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Compared effects of overall level and speech intelligibility on self-reported fatigue in open-plan offices: a laboratory study

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Extended ABSTRACT

It seems now accepted that speech noise in open plan offices is the main source of annoyance for employees [1]–[3]. Multiple laboratory studies have also shown the effect of speech on the participants performing different types of tasks (short-term memory task, arithmetic tasks, perceptive evaluation of sound annoyance etc.) [4]–[6]. During laboratory studies, it appears that the intelligible speech decreases participants' performances compared to stationary noise or babble speech. [7] shows that babble speech is more disruptive when it contains samples of intelligible speech from time to time. Recently, the second experiment in [8] explains that the intelligible speech effect also impacts the psychological state of the participants compared to stationary noise and speech-like modulated noise. During the experiment the participants' exposure time for each sound condition was six hours and forty-five minutes. During this time, the participants completed a press-review task, which seems to be a more ecologically valid task than a memory task. The author [8] concluded that the intelligible speech increased the self-reported fatigue and this effect was significantly more important with the increment of time exposure, which was not the case for the other two conditions (stationary and speech-like modulated noises). The results showed that this increment appears to be significantly important even during the first half-day.

Furthermore, multiple studies use STI (Speech Transmission Index) to measure speech intelligibility. However, in *in-situ* conditions it is not always possible to identify the speaker. The ambient noise is mostly composed of more or less intelligible conversations happening in the same time. The acoustic level of these conversations varies with time. To measure these variations and the time-dependent modulations, [9] have proposed an indicator called *MAeq*, which is a simple difference between the sound acoustic level *LAeq* and its *L90* fractile index.

The aim of the present study is to compare the effects of *MAeq* and *LAeq* in for four sound conditions representative of ambient noise in open plan offices, while the participants perform a task closer to the everyday open-plan office work (press-review task).

We conducted the experiment in a semi-anechoic room. Multiple participants could work at the same time, the maximum occupational capacity being six participants. An omnidirectional sound source was installed in the

center of the room at a height of 4 meters. The workplaces were in circle around the sound source so the acoustic field was homogeneous among participants. Forty-five subjects, thirty-two females and thirteen males, between 18 and 58 years old participated to the experiment.

They were exposed to four controlled sound conditions, made of intelligible speech superimposed to babble noise. The equivalent modulation index *MAeq* and the overall level *LAeq* were the two control factors (two levels each). The *MAeq* was either 3 dB(A) or 10 dB(A) and the *LAeq* was either 50 dB(A) or 55 dB(A). The combination of these values for both factors gave us four different sound conditions. The duration of sound exposure was three hours and twenty minutes for each sound condition. The intelligible speech signal was a series of one-minute-samples, randomly taken from different audio books. For each sound condition the series of the samples was different. The babble noise was a sum of ten voices taken from the same database of audio-books, having the same overall level. A signal-to-noise ratio was applied for each one-minute-sample superimposed to the babble noise, to have the desired values of *MAeq*.

During each sound condition the participants responded to multiple questionnaires so we can measure different psychological indicators such as self-reported fatigue, sound annoyance, sound perceived fatigue, workload, sleepiness, etc. During the exposure time, the participants responded to the questionnaires three times. The rest of the time they completed their principal task of the workday. The task consisted in writing a review of four newspapers. The interest of this task is that it can last multiple hours and it activates different cognitive processes such as: the generation of ideas, the long and short-term memory, the organization and the transformation of the ideas into orthographic presentation [10], [11].

Each person participated during four different half days of four hours. They were separated in 8 groups and each group was exposed to the sound conditions with a different order. During each half-day the participant had one break of ten minutes in the middle of the session. The experimenter was present in the room with the participants so he/she can survey the work, and follow each step of the experiment with a rigorous protocol. The experiment lasted one month and a half.

Finally, the statistical analyses were performed with respect to three factors, the two sound characteristics

(MAeq and LAeq) and the time of the half-day. The results show that a high intelligibility, which corresponds to a high MAeq value, significantly increased the self-reported fatigue, the sound annoyance and the sleepiness experienced by the participants. On the other hand, an increase of overall level did not significantly modify these values. Lastly, the results of this experiment were compared to a previous experiment conducted by Kostallari [8]. We concluded that, for all sound conditions, in both experiments, speech noise has a higher impact on the self-reported fatigue of the participants, compared to stationary noise or to the 'speech like' amplitude-modulated noise.

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