A WARNING SOUND PERCEPTION MODEL SOFTWARE

C. Giguère, C. Laroche, Y. Zheng, C. Sabourin
University of Ottawa, Canada

Introduction In many workplaces, acoustic warning signals are necessary to promptly alert workers of events that can compromise safety. However, the installation of warning devices in noisy workplace settings poses particular challenges in terms of volume adjustments for optimal detection and recognition. The required warning levels at a given workstation can vary widely depending on the hearing status of the individual(s), the wearing of hearing protectors, the noise characteristics and the frequency components of the warning sound. A software tool has been developed to obtain optimal target sound levels for warning signals in a noisy workplace given the particular conditions that exist at each workstation.

Methods The present work is a major upgrade of a former tool Detectsound [1]. It has been used to assess the audibility of warning signals such as sirens, buzzers, and reverse alarms by workers in noisy workplaces and of fire alarms by occupants of apartment buildings and offices [1,2]. Consequently, the model has been used to design safe sound signals or to propose modifications to currently existing signals in terms of spectral content and overall sound pressure level. The model not only addresses the requirement of detection of warning signals, but also the problem of recognition or identification of warning sounds. The effects of wearing hearing protectors on signal perception in noisy workplaces can also be taken into account.

In the new model, the facilities to account for the hearing status of workers have been greatly expanded. The characteristics of the optimal warning signal specified by the psychoacoustic model can now be tailored to the needs of an individual worker or of a target statistical population of workers. The general concept is illustrated in Figure 1. For a prediction based on individual workers, the model requires the absolute hearing thresholds of the worker at the standard audiometric frequencies, and data on frequency selectivity. The latter are derived using a notch-noise masked threshold method to provide auditory bandwidth (ERB) and efficiency factor (K) at 6 auditory filter centre frequencies for each individual. Alternatively, the auditory filter characteristics can be estimated from the absolute thresholds given data on the change in frequency selectivity with hearing loss. For a prediction based on a target population of workers, the absolute hearing thresholds are based on latest normalized data on the effect of age, gender and noise exposure (level, exposure in years) (ISO 1999). The model then takes into account the noise field at a given workstation and possible use of hearing protectors by the worker(s) to specify a conception window for the optimal target level of warning sounds at each frequency. Following [3], the conception window for the frequency components of the warning sound is set from 12 to 25 dB above the masked

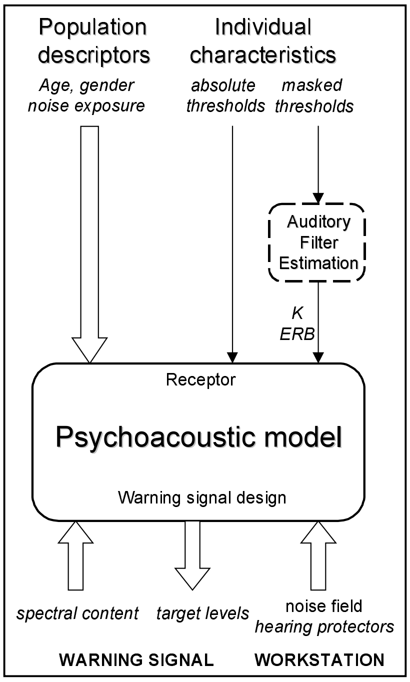

Figure 1: General concept

threshold with an upper limit of 105 dBA. Where absolute thresholds are the limiting factor for audibility, these are used to set the conception window.

Results In order to validate predictions based on the new Detectsound model, auditory filter characteristics and masked thresholds for pure-tone and complex signals presented in different types of noise have been collected on twenty normal hearing subjects. Firstly, six pure tones masked thresholds were measured in 6 notch-noises using a fixed-frequency Bekesy technique. A separate software tool (SHAPE) was used to derive the ERB and K factors from this data. Secondly, masked thresholds for various signals in representative background noises pre-recorded on a CD were measured. The noises were a white noise, a pink noise (unfiltered, low-pass and high pass), a riveter noise and a swagger noise, all at 80 dBA. The two last noises are classified as "impact noises" and all the others as steady-state noises. All signals were pulsed at 200 msec ON and 200 msec OFF in order to satisfy criteria for warning signals in noisy workplaces. The signals were: 0.5, 1, 1.15, 1.3 and 2.6 kHz, two three-component complexes (1, 1.15, 1.3 or 0.5, 1.15, 2.6 kHz) and a five-component complex (0.5, 1, 1.15, 1.3, 2.6 kHz).

Discussion Preliminary data were available on 6 subjects. Based on the notched-noise method, ERBs and K factors were computed. ERB values were quite similar from one ear to the other for a specific subject, but it was not necessarily the case for the K factor. Nevertheless, the use of these parameters in Detectsound allows the prediction of masked thresholds for white noise within a standard error of 1.6 dB when individualized K factors are used. We are in the process of analysing the results for the other types of noise, but it seems that the masked thresholds are over-estimated for the swagger and riveter noises. These over-estimations could be related to the fluctuations in the temporal patterns of these impact noises. It seems that the subjects are able to achieve low detection thresholds by listening in the lowest portion of the noise. A correction based on the temporal fluctuations of the noise may have to be introduced in the model in order to improve the predictions for impact noises. Data collected with complex signals (three or five components) will be analyzed in order to determine how the number of components influences detection in noise, especially when several components are adjusted to reach threshold at the same time. The same protocol will be applied with subjects with sensorineural hearing loss to validate the entire process.

The final step will involve the inclusion of a noise propagation model (OUÏE 2000) to account for the room acoustics in the work area and the distance between warning device(s) and workstation(s). The ultimate goal is to integrate both models into a tool that can help specify the best solution for the installation of acoustic warning devices in a given setting, in terms of number of devices to use, their optimal location and output level. [Project funded by NSERC].

Keywords: Auditory perception in noise, Auditory warning signals, Frequency selectivity

References

[1] Laroche, C., Tran Quoc, H., Hétu, R., and McDuff, S. (1991). “"Detectsound": A computerized model for predicting the detectability of warning signals in noisy workplaces,” Applied Acoustics, 32: 193-214.
[2] Proulx, G., Laroche, C., and Latour, J.C. (1995). “Auditory problems with fire alarms in apartment buildings,” Hum. Fact. & Erg. Soc., 39th Annual Meeting, San Diego, (2): 989-993.
[3] Quoc, H.T. & Hétu, R. (1996). La planification de la signalisation acoustique en milieu industriel: critères de conception des avertisseurs sonores de danger, Can. Acoust., 24(2):3-17.