Detrimental effects of traffic noise on basic cognitive performance in adults

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Theoretical Background and Research Interest

Noise is one of the most serious environmental problems. Especially traffic noise has been permanently increasing in the last decade and is expected to grow dramatically in the near future. Particularly at working places such as offices or schools, which are situated nearby highly frequented routes, traffic noise is becoming more and more a reason for complaints.

The research cooperation "Low noise traffic" (Forschungsverbund "Leiser Verkehr") of the Federal Ministry of Education and Research (Bundesministerium für Bildung und Forschung Deutschland) was founded by public authorities, industry, universities and research institutes aiming on the reduction of traffic noise under consideration of technical, operational and administrative aspects. The project is accomplished by the combined work of several task forces, one of them concentrating on the effects of traffic noise on cognitive functions.

The aim of the presented studies is to detect detrimental effects of traffic noise on basic cognitive functions, as decision making, concentration and reasoning.

In a first step, several tests are conducted under exposure to different background sounds in order to identify noise sensitive measures. The sounds that were used included traffic noise[1] varying in sound pressure level (60 dB(A) vs. 70 dB(A)) and temporal structure (100 cars per hour (c/h) vs. 2000 cars per hour (c/h)) and speech (60 dB(A)), the latter because of its well known effect size. In a second step the traffic noise with 2000 cars per hour with 70 dB(A) was lowered by 12 dB(A) in the frequency domain below 500 Hz. This modification was chosen because of its technical potential to reduce noise due to changes in the motor management [1].

Empirical Studies

The Stroop test

For testing the function of "conscious attention", which is very important for concentration, a Stroop test[2] [2] was conducted. In such a test, it is important to inhibit an automatic response and act in an unusual way. The task here was to respond to the colour in which a colour word was printed, not to the meaning of the word, which was half of the times incongruent with its ink colour.

In a first experiment (n=24) the effects of different sound levels (60 and 70 dB(A)) and traffic density (100 vs. 2000 cars per hour) in comparison to silence and background speech (60 dB(A)) were tested. It could be shown (Figure 1), that there is a significant disturbing effect of the sound pressure level of the traffic noise but as expected only within the incongruent items. The congruent (meaning of word congruent with colour) items weren't shown in figure 1, because they were used only as distractors. The loudest traffic noise (70dB(A)) impairs the performance significantly in comparison to the other conditions (F(5,115)=4.3; p<.01; T-test series, p<.05).

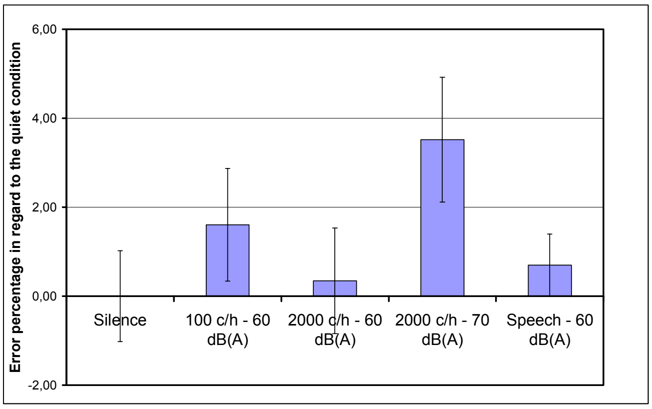

Figure 1: Means and standard errors of error percentages in regard to the quiet condition for the Stroop test (incongruent items) with variations of temporal structure and sound pressure level (n=24) (c/h = cars per hour)

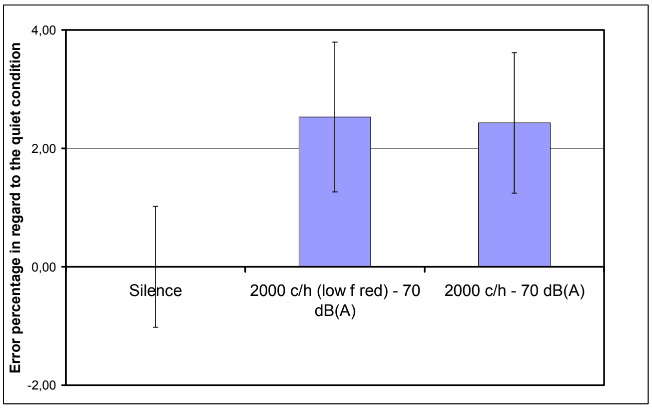

Figure 2: Means and standard errors of error percentages in regard to the quiet condition for the Stroop test (incongruent items) with variations of the frequency spectrum (n=24) (c/h = cars per hour; low f red = low frequency reduced)

The results of the second test (n=24) with the modified traffic noise signal (2000 c/h; 70 dB(A); low frequency reduced) in comparison to the original signal (2000 c/h; 70 dB(A)) in regard to a quiet condition are shown in Figure 2 (also solely the incongruent items). With both traffic noise signals, the performance (incongruent items) differs significantly from the quiet condition (2000 c/h, 70 dB(A), original: t(23)=-2,9; p<.01; 2000 c/h, 70 dB(A), low

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[1] Special thanks to Prof. Bisping (SASS acoustic research & design GmbH) for creating the traffic noise signals in the context of the project "Leiser Verkehr"

[2] Programm ERTS, Dr. Beringer (BeriSoft Cooperation)

frequency reduced: t(23)=-2,9; p<.01)) but not if they are compared to one another (t(23)=-0,1; p=.50).

A calculation test

To investigate the cognitive action of making decisions and doing two things at the same time (dual tasking), a difficult calculating test (computerised modification of the concentration- performance- test [3]) was carried out. Subtractions and additions must be made while memorising extensions, comparing them to one another and decide based on a rule how to use them for calculating the end sum.
Figure 3 shows the results of two experiments (n1=n2=18) with that test, illustrating the error percentages under the background sounds in regard to the quiet condition.
As background sounds served here four traffic noises differing in temporal structure (100 vs. 2000 c/h), sound pressure level (60 vs. 70 dB(A)) and frequency spectrum (2000 c/h, 70 dB(A) original vs. 2000 c/h, 70 dB(A), low frequency reduced) compared to speech (60 dB(A)) and a quiet condition (Figure3: bars that result from the 1st experiment: 100 c/h, 60 dB(A); 2000 c/h, 60 dB(A); silence; from the 2nd experiment are: 2000 c/h, 70 dB(A), original and low frequency reduced; speech, 60 dB(A) and silence).
The results show a detrimental effect of speech compared to silence (Wilcoxon: Speech vs. silence: Z=-2.7; p < .01) and of the traffic noise (2000 c/h) at the level of 70 dB(A) versus the quiet condition (Wilcoxon: 70dB(A) vs. silence: Z=-1.6; p=.06). In contrast, the same, but low frequency reduced traffic noise signal seems to have no harmful effect on the performance compared to silence (Wilcoxon: 2000 c/h, low frequency reduced, 70 dB(A) vs. silence: Z=-0.7; p=.24).

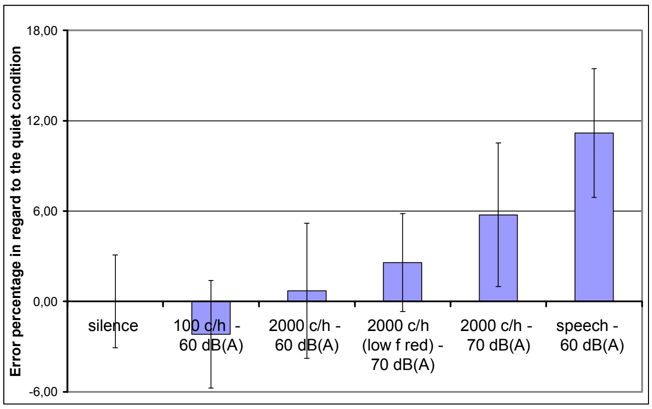

Figure 3: Means and standard errors of error percentages in regard to the quiet condition in the calculation test with variation of temporal structure, sound pressure level and frequency spectrum (2 experiments: n1=n2=18) (c/h = cars per hour; low f red = low frequency reduced)

A grammatical reasoning test

To look at a general reasoning ability, a grammatical reasoning task [4] was tested. The order of three symbols had to be verified compared to two sentences, which paraphrase the order of every two of them (with the verbs preceding and following: negative/positive, active/passive).
This test was conducted with two background traffic noises, only differing in their low frequency portion 2000 c/h, 70 dB(A), original vs. 2000 c/h, 70 dB(A), low frequency reduced) in comparison to speech (60 dB(A)) and a quiet condition.
Figure 4 shows that background speech (t (19)=3.2; p < .01) and the original traffic noise (2000 c/h, 70 dB(A); t (19)=2.5; p=.01) can decelerate the performance in this test. In contrast, the low frequency reduced traffic noise (2000 c/h; 70 dB(A); low frequency reduced) doesn't have this detrimental effect (T (19)=1.5; p=.08).

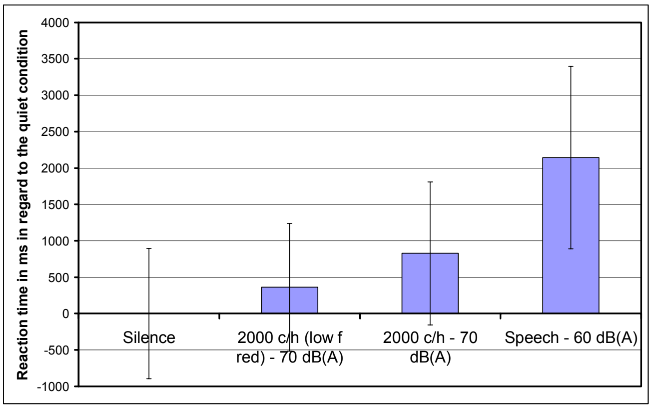

Figure 4: Means and standard errors of reaction times in regard to the quiet condition in the grammatical reasoning test with variation of the frequency spectrum of the traffic noises (n=20) (c/h = cars per hour; low f red = low frequency reduced)

Summary and Discussion

It follows from these experiments, that loud traffic noise (2000 c/h; 70 dB(A)) can disturb the performance in a magnitude that comes near to that of background speech (or even more) in several tests that demand cognitive functions like attention, short term memory or a general reasoning ability, all of them very important abilities for everyday efficiency.
The benefit of the frequency modification for noise abatement in the traffic noise sector seems to be dependent on the kind of cognitive work. In the Stroop test every change of the sounds that reduce their overall sound pressure level, but not the frequency modification itself, seems to be a helpful device to reduce the error rate caused by the traffic noises. In contrast, in the calculation and the grammatical reasoning test, the low frequency modification itself helps to reduce the impairment caused by the loud traffic noise (70 dB(A)). In the calculation test, it reduces the amount of errors caused by the loud traffic noise, and in the grammatical reasoning test, it does no longer decelerate the reaction time like the original traffic noise signal.

References

[1] Klingenberg, H. (1988). *Automobil – Meßtechnik (Akustik)*. Berlin: Springer

[2] Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology, 18*, 643-662.

[3] Düker, H., & Lienert, G. A. (1965). *Konzentrations-Leistungs-Test K-L-T (2. Auflage)*. Göttingen: Hogrefe

[4] Baddeley, A.D. (1968). A three-minute reasoning test based on grammatical transformation. *Psychonomic Science, 10*, 341-342.