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Effects of background speech on reading performance in adults

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Among the various factors that determine the working environment, noise is often rated as stressful by many employees. It is known that cognitive performance can be affected by background noise, even at moderate sound pressure levels. As reading is an essential requirement at work, a proofreading task was developed and applied to investigate effects of noise. The procedure was designed as a computer-based task for adult workers with normal reading ability. The participants had to find and mark mistakes in written sentences, under time pressure. In a pilot study, 12 participants worked on this task twice, once in a silence condition and once during the presentation of background speech at a moderate sound pressure level. With respect to the two different experimental conditions, it was found that there were significantly more correctly finished items and less reported effort in the silence condition than in the speech sound condition. The results indicate that the new procedure may have the potential to serve as an instrument for the quantification of effects of noise or specific noise characteristics on one important aspect of cognitive performance at work.

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1. INTRODUCTION

There are many factors that determine the environment at a particular workplace, for example: room size, space at workplace, furnishings, equipment, climate, illumination, and also the acoustical conditions. Noise is often rated as stressful by many employees, among the factors constituting the work environment, and in some professions noise is often named as a reason for calling consultation. This does not only hold for work places with especially high noise levels, like in certain industries; this even holds for work places with typically lower noise levels, e.g., noise in hospitals, schools, or offices.

It is well known that noise at high levels causes hearing damage. Therefore, occupational safety and health regulations exist stating that employers have to protect their workers from this possible impairment, by noise reduction, instruction and finally by using personal protective equipment. The prevention of noise induced hearing loss (auditory effect of noise) as a result of long term exposure to high sound levels is an important concern in the frame of the efforts in occupational safety and health. In addition to this concern, the question whether and to what amount noise at high and also at lower levels may also cause other detrimental, non-auditory effects on employees, like effects on the cardiovascular system, performance or mental stress, gained more and more interest in recent years.

This research deals with the effects of noise on one aspect of cognitive performance represented by effects on reading. For many years, it has been well investigated and documented in numerous studies that spoken language as an unwanted background sound affects working memory (e.g., [1; 2]). Working memory is of course involved in many cognitive tasks, but the tasks typically used to test the working memory (e.g., “serial recall”, i.e., repeating numbers or words in the same sequence as presented) are to some extent artificial tasks that are only rarely required in isolated form in working life.

Since the main interest was on possible effects on employees and typical tasks at the workplace, reading was chosen for this study as one representative task essential for many workplaces. This of course holds for office jobs but this also holds for jobs in many other settings, where for example, instructions on how to operate a machine have to be read accurately in order to work safely, or a report in a hospital setting has to be read correctly to choose the right medication for a patient.

Reading ability has different components, essentially reading fluency, reading accuracy, and reading comprehension. Therefore, reading performance in general can be measured in different ways and described along different parameters. Studies investigating effects of noise on reading have existed for many years, but the results about whether noise disturbs reading, or, more specifically, to what amount which characteristic of a sound disturbs which component of reading performance is not clear-cut (see, e.g., [3-6]).

As the following examples show, the comparison between different studies is often difficult, because different principles are used to measure the performance (different tasks that focus on different components), and also because the applied noise conditions and test settings are different. Weinstein [3] revealed a detrimental effect of moderate noise of a teletype machine on reading accuracy for contextual errors in a

proofreading task, while the noncontextual errors were not affected. In one of their experiments, Martin et al. [4] demonstrated that a task on reading comprehension was more affected by comprehensible background speech than by incomprehensible background speech, random noise or in a silent condition. Schwabe [5] did not find any detrimental effect of traffic noise on a three-hour proofreading task that merely contained typing errors. In a more recent study, Haka et al. [6] did not find a significant effect on performance in a proofreading task conducted in three acoustical background conditions with different speech transmission indices.

Because reading is such an essential part of everyday work, and effects of noise on reading even in safety critical situations might have considerable consequences, this topic should be treated in a more systematic way in future. A pilot study was undertaken as a step in this direction.

The aims of the pilot study were:

1) To test whether the in-house developed reading task is of practical usability for studies on noise effects on reading in employees.
2) To examine whether there are differences in the reading accuracy between a silence condition and a condition with background speech.

2. METHODS

A. READING TEST PROCEDURE

The preliminary design of the procedure had two different test versions (A and B). Both versions consisted of 52 items each. The items themselves were made up of one or two sentences of different length and content. The task was computer based, i.e., participants read the sentences on a computer screen. The items were either completely correct or they contained one mistake. The task for the participants was to read each item separately and to decide whether the item was correct or not. If the item contained a mistake, participants needed to mark the word that was not correct or that did not fit into the context of the sentence. If the item contained no mistake, participants were required to mark a field with the label “everything correct” (original: alles richtig).

After a decision for either a mistake or the field “everything correct”, participants clicked on a field labelled “finished” (original: fertig). The mistakes implemented in this procedure were of different quality. For example, there were orthographic mistakes, grammatical mistakes but also words that were not reasonable in the given context. The participants had to work on the sentences with time pressure. They knew that the sentences disappeared after a predefined time. Based on several pre-tests, the presentation time was set in a way to make the task challenging.

Finally, with this procedure, that can be titled as a proofreading task, information can be gathered about reading accuracy (number of correctly finished items), working speed (time for editing the items) and in part, about reading comprehension. The latter aspect only holds for those items with mistakes, where comprehension of relevant parts of the sentence is necessary in order to realize that one word does not fit with the rest of the statement. In this study, results referring to the reading test procedure focus on the number of correctly finished items.

The idea for this procedure was based on prior experience with a procedure the first author had developed for a study on noise effects in children [7]. The original procedure was shown to be sensitive to reveal effects on reading accuracy between different road traffic sounds [7-9]. Later the procedure was also applied in a study with adults, using considerably harder conditions concerning the time pressure and a speech noise condition. Again the procedure could uncover detrimental effects of noise on reading performance [10].

Based on these experiences, a new and separate procedure for adults was constructed as one next step. The main differences between the procedure for children and the new one for adults were: The contents of the sentences were adjusted to everyday life situations of adults, many of them with reference to working life; orthographic mistakes were inserted; the procedure was made computer based. The computer program used to implement the described application was an in-house development, especially created for this study. In the current form, the procedure was - concerning difficulty and time pressure - only appropriate for participants with normal reading ability.

B. ACOUSTICAL CONDITIONS

The reading task was applied in two different acoustical conditions: One condition without experimental background sound ("silence condition" or "silence") and one condition with background speech ("speech sound condition" or "speech"). In the speech sound condition, several sections from an audio drama were presented stereophonically via closed circumaural headphones (Sennheiser HD 380 pro). The mean sound pressure level for the entire maximal duration of the sound in the right ear was 62 dB(A) L_{eq} and in the left ear 57 dB(A) L_{eq}. The slight level difference was part of the setting of the audio drama. The recording contained scenes with different speakers sometimes in different rooms. The sound was played back with a notebook, the same computer that was also used to run the experimental task. Participants wore the headphones also in the silence condition, in order to give some shielding from unwanted sound events, but mainly in order to have a largely comparable situation as during the condition with speech sound.

C. EFFORT

After each test run, the participants were asked to assess the effort they experienced while they carried out the proofreading task. On the screen, they got a scale designed like a ruler from 0 (no effort at all) to 100 (very much effort). The personal judgment was marked as a stroke on this ruler by a mouse click.

D. PARTICIPANTS, STUDY DESIGN AND ROOM

Data from the first part of a pilot study are presented here. Twelve volunteers participated (age: from 26 to 62 years; male: 6; female: 6). All participants were staff members of the German Federal Institute for Occupational Safety and Health (BAuA). The participants differed in their particular jobs at the institution and the amount of prior experience with scientific studies. None of the participants knew the sentences and mistakes in advance. All volunteers carried out the test once in the silence condition and once in the condition with background speech. The sequence of the acoustical test conditions was balanced as well as the sequence of the test versions. In most cases the

two runs were carried out with an interval of one or two days between the different conditions. The study was carried out in 24 individual testings.

Before starting the first test run, all potential attendees got verbal information on the background of the research and written information about the current study. Once they agreed to participate, they signed an informed consent form. The participants then received written instructions about how to handle the actual task, followed by examples and training items simulating the subsequent test items on the computer. After the preparation phase, participants were asked to put the headphones on and to start the test sessions themselves. The pilot study was carried out in a quiet, single office room during typical daytime office working hours.

3. RESULTS

A. RANGE OF THE NUMBER OF CORRECTLY FINISHED ITEMS

Items were rated as finished correctly when they were completely edited correctly. That means the particular options required for items with a mistake and for items with no mistake were undertaken in time. The number of correctly finished items in the silence condition ranged from 27 to 45 items and in the speech sound condition, it ranged from 19 to 43 items.

B. EFFECT OF ACOUSTICAL CONDITION

A paired *t*-test revealed that the number of correctly finished items was significantly lower in the speech sound condition than in the silence condition ([$t(11) = 4.509$, $p = .001$]; *Mean* $(M)_{Silence} = 36.17$, $M_{Speech} = 31.33$; see Fig. 1). Differences were called "significant" when $p < .05$. The correlation coefficient (Pearson) between both conditions was $r = .88$.

C. DIFFERENCES BETWEEN TEST VERSION A AND VERSION B

The mean values for correctly finished items in versions A and B were generated by a calculation over all participants and both acoustical conditions. The mean value for version A was 34.17 items and for version B 33.33 items. This small difference was not statistically significant in a paired *t*-test [$t(11) = 0.465$, $p = .651$].

D. EFFORT

A paired *t*-test on the assessments of the effort during editing the items resulted in a statistically significant difference between both acoustical conditions. The ratings were significantly lower in the silence condition than in the speech sound condition ([$t(11) = -5.003$, $p < .01$]; $M_{Silence} = 42.17$, $M_{Speech} = 69.83$; see Fig. 2).

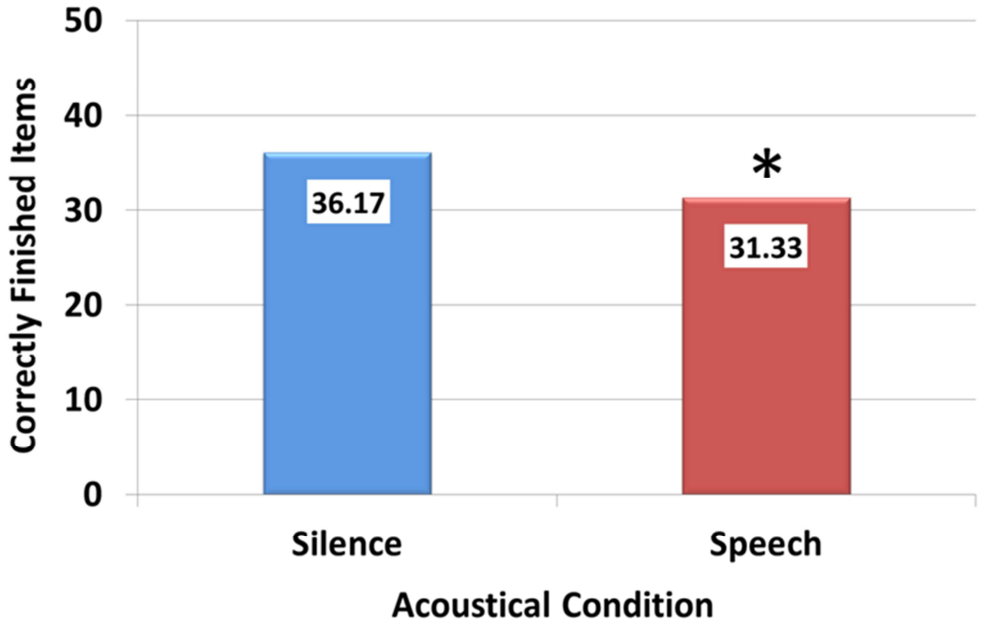

Figure 1. Number of correctly finished items in both acoustical conditions "Silence" and "Speech" (maximum number: 52 items, * = the difference is significant)

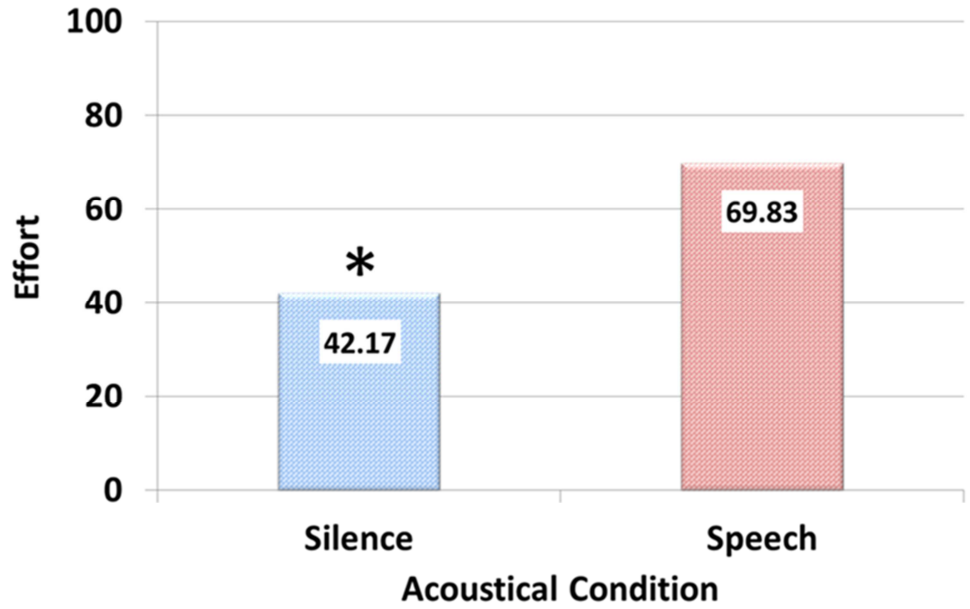

Figure 2. Rated effort during both acoustical conditions "Silence" and "Speech" (* = the difference is significant)

4. SUMMARY AND PROSPECTS

With respect to the first aim stated in the introduction, results suggest that the new reading task is of practical usability for studies on effects of noise on reading in adults. All volunteers got the instructions of the task quickly, and during a short conversation after the test runs, all test persons confirmed that the technical handling was easy. The range of the results shows that the procedure all in all was an adequate challenge for the tested group. There was a large variety in the results, but none of the attendants failed completely and nobody managed to find all mistakes in the given time. That means the procedure can cover a broad variety of reading accuracy. Most participants mentioned that there were a few (two or three) items which they would have liked to read twice, but the time given was over before doing so. There will be an in-depth analysis of these items, and if necessary the presentation time can be adapted, but in principle it is intended that the items are of diverse difficulty and that there are some items that will only be edited correctly by very few participants.

In reference to the second aim, there was a significant difference in reading accuracy between both acoustical conditions, even in this small group. Participants were less accurate in editing the items in the speech sound condition than in the silence condition. The proofreading task designed for this study appeared to be sensitive to effects caused by speech noise.

Several explanations are possible for the observed results. One reason might be the time restriction for each single item (time pressure) in combination with the uninterrupted test run. Both aspects together leave no chance to compensate for inaccuracy or a lack of attention in a noisy condition. Another reason why the proofreading was affected, e.g., in contrast to the results from Schwabe [5], might be the fact that intentionally the sentences contained a great variety of errors, also contextual errors, that are more likely to be affected by noise than errors that do not depend on the context [3]. In addition, due to the variety of errors in the current task, participants could not prepare for specific errors when they started to read an item.

As a next step the results from the first part of the pilot study (presented here) will be analysed together with data from a second part, also on aspects like effects on specific types of errors, difficulty of single items, training effects, and parallelism of the two test versions. A high level of parallelism and definite information about training effects are important requirements for any paradigm with a procedure that is to be carried out twice by one participant in a short time period. If there is a considerable training effect from one run to the next, for example, the training effect might mask a possible noise effect. Such a result finally may lead to an interpretation that a particular sound would not harm the performance in a particular test, although people feel disturbed by the noise. To avoid this sort of problems, it is necessary to deal with the respective test procedure in detail and thereby to keep an eye on the question how statements about effects of noise or the lack of observable effects at the work place are originally gained.

As mentioned above, there are many factors that constitute the work place environment and the entire work situation, and of course, reading is just one task that has to be carried out in a work-related setting. However, also in future research it is planned to stay with the reading task, since reading is essential in the daily work of many employees at different workplaces.

The task used in this study is still somewhat artificial. Nevertheless it is closer to reality than a serial recall task for numbers. The task contains several realistic elements. For example, it is a daily requirement for many employees that they have only a short moment to get a message from an e-mail or a report from the screen or that proof-reading has to be done under time pressure.

Since the first steps were successful, it is planned to refine the procedure to a straightforwardly applicable research instrument that might serve to gather detailed information about possible disturbance by different noise characteristics that are typical for work-related background sounds.

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