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THE EFFECTS OF CHRONIC AND ACUTE TRANSPORTATION NOISE ON TASK PERFORMANCE OF SCHOOL CHILDREN

M. Meis*, S. Hygge, G.W. Evans***, P. Lercher****, M. Bullinger*****, A. Schick***

* Institute for Research into Man-Environment-Relations, University of Oldenburg, Ammerländer Heerstr. 114-118, POB 2503, D-26111, Oldenburg, Germany

** Danish Building Research Institute, P.O. Box 119, DK-2970, Hørsholm, Denmark

*** Department of Design and Environmental Analysis, Cornell University, Cornell University, Cornell, United States Of America

**** Institute of Hygiene and Social Medicine, University of Innsbruck, University of Innsbruck, A-6020, Innsbruck, Austria

***** Department of Medical Psychology, University of Hamburg, Germany, Department of Medical Psychology, University of Hamburg, D-20246, Hamburg, Germany

Tel.: +494417985525 / Fax: +494417985522 / Email: meis@psychologie.uni-oldenburg.de

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ABSTRACT
In this paper (this paper contains data from two field experiments reported in an overview article written by M. Meis; Habituation to suboptimal environments: the effects of transportation noise on children's task performance; in A. Schick, M. Meis & C. Reckhardt, Contributions to Psychological Acoustics, Results of the 8th Oldenburg Symposium on Psychological Acoustics, pp. 509-531, 2000) findings of interactions between chronic traffic noise and acute laboratory noise on cognitive performance and school achievement will be reported. Some of the findings can be classified in terms of habituation: children from areas exposed to traffic noise were not or were less affected when they were confronted with laboratory traffic noise. Another prevailing habituation type can be described in terms of 'environmental stimulation congruence', indicating that children from noisy areas performed best under noisy laboratory conditions, whereas children from quiet areas performed best under quiet conditions. However, these short term 'benefits' are severely counteracted by impairment as a main effect due to chronic noise exposure in everyday life.

1 - INTRODUCTION

Suboptimal physical environmental conditions, such as traffic noise may elicit psychological stress. The effects of stressors can be measured on the levels of physiology, interpersonal behavior, mood states and task performance (see Evans & Cohen [1]).
Several investigators, e. g. the working group from Evans & Cohen, have examined the chronic effects of prolonged exposure to community or traffic noise on reading achievement, auditory discrimination, math achievement, concentration and attention. Many of these studies showed that chronic noise exposure is associated with reading deficits, deficits in high attention demanding tasks and a tendency to give up easily in performance situations (for an overview see Cohen, Evans, Stokols & Krantz [2]; Schick [3]).
In order to clarify underlying processes which are responsible for the aftereffects caused by prolonged noise exposure, one of the first important issues would be to avoid the confounding effects of the actual noise level in the experimental situation. This means, that one has to test children under carefully controlled, quiet laboratory conditions, e.g. in a movable trailer under standardized ambient noise conditions. Moreover, it is interesting to monitor a child's performance not only under quiet conditions

but also under noisy conditions in the laboratory. One possibility would be to confront the children with the same sound which naturally occurs in his or her environment and to compare this performance with children living in quiet communities. By means of this cross-over design it will be possible to investigate how children exposed to chronic noise will work under quiet and under noisy conditions in contrast to their quiet counterparts.

This experimental procedure was carried out in field studies, conducted by Hambrick-Dixon [4] and Müller, Pfeiffer, Jilg, Paulsen & Ranft [5]. In the Hambrick-Dixon study children from noisy day care centres showed the best performance in a coding task when they were confronted with laboratory noise whereas children from quiet day care centres showed the best performance under quiet laboratory conditions. In the Müller et al. study such a pattern of result was not observed, only main effects of the chronic noise exposure showed statistical significance. In the following we will present data from two studies in which this 2 by 2 cross-over design from 'acute' and 'chronic' noise conditions was realized.

2 - THE MUNICH AIRPORT NOISE STUDY

2.1 - Description of the sample and noise measurements

This experiment was part of the Munich Airport Noise Study from 1991-1994 (Evans, Hygge & Bullinger [6]). Before the closure of the old Munich Airport (Muenchen-Riem) in May 1992 and the installation of the new airport (Franz-Josef Strauss Flughafen), children were divided into one experimental (noise exposed) and one control group at both airports. The experimental design was a four group quasi-experiment with repeated measurements in three waves. The data which will be reported here is cross-sectional from the last wave (new airport). On two days, 218 children with an average age of 12 years, were tested individually in 1.5 hr sessions in a sound-attenuated movable laboratory. 110 children from the noisy areas (62 dB(A) L_{eq}, peak = 73 dB(A)) and 108 from quiet control areas (55 dB(A) L_{eq}, peak = 64 dB(A)) performed in the implicit memory test. During the study phase one half of the children were confronted with 80 dB(A) L_{eq} (peak = 83 dB(A)) fluctuating aircraft noise over headphones, the other half encoded under silent conditions.

2.2 - The memory test

From each of eight categories (e.g., a part of the human body), five common examples were selected so that these 40 category examples formed the target items for the experiments. The material consisted of two lists of 20 randomly presented items (five examples x four categories) for each participant. The label from each category was used as a cue for the priming test and for the cued recall test. Subjects were tested individually. They were instructed to read 20 items and to rate their preference for each word. During the study phase the acute noise conditions were manipulated. After a retention interval of five minutes the subjects were given a priming test ('implicit' memory test; see Schacter [7]), followed by a free recall and a cued recall test ('explicit' memory test). The priming test instructions advised the subjects to produce eight exemplars from each of the eight presented category labels, one at a time, as quickly as they could. Four of the eight categories were always the ones from which the study items were drawn ('old' items), the other four had not been presented before ('new' items). The probability of producing new items provided a measure of baseline performance for word production. After the word production, a free recall test was given. Finally, the participants were shown the four category labels from the items encoded in the study phase with an explicit memory instruction.

2.3 - Results

The significant priming effect ('old' − 'new' items, $M = 13.14$, $F(1, 214) = 227.26$, $p <.01$), calculated by MANOVA, was, as predicted, totally unaffected by the chronic and/or acute noise conditions (all F's < 1; for a detailed look, see Meis, Hygge, Evans & Bullinger [8]). ANOVA's showed that neither the base rate ('new' items) nor 'old' items were affected by the exposure to acute or chronic noise. This pattern of result is consistent with models of implicit memory, because implicit memory seems to be less dependent on attention [9].

Regarding the explicit memory tests, the following findings were observed. Children exposed to chronic aircraft noise performed in the free recall test better under acute noise (Acute Noise: $M = 20.00$, Quiet: $M = 18.17$), whereas children from relatively quiet areas performed best under quiet laboratory noise conditions (Acute Noise: $M = 20.46$, Quiet: $M = 23.06$). This interaction did not show a significant effect ($F(1, 214) = 2.39$, $p =.12$; the pure effect of the chronic noise exposure showed a tendency: ($F(1, 214) = 3.49$, $p =.063$). A stronger cross-over effect was demonstrated for the error rate of the free recall (error relative to the total score). Only the control group was affected by the exposure to acute laboratory noise. They made more errors under noise than under ambient sound conditions (Acute Noise: $M = 28.31$, Quiet: $M = 17.82$). Children from noisy areas made more errors in general (main effect)

but were unaffected by the acute noise condition (Acute Noise: $M = 33.81$, Quiet: $M = 34.58$). This interaction showed a tendency ($F(1,\ 214) = 2.75$, $p = .098$; the main effect of the chronic noise exposure was significant: ($F(1,\ 214) = 10.77$, $p < .01$).
A similar pattern of results was demonstrated for the cued recall (Note: minor subjects because of analyses of covariance with the covariate 'density'). Children from noisy areas were less affected by the exposure to acute noise (Acute Noise: $M = 23.70$, Quiet: $M = 25.50$) than their quiet counterparts (Acute Noise: $M = 25.19$, Quiet: $M = 32.90$; $F(1,\ 206) = 3.30$, $p = .071$; see fig. 1). The main effect of the chronic noise exposure was significant: ($F(1,\ 202) = 4.88$, $p = .028$). Once again the cross-over effect was stronger with regard to the error rate. As Fig. 1 shows, the experimental group was unaffected by the acute noise (Acute Noise: $M = 39.67$, Quiet: $M = 41.23$), whereas the quiet control group showed a higher error rate under acute noise (Acute Noise: $M = 40.89$, Quiet: $M = 23.71$. This interaction showed statistical significance $F(2,\ 214) = 8.93$, $p < .01$; the main effect of the chronic noise exposure was marginal ($F(1,\ 202) = 3.41$, $p = .066$).

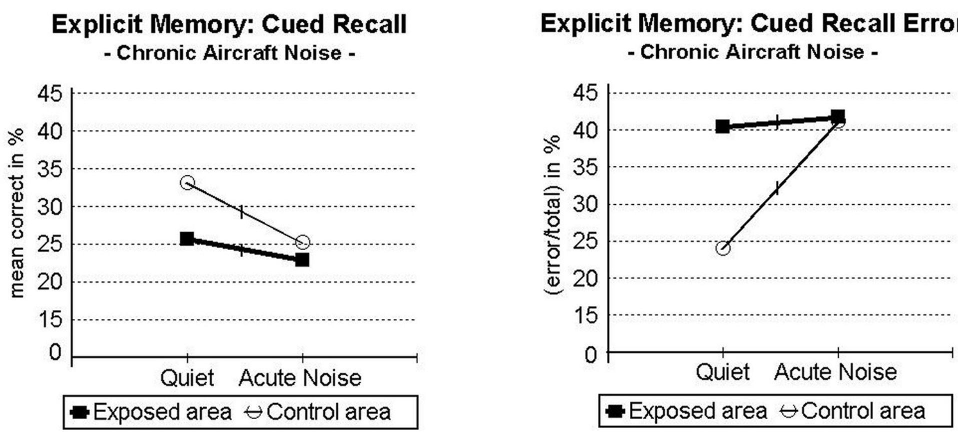

Figure 1: Munich Airport Noise Study: explicit memory; cued recall and the error rate; laboratory aircraft noise by chronic aircraft noise (exposed areas vs. control); mean correct and error rate (error/total) in %.

3 - TYROL SCHOOL STUDY II

3.1 - Description of the sample and noise measurements

The following experiment examined the effects of combined road and railway traffic noise on the memory performance of primary school pupils. This experiment was part of the 'Tyrol school study II', as a supplement to an Environmental Health Impact Assessment for the Austrian Government concerning a new rail track in the Tyrol (Meis, Lercher, Roitner-Grabher & Roner, 1999). The multimethodical design of this field study comprised the collection of physiological parameters, annoyance ratings, test procedures concerning psychological states, such as stress scales, coping with noise, and motivation as well as the examination of school-related achievement tests such as reading skill, visual and verbal memory and concentration ability. One hundred and twenty three primary school pupils with an average age of 9.7 years (54 girls, 69 boys) were examined in a sound-attenuated laboratory trailer. The trailer was placed near the children's schools. These pupils formed two previously defined, socio-economically matched groups with combined rail and road traffic noise exposure $L_{Aeq/8h-Night} < 40$dB and $L_{Aeq/8h-Night} >$ 50dB. The pupils were chosen from towns in and along the Inn valley (Unterinntal) between Wörgl and Wattens.

3.2 - The memory test

The children had to read a story about an accident with 119 words and 13 lines, which was an unpublished parallel version ('Form C') used in a test battery by Seyfried [11]. The memory instruction was intentional. Half of the children were exposed over AKG headphones to acute traffic noise conditions (80 dB $L_{Aeq/3\ min.}$, peak = 91.8 dB(A)), fluctuating combined road and railway traffic noise), the other half worked in quiet during the tasks, so that it was possible to examine systematically, apart from the subsequent effects of the 'chronic noise exposure', the interaction of 'chronic traffic noise by acute traffic noise' as in the study above. The noise material was a stereophonic recording via DAT of a typical, ecologically valid, combined traffic noise situation in the Inn valley with passing freight trains and background motorway noise (psychoacoustic parameters: $S_{acum} = 2.08$, $RGH_{asper} = 1.76$, $Ton_{tu} = 0.042$ related to the 3 min. L_{eq}-level; BAS head acoustics, v. 4.40). After a retention interval of 10 minutes the children had to complete 14 sentences in the test phase under ambient sound conditions. The maximum score was 15. The error rate was computed as error divided by total score in percent.

3.3 - Results

There are no significant differences between the children exposed to chronic noise and the control group and/or the acute noise condition in the laboratory regarding the correct items (all F's < 1). With regard to the error rate an interesting pattern of results occurred: children from areas exposed to noise performed better or they made fewer errors under noisy conditions, whereas children from quiet control areas worked better under quiet conditions ($F(2,119) = 2.43$, $p < .092$; the main effect of the chronic noise exposure was marginal ($F(1, 122) = 3.67$, $p = .058$). The interaction is consistent with both Hambrick-Dixon [4] and the Munich study data presented above. The children performed best under congruent environmental stimulation conditions (see Fig. 2).

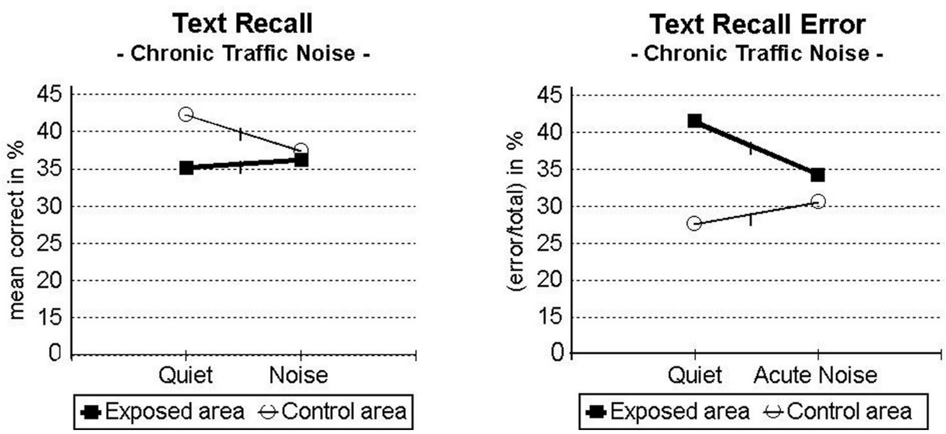

Figure 2: Tyrol School Study II: text recall and error rate; laboratory traffic noise (quiet vs. acute noise) by chronic traffic noise (exposed areas vs. control); mean correct and error rate (error/total) in %.

4 - DISCUSSION

The reported findings can be classified in terms of *habituation to acute noise*. This indicates that children chronically exposed to noise were not or were less affected when confronted with laboratory noise. Thus children habituate to traffic noise conditions. In comparison to their quiet counterparts, the children in the Munich Airport Noise Study showed in *quiet conditions* a comparable performance to the children from quiet areas *under laboratory noise*. It is important to note that this form of habituation was not found regarding the main effects of the chronic noise exposure when analyzing children exposed to chronic noise vs. the controls: the reported and other memory data from the Munich Airport Noise Study (see also Hygge, Evans & Bullinger [12]) showed that complex task performance was impaired in general as a main effect, when the children were living in communities exposed to chronic transportation noise.

Another type of habituation can be described in terms of *'environmental stimulation congruence'*. This pattern of results was observed in the error rate from the text recall in the Tyrol Study. This pattern of results is consistent with the idea that different levels of cognitive performance are established and maintained according to the prevailing levels of environmental stimulation (see also Hambrick-Dixon [4]) in terms of congruent living and learning situations. Following this idea, incongruent living and working conditions will lead to impaired performance. This model contradicts prior theories which hypothesized that noise impairs complex cognitive tasks because of deficits in memory and attention.

Future research should concentrate on sound material with a high ecological validity, the prediction of sensitive and non-sensitive performance measures, the development of age related complex tasks, the standardization of a task battery, well documented noise measurements from all living areas and situations in addition to noise diaries. In this way, it would be possible in the future to develop a model concerning habituation with regard to the effects of chronic transportation noise.

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