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A study of noise-induced annoyance and fatigue in open-plan offices: comparison between hearing-impaired and normal-hearing listeners

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ABSTRACT

Several studies outline a future scenario of longer working lives and later retirement, meaning that there could be a large number of elderly workers in offices. Add to this the natural effect of hearing loss due to ageing (presbycusis; which usually presents after the 5th decade of life) and you have an open door to questions regarding the acoustic comfort of this group. In a first study,

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it was shown that the effect of intelligible speech on performance in a serial recall task is similar for listeners with normal hearing and presbycusis. The aim of this new experiment is to assess whether any differences might occur when people are involved in a more ecologically valid task (long exposure to noise - 3 h/condition - and similar tasks to those performed in open-plan offices). Given the validation of a hearing loss simulator in previous studies, this one will be used to reproduce the group of people with mild hearing loss (onset of presbycusis). Therefore, the same group of people (32 participants) with normal hearing will perform the experiment under two listening conditions, with and without the simulator. Each listening condition will have two noise conditions, irrelevant speech, each with a different intelligibility level.

1. INTRODUCTION

The need for more inclusive acoustic environments is clear due to the increasing prevalence of hearing loss among the elderly. This is coupled with demographic shifts towards an aging population and extended working lives owing to pension reforms.

Age-related hearing loss, commonly known as presbycusis, primarily affects those over 50 years old [1]. This condition is influenced by various factors, including genetics, pre-existing ear conditions, chronic illnesses, noise exposure, medication, and lifestyle choices [2, 3]. Global Burden of Disease estimates indicate that over 65% of individuals over 60 years old experience some degree of hearing loss [4].

The aging population exacerbates the problem, especially in countries with a significant portion of the population over 65 years old. This demographic shift introduces economic challenges, requiring potential changes in retirement ages and pension systems [5]. Moreover, a notable proportion of seniors are participating in the labor force in some countries [6, 7], emphasizing the importance of considering hearing impairment demands in workplace design.

Apart from hearing disorders, these individuals face challenges intrinsic to modern work environments, such as open-plan offices. Noise, a primary distraction source, has been linked to reduced employee satisfaction and productivity in open-plan offices [8, 9]. Even noise levels below 60 dBA can interact with work-related stress to significantly impact well-being [10]. Among various noise sources, speech stands out as the most disruptive, affecting cognitive tasks [11].

Given that the adverse effects of speech noise extend beyond mere decrease in performance in exposed individuals, it is also important to assess its impact on psychological factors such as perceived fatigue, mental workload, and noise annoyance [12].

These effects are often difficult to assess in short experiments. Therefore, this work is intended to assess the impact of prolonged noise exposure while performing clerical tasks on people with normal hearing and people with mild age-related hearing loss, and compare their results.

2. EXPERIMENT

This study aims to simulate the working day in an open-plan office, performing clerical tasks (such as reading, note-taking, writing, etc.) in the presence of continuous speech noise and to investigate how the noise affects the comfort (fatigue and annoyance) of occupants with normal hearing and those with hearing loss.

2.1. Participants

Thirty-two normal-hearing native French speakers (age range = 18-60) will be recruited by a company specializing in recruitment for research experiments. All participants will be informed about the aims of the study. They will provide their written consent and receive monetary compensation for their participation.

2.2. Procedure

The experiment will be conducted in the semi-anechoic chamber of the Laboratory of Vibration and Acoustics at INSA Lyon. Four workstations will be set up in the chamber at equal distances from an omnidirectional source which will diffuse the stimuli.

Thanks to the validation of a hearing loss simulator, developed by Grimault et al. [13], in previous experiments [14], it will again be used to replace a group of elderly people in the early stages of presbycusis (mild hearing loss). Thus, all the participants have a normal-hearing, and will be tested in two hearing conditions: with and without the simulator.

As for the noise conditions, analysis of the results of the previous experiment led us to choose four conditions, two with the simulator (SNR -9.0 and -4.5 dB) and two without it (SNR -4.5 and 7.5 dB) - for a mix of speech and white noise, both LTASS filtered [15]. The choice of these values is based on the fact that the conditions with the simulator at SNR 7.5 dB and without the simulator at SNR -4.5 dB have a similar level of speech intelligibility (68.3% and 63.3% respectively, for sentences) [14] and induce an equivalent Decrease in Performance in a serial recall task (5.9% and 5.8% respectively) [14], and should therefore yield similar psychological effects at long exposure. The other two conditions were chosen because they have a very low intelligibility level, close to zero (but maintaining a speech-like quality), which would allow us to understand whether the annoyance of long exposure has a unidirectional relationship with intelligibility or whether other parameters are equally or more important.

The stimuli consist of podcast-style dialogues in French (two voices) about different topics. Stimuli for conditions with and without the simulator will be diffused at the same level - 60 dB(A). However, the simulator (with the chosen loss profile) produces a significant reduction in sound pressure level, around 20 dB compared with the reference level, i.e. stimuli with simulator would have a sound level of around 40 dB(A).

The experiment will proceed as follows: each participant will come to the laboratory to take part in four sessions, where each session will represent a different noise condition and will last 3h10min, 2h55 in the noise. In each session, participants will receive two documents consisting of a compilation of press reports and articles on a specific topic, unrelated to the stimuli. Each document will serve as the basis for the following tasks: press review and note-taking; summary writing on the subject; and answering multiple choice questions (MCQ).

The documents are composed of a set of main texts with around 9,500 words in total, equivalent to 40 minutes of reading [17], plus a supplementary text of around 2,000 words to ensure that participants will have material to work with in case they finish their reading and note-taking before the 45 minutes. Note-taking will be done with pencil and paper. Each document addresses a specific theme. However, each text addresses a different aspect of the subject, without repeating the content, so as to avoid shallow reading.

After reading and note-taking, the compilation of texts will be collected and participants will be requested to write a summary of the texts read (they can use the notes taken in the previous step). As some participants may find it difficult to write a proper summary of the topics, they will be asked to write down what they have understood and retained from the texts read over the 15 minutes, without necessarily following the formal structure. Participants will write on a computer (with silent-like keyboard), using the software ScriptLog [18] to register and analyze writing process.

After writing, all the material will be collected and participants will have 15 minutes to answer 20 MCQs based on the main texts (supplementary texts have not been taken into account). Since there are two documents per session, the same dynamic will be repeated for the second document after a short break, Figure 1.

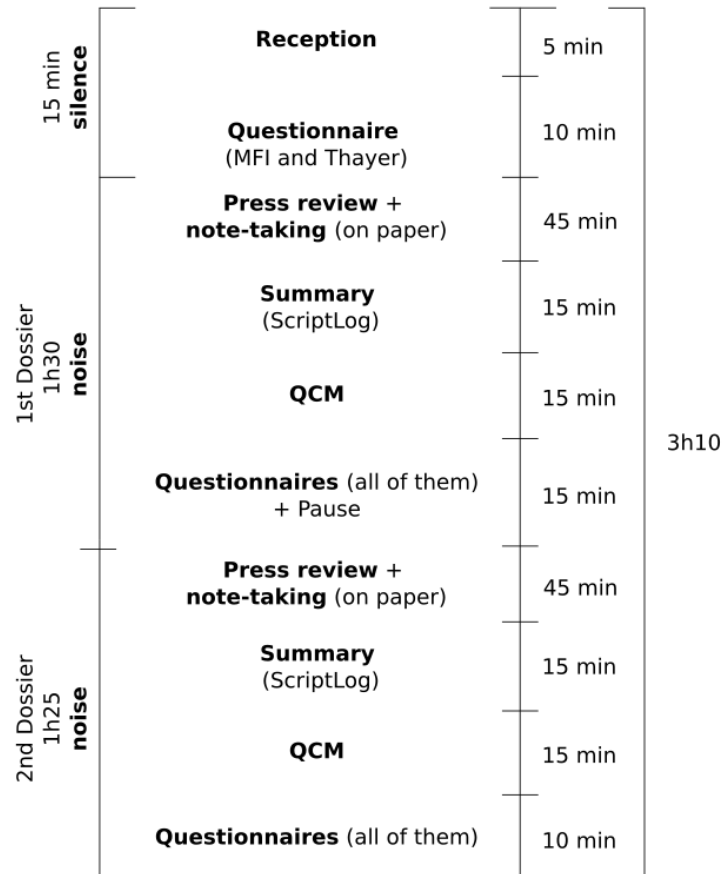


Figure 1: The experimental planning.

Fatigue and annoyance will be assessed using four questionnaires: perception of the sound environment [19], Individual - Workload - Activity (IWA) [20], Multidimensional Fatigue Inventory (MFI) [21] and Thayer [22]. The questionnaires will be administered three times during each session - in silence, before the start of the experiment (MFI and Thayer only); after the end of the first document, in noise (all questionnaires); and at the end of the experiment, in noise (all questionnaires) - allowing us to monitor the evolution of these parameters over time. Participants will have 10 minutes each time to answer the questionnaires. At the end of the four sessions of experiment, the participants will answer a Hyperacusis Questionnaire [23]. Each participant will participate in the four sessions on different days and at the same time of day (morning or afternoon), so as to always have the same state in their circadian cycle [24].

3. RESULTS

The results will be presented at the conference.

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