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WEARING HEARING AIDS IN AN OPEN PLAN OFFICE ENVIRONMENT: EFFECTS DURING A COGNITIVE TASK

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ABSTRACT

This last decade, the number of people wearing hearing aids at work has increased. The services sector is no exception especially in open-plan offices where concentration is sometimes required. The aim of this study is to assess the cognitive effects of wearing hearing aids on employees in open-plan offices. Forty-six normal hearing people have participated to a laboratory study. Using a mix of a speech signal and open office ambient noise, four sound conditions more or less intelligible were created by varying the SNR. Stimuli were recorded in an anechoic room through an acoustic dummy head with and without hearing aids, then hearing loss was induced using a simulator. During the experiment over 4 half days, participants performed a cognitive task while the stimuli were played through headphones. Task performance, perception of the sound environment, fatigue and mental workload were assessed. ANOVA were performed to determine the effects of hearing aids and SNR on the dependent variables. A slight effect on fatigue was found to be significant. In addition, the use of hearing aids did have a strong effect on the rating of the dimensions of the noise environment (noisy, annoying, tiring) as well as on one dimension of mental workload.

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1. INTRODUCTION

In the occupational sector, the number of working people with hearing loss who wear hearing aids is increasing significantly, including in open-plan offices. While it is recognised that hearing aids bring many benefits to everyday life, it is important to consider whether this is also the case in a noisy open-plan office environment. Hearing aids have the advantage of improving speech intelligibility. However, speech intelligibility, particularly in open-plan offices, can be detrimental when a concentration task, for example, has to be performed. Indeed, the deleterious effect of speech, known as the Irrelevant speech Effect, on normal hearing people is now well studied [1]–[4].

So, for people with hearing loss, the question may arise: does wearing hearing aids in a noisy work environment have advantages, or does it increase the perceived discomfort?

A laboratory experiment simulating half a day's work in an open-plan office for employees with hearing loss was constructed. The aim of this experiment was to observe the effect of wearing hearing aids in a noisy open-plan office environment as a function of intelligibility, characterised by the signal-to-noise ratio (SNR) between speech and background noise.

For practical purposes, the participants in the experiment were normal hearing people and hearing losses were simulated [5].

2. METHODS

2.1 Audio stimuli

The sound signals played in the experiment consisted of a speech signal and a background noise (open-plan office noise + ventilation). A total of eight sound conditions were tested, two hearing aid conditions and four overall SNR conditions, namely -4 dB(A), 0 dB(A), 4 dB(A) and 8 dB(A) (see section 2.1.2).

2.1.1 Samples

The speech signal was generated from interviews downloaded from the internet. The background noise consisted of recordings of open-plan office background noise (babble noise, etc.) and miscellaneous noise (printers, etc.) from a free sound source bank. All signals containing speech were filtered to match a standard LTASS speech spectrum [6]. A ventilation broadband noise was added to this sound environment. The duration of the sound stimuli for each experimental condition was 1h40.

2.1.2 Signals acquisition in anechoic room

Signals were recorded in an anechoic room using a KEMAR acoustic dummy (head + symmetrical ears + chest). Five loudspeakers were placed around the dummy at a distance of 1.10 m. The loudspeaker in front of the dummy transmitted the speech signal, which was set to 54 dB(A) at a reference microphone placed above the dummy. The other four loudspeakers broadcast the background noise, i.e. the superposition of a ventilation noise set at 30 dB(A) (at the reference microphone) and the office noise, the level of which was set from the chosen global SNR, i.e. -4 dB(A), 0 dB(A), 4 dB(A) and 8 dB(A) from the speech signal level. For each SNR variation, recordings were made once with the dummy without hearing aids and once with hearing devices.

2.1.3 Hearing losses

The hearing losses were applied to each of the recorded sound signals using a hearing loss simulator [5]. The loss profile used (see Figure 1) is based on the N3 profile from the work of Bisgaard et al [7] and corresponds to a moderate first-degree hearing loss.

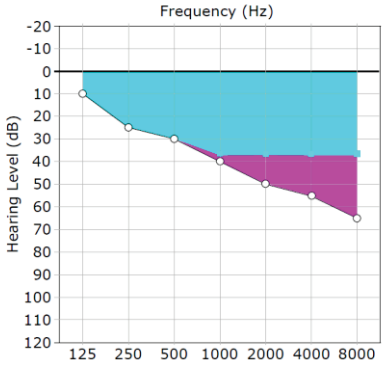

Figure 1. Hearing loss profile simulated and implemented in hearing aids.

2.2 Experimental design

2.2.1 Cognitive task

In order to place the participants in working conditions, they were asked to produce a press review. In a practical sense, the participants had to read articles in the press very carefully. For each sound condition, the press review consisted of two articles (approximately 10 pages) dealing with different news topics. In total, each participant dealt with 16 news topics (2 per sound condition, i.e. 2 hearing aid conditions and 4 SNR conditions). For each of the press reviews, the participants had to take as many notes as possible in order to answer final multiple-choice questions (MCQ) at the end of the session.

2.2.2 Questionnaires

The main aim of the MCQs was to encourage the participants to read and remember as many articles from the press reviews as possible. In addition, a performance score was calculated for each sound condition. In addition to performance, questionnaires were used to assess the subjective effect of the sound environment on the participants. Several dimensions were measured.

Fatigue: Mental and general fatigue were assessed using the Multidimensional Fatigue Inventory (MFI) questionnaire[8], [9].

Noise environment perception: A noise environment assessment was conducted, covering three dimensions: noisy, annoying and tiring.

Mental workload: the cognitive mental workload was estimated with the IWA questionnaire [10] (Individual - Workload - Activity) in a laboratory version. This questionnaire evaluates four dimensions of mental workload generated by the activity: intrinsic workload,

external workload, available resources and essential workload.

2.2.3 Procedure

Forty-six participants, 14 males and 32 females, were recruited. All participants had normal hearing (hearing loss < 20 dBHL). The participants were divided into 12 groups: 10 groups of 4 people and 2 groups of 3 people. Each group visited the laboratory for 4 half days, alternating between mornings and afternoons.
In order to recreate a physically open office environment, 4 workstations were set up in a quiet square office, separated by panels approximately 2 m high (see Figure 2).

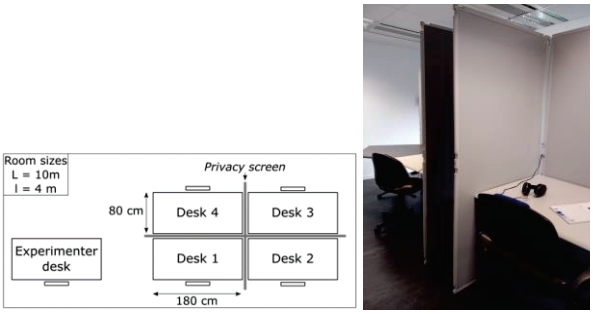

Figure 2. Experimental set-up.

Sennheiser HD650 headphones playing the stimuli described in section 2.1 were placed at each workstation. The sound system (sound card + headphones) was equalized and calibrated to reproduce the 0 dB SNR condition for a normal hearing listener at a level of 57 dB(A) on headphones. The sound levels for the simulated hearing losses were between 33 and 34.5 dB(A) without hearing aids and between 38.5 and 47.5 dB(A) with hearing aids, depending on the SNR condition.

2.2.4 Statistical Analysis

All statistical analyses were repeated measures analyses of variance. Analyses were performed with R, package afex [11]. P-values presented take into account the Greenhouse-Geisser corrections when sphericity conditions were not met.

3. RESULTS

An initial analysis of the performance of all the participants was carried out. This analysis identified a group of 7 participants who were suspected of lacking commitment to the experiment. These participants were therefore excluded from the analysis.
In general, no effect of overall SNR on the different dimensions assessed could be demonstrated. On the other hand, the use of hearing aids (during simulated hearing losses) had a weak significant effect on mental fatigue and external workload (representative of the external environment), and a strong significant effect on perception of the sound environment. This is evident in all three dimensions of the noise environment assessed: noisy, annoying, tiring.
For example, the results of the analysis of variance show that the wearing of hearing aids leads to a significant difference ($F(1,37 = 67.41$, $p < .001$, $\eta_g^2 = .018$) in the estimation of the annoyance dimension between the condition with hearing aids ($M = 4.31$, $SD = 2.05$) and without hearing aids ($M = 2.59$, $SD = 1.68$). Mean values are given Figure 3.

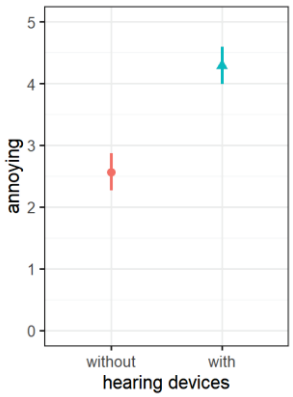

Figure 3. Mean values of the responses from the assessment of the perception of the noise environment on the annoyance dimension.

4. CONCLUSION

The signal-to-noise ratios chosen did not show any significant (or very small) differences in the perceptual dimensions evaluated. On the other hand, the use of hearing aids, which leads to an increase in the overall level and an improvement in intelligibility, has a negative effect on the users in that it affects the variation in mental fatigue. This effect is also visible in the external mental workload rating, which is characteristic of the external environment. Finally, this effect is particularly marked on the three perceptual dimensions of the noise environment, namely noisy, annoying and tiring.

So, in the specific case of open-plan offices where the work task performed requires concentration, the use of hearing aids might not be beneficial for hearing impaired people, knowing that, in this study, the hearing loss was simulated on normal hearing people. This may be a limitation on the approach that should be discussed during the conference.

5. ACKNOWLEDGMENTS

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