this criterion is identical to that used in screening Department of Fisheries and Oceans Canada personnel with the English version of the HINT (Giguère et al. 2008).

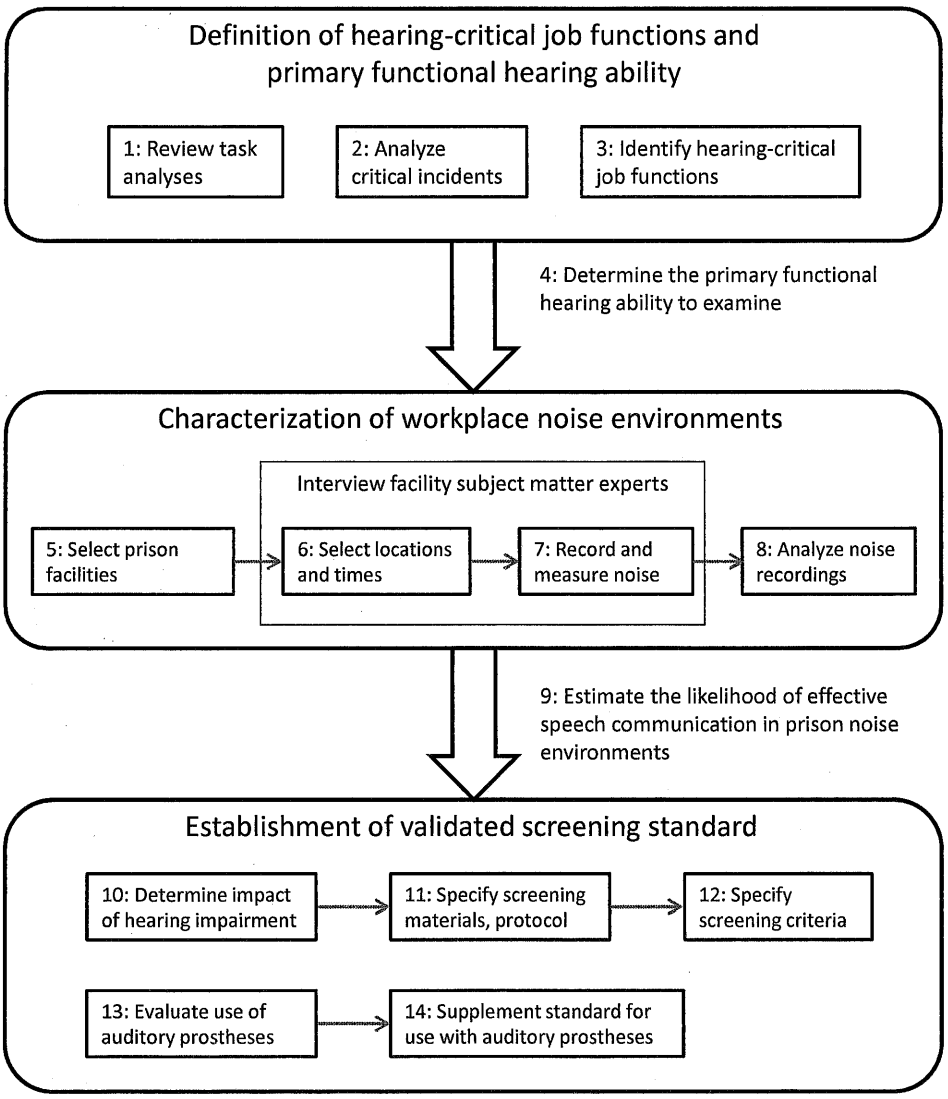

Figure 1: Protocol used to establish validated screening standards for Correctional Officers. Reproduced from CSA 2011, used with permission

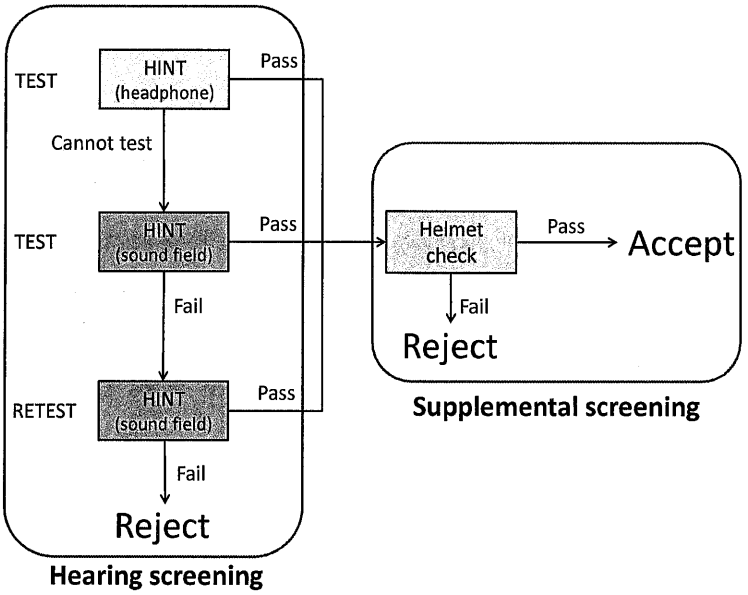

Figure 2: Screening protocol including the wearing of helmet or other protective devices. Reproduced from CSA 2011, used with permission

CONCLUSIONS

The few documents published over the last three years emphasize the need to move beyond the audiogram in the establishment of hearing standards and during AFFD testing. Where hearing-critical tasks must be performed in noisy environments, and where worker or public safety is at stake, valid assessment of the workplace and of the functional auditory abilities must be undertaken, in close collaboration with employers, SMEs, and other experts in audiology and engineering. The examples described above (RCMP, CSA) represent two work environment situations that can also occur in other military and civil organizations. In the case of the RCMP, faced with a significant number of job restrictions among its workforce, functional criteria were immediately needed prior to performing a detailed job analysis and obtaining workplace noise data to establish more definitive criteria. This approach has helped guide the employer in making more informed decisions for individual officers, thereby minimizing the number of experienced police officers being assigned to administrative duties due to elevated hearing thresholds when, in reality, they did not present a significant safety risk based on functional hearing measured.

Further, hearing aids can positively or negatively affect functional hearing abilities, the latter occurring in a significant number of cases for sound localization, and to a lesser extent for speech communication in noise, as measured by the HINT Composite score. Thus, AFFD testing both with and without hearing aids is needed to help the employer determine the most suitable conditions during operational duty in each officer. The CSA example clearly illustrates how a valid AFFD protocol can be proposed when all key players (SMEs, experts, employer) are involved and when the tools used (e.g. HINT, ESII) have been scientifically established. Other organizations are encouraged to use a similar approach to establish criteria that are directly linked to their work environment and job requirements. In some cases, the methodology may need to be adapted to deal with the effects of hearing protectors on auditory performance if used in the workplace, for example through use of speech intelligibility

(Giguère et al. 2010) or alarm detection (ISO 7731:2003, Zheng et al. 2007) models. Further work is needed to be able deal with communication devices and advanced adaptive hearing protection technologies.

REFERENCES

Corrections Standards Authority (2011). Hearing standard for selection of entry-level correctional officers. Sacremento, CA: Corrections Standards Authority.

Giguère C, Laroche C, Soli SD et al. (2008). Functionally-based screening criteria for hearing-critical jobs based on the Hearing in Noise Test. Int J Audiol 47: 319-328.

Giguère C, Laroche C, Vaillancourt V et al. (2010). Modeling speech intelligibility in the noisy workplace for normal-hearing and hearing-impaired listeners using hearing protectors. Int J Acoust Vibr 15: 156-167.

Goldberg RL (2001). Hearing guidelines for the California Commission on Peace Officer Standards and Training. www.post.ca.gov (accessed May 15, 2011).

ISO 7731 (2003). Ergonomics – danger signals for work places – auditory danger signals (ISO 7731). [Standard] Geneva: ISO.

Laroche C, Soli S, Giguere C et al. (2003). An approach to the development of hearing standards for hearing-critical jobs. Noise & Health 6(21): 17-37.

Laroche C, Giguère C, Zheng Y et al. (2008). Establishment of fitness standards for hearing-critical jobs. In: 9th International Congress on Noise as a Public Health Problem (ICBEN), Mashantucket, USA, (July 28th- August 1st 2008), pp. 210-217.

Nilsson M, Soli SD, Sullivan JA (1994). Development of the hearing in noise test for the measurement of speech reception thresholds in quiet and in noise. J Acoust Soc Am 95: 1085-1099.

Rhebergen RS, Versfeld NJ, Dreschler WA (2006). Extended speech intelligibility index for the prediction of the speech reception thresholds in fluctuating noise. J Acoust Soc Am 120: 3988-3997.

Soli S, Wong LN (2008). Assessment of speech intelligibility in noise with the hearing in noise test. Int J Audiol 47: 356-361.

Tufts JB, Vasil KA, Briggs S (2009). Auditory fitness for duty: a review. J Am Acad Audiol 20: 539-557.

Vaillancourt V, Laroche C, Mayer C et al. (2005). Adaptation of the HINT (Hearing In Noise Test) for adult Canadian Francophone populations. Int J Audiology 44: 358-369.

Vaillancourt V, Laroche C, Giguère C (2011). Evaluation of auditory functions for Royal Canadian Mountain Police (RCMP) Officers. J Am Acad Audiol (accepted for publ.).

Zheng Y, Giguère C, Laroche C et al. (2007). A psychoacoustic model for specifying the level and spectrum of acoustic warning signals in the workplace. J Occup Environ Hyg 4: 87-98.