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INFLUENCE OF TRAFFIC SOUND PARAMETERS ON THE READING PERFORMANCE IN ELEMENTARY SCHOOL CHILDREN

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Abstract

Reading is an important and frequent activity in the daily life of school children. In addition to personal factors, reading development and reading skills can also be influenced by external factors, like e.g. environmental noise caused by airplanes, cars or trains. The question in the current study was, whether variations of the sound parameters "spectral shape" and "traffic density" in moderate road traffic sounds have an influence on the reading performance in elementary school children. The results show that a variation of a few isolated sound parameters can have an acute effect on reading performance even for moderate traffic noise. Despite of the small statistical significance achieved so far, further research in this field will be valuable, since the exposure to traffic noise is still increasing in our environment. In future research more variations along the chosen dimensions (spectral shape, realized by a filter procedure; traffic density) and also other sound parameters like loudness, tonal and temporal character should be investigated.

1. INTRODUCTION

Reading skills are of great relevance in the daily life of school children. Reading is needed for most classes and it is also relevant for many activities outside school. Problems with reading are well known for their cumulative effects and their stability over many years. So there are many reasons to take great care in preventing children from adverse effects caused by traffic noise, and noise-related disadvantages have to be regarded as a serious problem.

Of course, reading ability is also influenced by many personal factors and by many environmental factors which are not associated with traffic noise. In Germany, for example, the results of the PISA-Study (Programme for International Student Assessment of the OECD) [1] revealed a strong association between the social status and the reading ability measured as reading comprehension. Moreover the reading ability also depends on the competence of teachers and parents to introduce it in the appropriate way, especially in the first years of reading acquisition. In spite of the fact that there are many possible influences, ambient noise exposure also plays an important role, and many people are actually affected by at least moderate traffic noise.

Field studies conducted in areas with a high amount of traffic noise revealed that children exposed to chronic traffic noise have more problems (poorer performance) in reading tests than children from quiet or less noise exposed areas [2, 3]. These effects are denoted “chronic effects”, that means the effects even exist when the noise is momentarily not present. Although it is not deniable that chronic noise effects are an outcome of repeated situations of acute noise exposure, and adverse effects of acute noise on isolated cognitive functions like working memory have been demonstrated so far [4], only a few studies investigated the influence of *acute* noise exposure on reading skills as a complex capability [5].

At the University of Oldenburg, we carried out a laboratory study on effects of traffic noise on various aspects of cognitive performance in children. Within this study, the effects of acute noise exposure on reading skills were investigated. This study was conducted in the frame of the research network “Low Noise Traffic” funded by the German “Ministry of Education and Research”. The aims in this study can be described as follows: 1) The general aim was to investigate the effects of acute traffic noise on visually and auditory presented tasks under controlled laboratory conditions. 2) The tasks should have a high ecological validity for children from elementary schools. 3) Traffic noise at moderate levels should be used as sound condition, since moderate noise happens to be relevant for very many people. 4) An attenuation at low frequencies should be tested for its effects on performance and annoyance, because it is known that the disturbing character often is caused by low frequencies. 5) From the results the conclusion should be drawn, how traffic sounds could be modified to become less disturbing.

The study was carried out in three parts with a total of 277 children. In this contribution we focus on the first part, that included the investigation of the reading competence as a complex ability. Before we start to describe the study in detail we define the phrase “reading problems”, as it is used in this paper. By “reading problems” we do not mean dyslexia as a diagnosable disorder and we do not assume that noise-induced reading problems are supposed to cause dyslexia. We just mean that a child is hindered to develop his or her potential in reading ability by environmental noise, irrespective of whether the individual reading skills in general are of high or low standard.

2. METHODS

The assessment of reading performance is the main focus of this paper. In addition to a reading test, an arithmetic test was applied as a second cognitive task in the current study. Reading and arithmetic are supposed to be of high ecological validity because both skills are frequently demanded in the everyday life of school children. Both tasks were presented visually, that mean the tasks were presented on prepared sheets of paper. We also applied a noise assessment task [6]. The experimental sounds chosen for this part of the study were road traffic sounds which were presented at a comparatively low level.

2.1 Participants

The participants in the current study were 103 children (51 boys, 52 girls) from five different elementary schools. All children were in the third grade. They were aged between 8 years, 5 months and 11 years, 4 months (mean: 9.54 years). Eleven children were excluded from the data analysis, either because they did not finish the whole test following the instructions or because their results were identified as outliers or extreme values by a statistical procedure.

2.2 Sounds

During the cognitive performance tasks overall five sounds were used in this study: one control sound and four different experimental sounds. The control sound was a simulated motorway noise from 200 m distance and was used in the control condition to avoid the unnatural quietness in our sound lab. The experimental sounds also were road traffic sounds. They varied along two dimensions: traffic density (TD) and spectral shape, realized as attenuation of low frequencies (< 500 Hz) by a filter procedure (Filter). Both sound parameters, “traffic density” and “filter”, were varied in two steps: 500 and 2000 vehicles per hour; no filter, 12 dB attenuation at low frequencies. While the filter procedure represents a manipulation in the spectrum, the variation of traffic density emphasises a temporal change in the sound. The sounds were presented under free-field conditions using two loudspeakers and a subwoofer located at the front of the room. The presentation levels were 37 dB(A) for the control sound and varied between 49 and 57 dB(A) for the four different experimental sounds.

2.3 Tasks

2.3.1 Reading test

A new reading task was developed by the first author for the use in this study, because there were special demands concerning theoretical (context of noise effects) and organisational aspects (group application, parallel test forms, silent reading, short test time). None of the existing reading tests was rated as appropriate for this study.

The main idea of the test is to find mistakes in written sentences. This is in principle a very easy task for children aged about 9 or 10 years, and it is no problem to motivate the children to work on this task, because they are allowed to do something that is normally done by their teachers. Another advantage of this kind of test is that reading skills can be assessed by silent reading.

The test was constructed in two parallel test forms, with 48 items each. The items vary in length and complexity. Thirty-six items contain one mistake, twelve are correct. The mistakes will be denoted “experimental mistakes” throughout this paper. The two test forms are parallel with respect to the length of the sentences and the kind of experimental mistakes, realised as either grammatical mistakes (18 items) or semantic mistakes (18 items). The test allows to measure general reading fluency and also reading accuracy.

Before starting the test, example runs and practice items were given and the children were instructed in a standardized way. In this reading test the task for the children was to read silently on prepared sheets of paper. For each sentence the children had to decide if the sentence was correct or incorrect and subsequently mark this decision on the sheet in a defined way. If they decided for “incorrect” they were instructed to also mark the wrong word in the sentence.

2.3.2 Arithmetic task

The arithmetic task was used to measure attention and concentration. For this we used a modified version of the “KLT-R Konzentrations-Leistungs-Test” (concentration performance test) [7]. The test requires the solution of simple arithmetic problems. While doing the calculations the subjects have to store provisional results in short-term memory for use in the next calculation step. This intermediate step makes the test a task of high cognitive demand.

2.3.3 Noise assessment task

In this task the children had to judge short sound presentations according to their disturbing and humming character. Each child listened to three out of nine short segments of different road traffic sounds and also to a control sound. The children were asked: (1) Please imagine you are doing your homework. How disturbing would this sound be to you? (2) How humming („brummig“) do you feel this sound is? For each sound the participants had to mark their judgments by marking two rulers printed on a sheet of paper (one for each question) with a stroke at a number between zero and one hundred (for example: zero = not at all disturbing; 100 = very disturbing). Overall, the results showed that “traffic density” was the most prominent factor among the road traffic sounds. The factor “filter” appeared to be more relevant for the judgement of the humming character in case of high traffic density.

2.4 Procedure

All children worked twice on the reading task and the arithmetic task, once in the control condition and once in one of the four experimental conditions. We therefore had four sub-groups with different experimental conditions. Both the control and the experimental condition were carried out in the same session. The experimental order was balanced: 50% of the children started with the control and 50% with the experimental condition. At the end of the test session all children did the noise assessment task. The entire investigation took place in a sound insulated lab, with a maximum of six children simultaneously in one session. All test sessions were conducted by the first author, a psychologist with experience in investigations with children.

2.5 Data analysis

In this paper we just look at the effects of the filter and the traffic density. For this we combine the results either for both filter conditions or both traffic density conditions. Results for single sound conditions are not reported. The statistical analysis of the data was carried out using the statistics program SPSS. Two variables were created from the children’s response sheets:
(1) Number of correct items, i.e. the overall number of correctly identified experimental mistakes and the number of correctly identified right sentences. This number mainly represents the reading fluency, but also the reading accuracy.
(2) Error percentage, i.e. the number of items handled incorrectly divided by the overall number of items worked on (x 100). A high error percentage represents a poor performance. This number represents the working accuracy. It is a very important variable, because the ratio of overall handled items and incorrect items reveals information about the working strategy.

3. RESULTS

Results are presented for the reading task only. The effects caused by the two sound parameters “filter” and “traffic density” are in the main focus. The analysis for these parameters was carried out in two steps. First, an analysis of variance (ANOVA) is presented for the entire test. Then the effects for the different types of experimental mistakes (grammatical vs. semantic) are demonstrated.

3.1 Overall effect of the sound parameters

An analysis of variance was carried out separately for the two independent variables representing the performance, “number of correct items” and “error percentage”. In both analyses, the within-subject factors were the sound parameters “filter” and “traffic density”. While the performance of the children in the sound condition was analysed, the performance in the control condition was taken into account as a covariate. This procedure ensures that overall differences between individuals are irrelevant.

The factor “filter” did not show a significant effect on both variables, “number of correct items” and “error percentage”. The “traffic density” had an effect on the variable “error percentage” ($F(1/87) = 5.785$, $p = 0.018$). In the condition with high traffic density a worse performance in accuracy was observed ($Mean_{2000} = 17.62\%$) than in the condition with low traffic density ($Mean_{500} = 14.13\%$). There was no significant effect of “traffic density” on the “number of correct items”. Also no significant interaction for the two factors (filter x traffic density) was observed. The results for the variable “error percentage” are summarized in Figure 1. As mentioned before, the apparent influence of the filter condition did not reach significance.

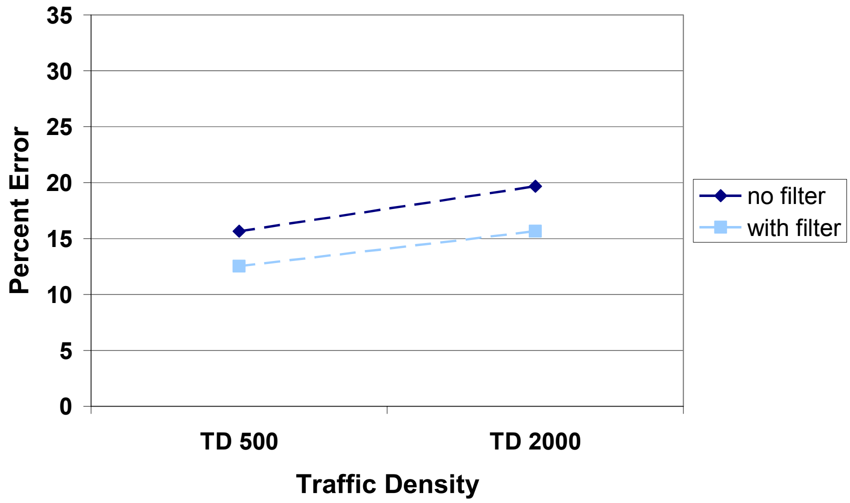

Figure 1. Overall effect of the factors “filter” and “traffic density” on the experimental variable “error percentage” in the reading test performance. Significant effect of “traffic density” ($p < 0.05$). The apparent influence of the filter condition did not reach significance.

3.2 Effects for different kinds of experimental mistakes

3.2.1 Grammatical vs. semantic mistakes

The first analysis concerning the experimental mistakes was carried out to clarify whether it was easier to detect the semantic or the grammatical mistakes. For this a 2 x 2 ANOVA with the within-subject factors “sound condition” and “experimental mistakes” was performed separately for both variables, “number of correct items” and “error percentage”. “Sound condition” in this case means the performance in the experimental conditions vs. the control condition.

The analysis did not reveal a significant effect for the factor “sound condition”, neither for the “number of correct items” nor for the “error percentage” variable. However, for both variables an influence of the factor “experimental mistake” could be demonstrated. A higher “error percentage” and a lower “number of correct items” were found for grammatical mistakes than for semantic mistakes (Error percentage: $Mean_{gram} = 27.2\%$, $Mean_{sem} = 10.5\%$. Correctly finished items: $Mean_{gram} = 10.7$, $Mean_{sem} = 13.7$). That means it was much easier for the children to detect the semantic mistakes than the grammatical mistakes.

3.2.2 Interaction with sound parameters

The second analysis also was an ANOVA. In this case the fixed factors were the within-subject factors "filter" and "traffic density". Again the independent variables were the two variables representing the performance, and as in the analysis in section 3.1, we looked at the performance in the sound conditions while the performance in the control condition was included as a covariate. The analysis was carried out separately for the two groups of experimental mistakes. Table 1 shows all results from this ANOVA, that were significant (at $p < 0.05$) or showed at least a trend ($p < 0.10$).

Table 1. Results from the analysis of covariance including the factors "filter" and "traffic density" for the two variables "number of correct items" and "error percentage", and for the two groups of experimental mistakes (grammatical and semantic). Only significant results ($p < 0.05$) and trends ($p < 0.10$) are shown.

Experimental mistake	**Variable**	**Factor**	***Df***	***F***	***p***	**Posthoc analysis**
semantic	correctly finished items	filter	1/87	7.452	**.008**	with filter > no filter
semantic	error percentage	filter	1/87	3.149	**.079**	no filter > with filter
grammatical	error percentage	traffic density	1/87	4.151	**.045**	TD 2000 > TD 500

Semantic mistakes. For the semantic mistakes the analysis showed a significant effect of the factor filter on the number of correctly finished items. In the condition "with filter" significantly more items were handled correctly than in the condition "no filter" ($Mean_{with\ filter} = 15.15$, $Mean_{no\ filter} = 12.22$). The factor filter also had an important influence on the reading accuracy. Again in the condition "with filter" the children performed better (lower error percentage) than in the condition "no filter" (higher error percentage) ($Mean_{with\ filter} = 8.93\%$, $Mean_{no\ filter} = 12.66\%$, see Fig. 2). Significant influences for the factor "traffic density" or significant interactions between both factors could not be demonstrated for any variable.

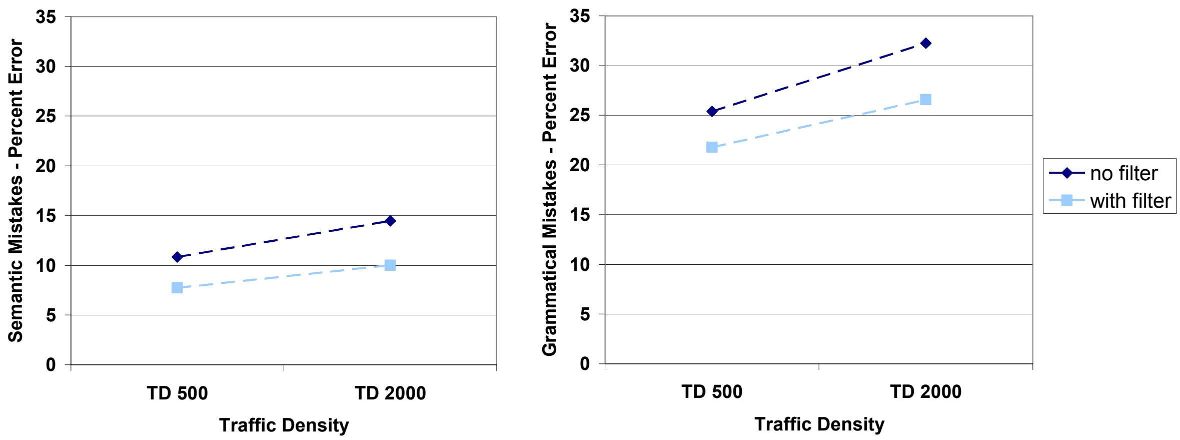

Figure 2. Effects of sound parameters "filter" and "traffic density" on the experimental variable "error percentage", separately for semantic (left panel) and grammatical mistakes (right panel).

Grammatical mistakes. For the grammatical mistakes one significant effect was found. While the factor “filter” did not lead to any significant result in contrast to the semantic mistakes, now there was a significant effect of the factor “traffic density”. The reading accuracy (error percentage) was significantly affected by this factor. In the condition with high traffic density the children performed worse than in the condition with low traffic density ($Mean_{TD\ 500}$ = 23.62%, $Mean_{TD\ 2000}$ = 29.35%). There was no effect of traffic density on the “number of correct items”. There were also no significant interactions. The results for the variable “error percentage” are summarized in Figure 2, separately for both kinds of experimental mistakes.

4. DISCUSSION

In this study we investigated whether moderate traffic sounds can affect reading ability in children. The road traffic sounds chosen for this study differed in respect to the two sound parameters “filter” and “traffic density”. One aim was to explore if a modification of these parameters affects cognitive performance. Because *moderate* traffic sounds were used and the reading ability was determined by a comparatively easy task it is no surprise that the revealed effects are small and that only some of them have statistical significance.

The analysis for the entire test showed a significant effect for the factor traffic density on the variable “error percentage”. Children performed worse in the condition with higher traffic density. There was no effect for the factor “filter”. At the first glance, the conclusion seems appropriate, that an attenuation of low frequencies would have no advantage. But a more elaborate analysis carried out separately for both kinds of experimental mistakes (semantic vs. grammatical) demonstrated that each of the sound parameters mainly affected the detection of one particular kind of mistake. Working on the semantic mistakes was influenced by the factor “filter”. In the condition “with filter” the children reached a higher amount of correctly finished items and a lower error percentage than in the condition “no filter”. In contrast, handling of the grammatical mistakes was not significantly affected by the filter, but an effect of the factor “traffic density” was demonstrated for the error percentage with worse performance in the conditions with higher traffic densities.

At this stage of data analysis we can just guess the reason for these differences in the effects. To find a semantic mistake it is necessary to understand the whole sentence. So it seems that changes in spectral shape have more effect on the reading comprehension. To find a grammatical mistake it is sufficient to focus on the relationship between two single words in most cases. That means the “detection task” for grammatical mistakes is restricted to a short section of the sentence. Many changes in the temporal structure of the noise (high traffic density) appear to interfere with the appropriate application of grammatical knowledge.

In general, all figures showed consistently that the children performed best in the conditions with low traffic density *and* an attenuation of the low frequencies. However, not all effects reached significance in all analyses.

The main messages from this study are: (1) children perform worse in a reading task when they listen to sounds of high traffic density. So a general reduction of traffic density would have a positive effect in any case. (2) The manipulation of the filter dimension just showed weak effects. Still, an attenuation of low-frequency traffic noise should also be helpful to increase cognitive performance.

The analysis concerning the experimental mistakes revealed a significant difference in performance concerning the grammatical and the semantic mistakes. In this particular reading task it was easier for the children to detect the semantic mistakes than the grammatical ones. Psycholinguistic aspects might be responsible for this interesting finding. However, as this result is independent from the noise effects, and both test versions are parallel in any respect, there is no immediate consequence for the use of the test in noise studies.

The semantic mistakes are detected much easier, nevertheless there are adverse effects of the filter condition on these sentences. This finding *is* important for the application of the test in a study on noise effects and it is also very important for a further modification of the test versions, because it indicates that we should not exclude the semantic mistakes. The mixture of both kinds of mistakes in the sentences should be kept.

Although only small effects could be demonstrated in this study, the adverse effects of noise on reading ability should be considered as a serious problem. On one hand, there will still be a further increase in traffic noise in future, on the other hand, reading skills are of high relevance in the everyday life of school children, as pointed out in the introduction. We should also bear in mind that the children just worked for 10 minutes on each test form. In comparison to a usual day at school these are short periods. The fact, that small effects could already be demonstrated for these short periods of time, suggests that there will be even stronger adverse effects when children work on cognitive tasks for a longer time.

In future, slight modifications of the test will be conducted to exclude items that are not sensitive to effects of noise. A further analysis to explain the relationship between the sound parameters and the different kinds of experimental mistakes will be carried out. Besides these test-related aspects the effects of other sound parameters like level or tonal character should be taken into account in future studies. It should also be analysed whether a reduction of level at high frequencies rather than low frequencies might be more effective in the relief from adverse noise effects on cognitive performance.

Acknowledgements

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