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Disruption of writing by background speech: The role of speech transmission index

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ABSTRACT

Speech transmission index (STI) is an objective measure of the acoustic properties of office environments and is used to specify norms for acceptable acoustic work conditions. Yet, the tasks used to evaluate the effects of varying STIs on work performance have often been focusing on memory (as memory of visually presented words) and reading tasks and may not give a complete view of the severity even of low STI values (i.e., when speech intelligibility is low). Against this background, we used a more typical office-work task in the present study. The participants were asked to write short essays (5 min per essay) in 5 different STI conditions (0.08; 0.23; 0.34; 0.50; and 0.71). Writing fluency dropped drastically and the number of pauses longer than 5 s increased at STI values above 0.23. This study shows that realistic work-related performance drops even at low STI values and has implications for how to evaluate acoustic conditions in school and office environments.

1. Introduction

Undesired background speech in offices and similar environments potentially impairs work-related skills like writing [1–3], reading comprehension [4,5], proofreading [6–8], and prose memory [9,10]. Occupational noise, and speech in particular, are amongst the most often mentioned sources of annoyance at work [11–13], decreases satisfaction with the work environment [14], and are stressful [15,16]. Thus, performance and health are challenged when working in open-office environments wherein background sound, like talking colleagues, ringing phones, noise from copying machines, and so on, is common place.

One objective predictor that is used to evaluate the acoustic environment is the Speech transmission index (STI) e.g., [17]. STI is a physical measure of speech intelligibility (i.e., the possibility to hear what is said) and is standardized by IEC 60268-16 [18]. It ranges from perfect speech intelligibility (i.e., 1.00) to no intelligibility at all (i.e., 0) and depends mostly on signal-to-noise ratio, reverberation and the amount of early reflections between the source and the receiver. A number of studies have investigated the relation between STI values of background sound and work-related performance e.g., [8,19–21]. A dominant view developed by Hongisto [17] is that performance drops most drastically when the background speech has an STI around 0.30 and 0.40, and that the decrement in performance fades out after an STI of 0.50.

Hongisto's model is based on a generalization across several, different cognitive tasks. More recent studies have investigated the influence of STI on specific tasks and those studies indicate that marked performance decrements are observed with as low STI values as 0.34 [21], and that there is no significant decrease in performance with exceeding STI values. The tasks used in those studies were a short-term memory task denoting recall of visually presented word sequences; an information search task with the instruction to search through a matrix to find answers on certain questions; a math task containing addition of three-digit numbers; and a phonemic and semantic fluency task that requires generation of words from specific categories (i.e. animals or vegetables). In all, the type of tasks used to demonstrate this potentially disruptive effect of relatively low STI values have been rather unrepresentative for office work (e.g., memory of visually presented word sequences) and there is little reason to assume that this type of task is particularly sensitive to disruption from background speech e.g., [9]. In an attempt to improve upon past studies, we used word processed writing in the present experiment as a tool to investigate whether marked performance decrements kick in at relatively low STI values in a more realistic and common type of office related task—word processed writing—that is known to be particularly susceptible to disruption from background speech.

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Several cognitive processes are involved in writing such as idea generation, retrieval from long-term memory, organizing ideas and transforming thoughts and ideas into orthographic representations [22]. Most essentially, writing requires processing of meaning, a situation that makes writing easily disrupted by the presence of background speech [26,27]. For instance, Sörqvist et al. [3] found that writing performance is impaired by background speech (predominantly an impairment of quantitative aspects of the writing process such as writing fluency, but also an increase in pauses during the writing process) in comparison with a silent condition and with a condition wherein the background sound consisted of a spectrally-rotated version of the speech signal. The impairment of writing fluency (the sum obtained when adding deleted characters to the total number of characters in the final edited text) and an increase in the number of pauses (longer than 5 s) by background speech have also been confirmed in related studies [1,2]. Thus, writing (especially writing fluency) appears to be impaired specifically by the meaning of background speech, whereas acoustic properties of the sound are not especially disruptive. This finding fits well with the general view that deliberate semantic processes (e.g., interpreting the meaning of a word) is disrupted by meaningful background speech, because the meaning of the background speech is semantically analyzed, and this involuntary analysis activates cognitive representations in semantic memory that interfere with the execution of the deliberate semantic processes [23–25].

In accordance with this interference-by-process view, writing processes should be increasingly impaired as STI values increases, because higher STI value are associated with higher speech intelligibility. In low STI conditions, the semanticity of the background speech is hardly noticeable, meaning there will be no (or at least only weak) conflict with the deliberate semantic processes. In the present study, the function between STI and writing performance was investigated by using five different STI conditions, giving a more fine-tuned manipulation of background speech intelligibility than in the study by Sörqvist et al. [3]. The expectations in the present study were that writing fluency would decrease, and the number of pauses above 5 s would increase, as a function of background speech intelligibility. Specifically, writing fluency should drop as STI value increases and the largest drop should be observed at values around 0.34. Moreover, the number of pauses should increase with increasing STI and the largest increase should be found around 0.34.

2. Methods

2.1. Participants

A total of 33 students (mean age = 25.36 years, SD = 5.99) at the University of Gävle participated in the study. All participants had completed Swedish compulsory school and high school and all participants had normal or corrected to normal vision. One participant reported hearing loss. As this person's data were not markedly different from the sample means, and control analyses without this person's data excluded were entirely consistent with analyses with those data included, data from this person were included in the reported analyses. The participants received a cinema ticket for participation.

2.2. Apparatus and materials

2.2.1. Sound

The irrelevant speech consisted of five different stories. The stories were about different topics (e.g., frogs' and fish's ability to predict weather and history of poems). They were spoken in a male voice and binaurally recorded at 44.1 kHz using an artificial head (Head Acoustics HMS IV) in an anechoic chamber at 0 degrees azimuth. Octave levels for the five stories are presented in Fig. 1. Each story was masked by binaurally uncorrelated pink noise (i.e., equal level at every third octave band) to produce five different STI values (0.08, 0.23, 0.34, 0.50, and 0.71). The pink noise was band-pass filtered between 22 Hz and 18 kHz. The better-ear STI value was used, as recommended in [18]; however, the experimental setup caused insignificant binaural differences. The equivalent A-weighted levels (summed for left and right channel) were normalized between sound files. See Fig. 2 for an overview of how the sound stimuli were composed. In all, a total of 25 sound files were used. All sound stimuli were presented through headphones (Sennheiser HD 202) at approximately 60 dBA, corresponding to the sound level of a conversation within 1–2 m. The noise level is typically a little lower (45–55 dBA) in open office environments [18].

2.2.2. Writing task

The participants were asked to write five stories associated with different target-words displayed on a computer screen. The target-words were the names of different nature scenes (i.e., forest, desert, sea, field, and mountains). A different name was used for each story. They were presented in the same sequential order to all participants. The onset and the offset of the target-word and the sound were synchronized. The time limit for each story was set to five minutes. After five minutes, a warning signal was played in the headphones and the participants received spoken instructions that told them to delete all written text and press a button to pass onto the next condition. The computer software ScriptLog was used to obtain data. This program is developed for real-time analysis of the writing process and it registers all keyboard activity. This makes it possible to replay the writing sequence for real-time analysis and to extract relevant statistics automatically by using the built-in functions.

2.3. Dependent variables

Two dependent variables were extracted using ScriptLog: writing fluency (i.e., the number of characters in the final edited text plus the number of characters deleted during the writing process) and the number of pauses longer than 5 s. Another set of potentially relevant dependent variables (the same as in Sörqvist et al. [3]) was also considered but did not reveal anything valuable beyond the two reported.

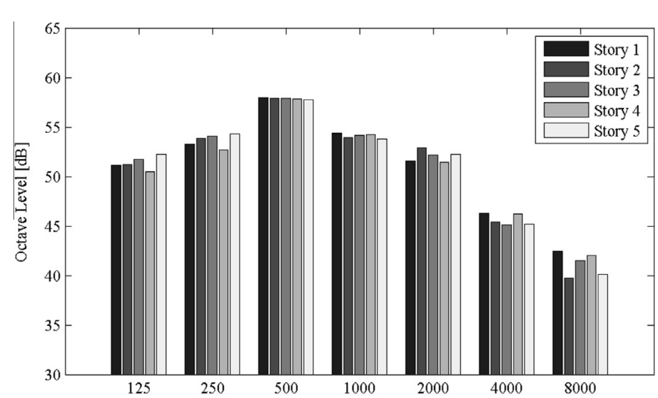

Fig. 1. The sound pressure levels in octave bands for the 5 different speech stories plotted for the ear with maximum A-weighted level.