Applied Acoustics 118 (2017) 1–7

Contents lists available at ScienceDirect

Applied Acoustics

journal homepage: www.elsevier.com/locate/apacoust

Background babble in open-plan offices: A natural masker of disruptive speech?

Maria Zaglauer [a,b,*], Horst Drotleff [a], Andreas Liebl [a]

[a] Fraunhofer Institute for Building Physics, Nobelstraße 12, 70569 Stuttgart, Germany
[b] University of Hohenheim, Business and Organizational Psychology, Wollgrasweg 49, 70599 Stuttgart, Germany

ARTICLE INFO

Article history:
Received 2 June 2016
Received in revised form 8 October 2016
Accepted 8 November 2016
Available online 21 November 2016

Keywords:
Sound masking
Irrelevant sound effect
Babble effect
Speech privacy
Open-plan office
ISO Standard 3382-3

ABSTRACT

Numerous studies have shown that task-irrelevant background speech impairs performance of verbal short-term memory. This well-established effect is related to practice in open-plan offices, where employees are potentially disturbed by the speech of their colleagues. One option to reduce the disruptive effect is by masking the speech, for example, using random noise. Based on past research by Jones and Macken (1995), the ISO Standard 3382-3 (2012) assumes that multiple background speakers in open-plan offices may mask each other in a natural way, consequently reducing the disruptive effect of speech. The aim of this study was to check this assumption using a realistic acoustical simulation of an open-plan office situation. A combination of a nearby speaker and a varying number of background speakers was played to 26 participants while they performed on a verbal short-term memory task. Additionally, the intelligibility of the presented speaker sentences, levels of annoyance, and workload were checked. The results show a significant trend towards an improvement of short-term memory performance when the number of babble voices grows from one to six. However, performance levels are far from those reached under silent conditions. Moreover, annoyance and measures of subjective workload did not diminish due to babble masking.

1. Introduction

1.1. Background speech impairs cognitive performance, privacy and comfort

In open-plan offices workers often complain about noise, especially speech of talking people at adjacent desks, e.g. [3]. Task irrelevant background speech in open-plan offices is judged to be annoying [4] and is related to an increased mental workload [5]. Furthermore, numerous laboratory studies in the field of cognitive psychology have shown that irrelevant background speech impairs cognitive performance significantly. The effect of background speech on verbal short-term memory performance was first described by Colle and Welsh [6] and has been replicated by a wide series of studies e.g., [7–9]. Beyond these findings, there is growing evidence that background speech affects performance in several other tasks, such as mental arithmetic [7,10], proofreading [5,11,12], or reading comprehension [13,14].

Disturbing effects of background speech are of special practical relevance in open-plan offices, where employees are potentially distracted by the speech of their colleagues. It was found that the disruptive power of speech is not dependent on sound level, but mainly on speech intelligibility [6,7], which can be physically described by the speech transmission index (STI) [15]. STI can obtain values between 0 (speech cannot be heard) and 1 (excellent speech intelligibility) and describes the loss of modulation depth from sender to receiver, which is influenced by the reverberation time and background noise of the room. Hongisto [16] developed a model which describes the decrease in performance due to background speech compared to performance in silence as a function of the STI. It predicts the highest decrease in performance when speech is highly intelligible (STI > 0.70) and no decrease in performance when no speech can be heard at all (STI = 0.00). The author recommends STI values below 0.5 to reduce negative effects of background speech on performance. According to the model the decrease in performance begins to diminish at STI below 0.5. Based on the model, the distraction distance, also referred to as radius of distraction, is defined as the distance where STI falls below 0.5 [2]. It is assumed that people working within the radius of distraction of a particular person are strongly affected by its speech, whereas

* Corresponding author at: Fraunhofer Institute for Building Physics, Nobelstraße 12, 70569 Stuttgart, Germany.

E-mail address: maria.zaglauer@ibp.fraunhofer.de (M. Zaglauer).

http://dx.doi.org/10.1016/j.apacoust.2016.11.004
0003-682X/

people placed outside the radius of distraction will be disturbed much less.

In open workplaces, highly intelligible speech does not only impair cognitive performance, but comfort, as well, e.g. [11]. In the field of acoustic research, speech privacy is defined as the opposite of speech intelligibility, which is expressed by different measures as the articulation index (AI) or speech transmission index (STI), e.g. [17–19]. When speech can be overheard by colleagues, it is impossible to have confidential conversations. Moreover workers are compelled to follow conversations around them, even if the content is irrelevant or uninteresting to them.

1.2. Sound masking and the "babble effect"

But how can speech intelligibility in open-plan offices be reduced? According to Bradley [20] and Hongisto [16], there are three important factors to be considered: improving isolation, e.g., using higher screens, increasing absorption, and masking the speech, e.g., using broadband noise. Furthermore, there are some indications from older studies suggesting that background speech itself may function as a masker of distracting speech. Jones and Macken [1] found that six background speakers caused less disruption on performance in a serial-recall task than one or two background speakers. It was shown that the disruptive effect is already reduced when there are at least four speakers and that error rates continue to decline when the number of speakers is further raised to five or six. The improvement of performance by a group of speakers compared to the single-speaker situation is referred to as the "babble effect". Similar results have been reported by Kilcher and Hellbrück [9], who found reduced error rates under conditions with eight background voices.

Based on these findings, ISO Standard 3382-3 [2] mentions that the masking of background speech may occur naturally in open-plan offices. More specifically, it is assumed that a number of people talking at the same time will mask each other, consequently reducing the disturbing effect of background speech. This raises the question whether and to what extent there are actual positive effects of babble speech in open-plan offices. Is there also a possible benefit of multi-person offices compared to a two- or three-person office, besides the well-known acoustical disadvantages?

The aim of the present study was to investigate the possibility of the natural occurrence of babble-masking in open-plan offices. In order to test this assumption, it was examined whether the distracting speech of a person at a nearby desk can be masked by speakers in the background. In contrast to previous experiments by Jones and Macken [1], the speaker, who is a source of disturbance to the receiver, and the babbling voices were placed at different spots in an acoustically simulated open-plan office. More precisely, the receiver was placed within the distraction distance, whereas the babble speakers were positioned outside the radius of distraction, in order to minimize their distracting influence on the receiver. In accordance with the ISO Standard 3382-3 [2], distraction distance in this study is defined as the point where the STI falls below 0.5. At this point, a decrease in performance is expected to reach its maximum or plateau, and below this point, negative effects on performance are expected to start to diminish. It should, however, be mentioned that there are already some indications that the STI may even have to be reduced to a level below 0.5. Ebissou et al. [21] for example found that the maximum decrease in performance is already achieved at STI 0.45 – although this only applies to "low-performing" individuals. A study by Jahncke et al. [22] suggests that maximum loss in performance can even occur at STI 0.35, depending on the type of task. Hongisto [16] also stated that more studies have to be done to refine the model, especially in the range of STI values between 0.2 and 0.6, where the biggest change in performance is expected to take place.

Additionally some comments on the calculation of the STI in this study should be made. In order to determine the STI-value of a particular speech signal, the loss of modulation depth from sender to receiver, which is influenced by the reverberation time and background noise, has to be calculated. Corresponding to ISO 3382-3, the required measurements are usually performed in vacant rooms and background speech is not regarded as background noise. Nevertheless, it was necessary to treat babble speakers as noise in this study in order to test our hypothesis. Besides that, ISO 3382-3 similarly suggests this procedure, assuming background speech to have a masking effect.

With respect to the hypothesis, it was expected that performance in a serial recall task which refers to verbal short-term memory performance will improve with a growing number of background voices. More specifically, one speaker without any background speakers should produce the highest degree of disruption compared to silence. Error rates should decrease significantly with an increasing number of added background voices and a reduction of the STI. Additionally, the performance in a speech intelligibility task was expected to decrease as the number of background speakers was raised. We expected subjective ratings of workload, specifically mental demand, effort, and frustration, to decrease and perceived success to improve when the number of babble speakers was increased.

2. Material and methods

2.1. Participants

A total of 26 students (9 female, 17 male) aged 16–28 years (M = 23.5; SD = 2.8) took part in the experiment. They were paid 20 euros for their participation.

2.2. Materials and sounds

On the basis of previous work [1] the maximum number of babble speakers in this study was set to six. An acoustically simulated open-plan office was generated using ODEON, which is a room acoustics software for measurement, simulation and auralisation. Dimensions of the room were 16.8 m × 15.0 m × 3.0 m (length × width × height). Reverberation time of the virtual room was T_{30} = 0.58 s. The spatial decay rate $D_{2,S}$ of the sound pressure level was calculated for three measuring paths corresponding to ISO 3382-3. For the first, second and third path the resulting $D_{2,S}$-

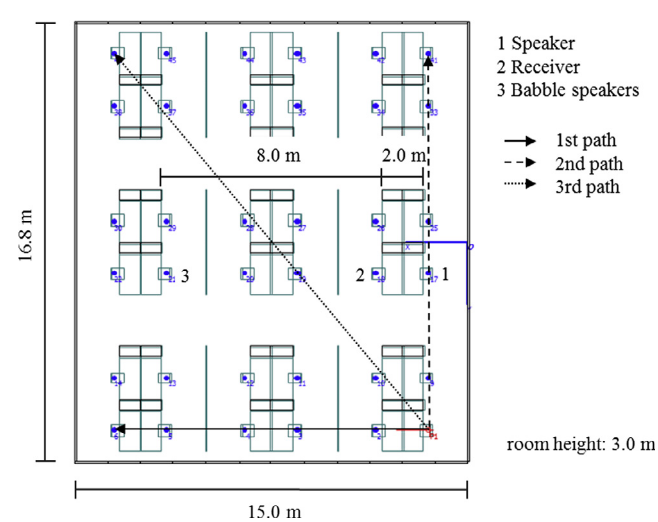

Fig. 1. Schematic top view of the acoustically simulated open-plan office.