Effects on Spatial Skills after Exposure to Low Frequency Noise*

Jessica Ljungberg[1,2] Gregory Neely[1] and Ronnie Lundström[2]
1National Institute for Working Life P.O. Box 7654, SE-907 13, Umeå, Sweden
2Department of Public Health and Clinical Medicine, Occupational Medicine, Umeå University, Umeå, Sweden

A study of spatial skills was conducted with 27 male and 27 female participants. The aim of the study was to examine the post-exposure effect of a complex low frequency noise (21 Hz) on a mental rotation task. It was hypothesised that reaction time and number of errors would increase after 20 minutes exposure to noise exposure compared to performance after a control condition, and that groups exposed to higher intensity noise would exhibit greater impairment. Three groups of participants were exposed to a control condition and a noise condition (either, 77, 81 or 86 dB (A)). After each exposure, subjects completed a mental rotation task where the stimulus consisted of one of three letters presented in five different rotations, showed either normally or mirrored. The participants were asked to respond as quickly and accurately as possible, affirmatively if the letter presented was not mirrored and negatively if it was mirrored. Statistical analysis revealed that the medium intensity level generated significant post-exposure effects while no effects were seen at the low or high intensity levels.

1. INTRODUCTION

Many people are exposed daily to unwanted noise in their working environment. One of the primary effects of noise is loss of attention during a cognitive activity, such as disruptions during reading or writing. Sounds often seem to influence our awareness. Research in this area has been focused on effects during exposure, both in terms of physiological and cognitive functioning.

For instance, studies have demonstrated the negative influence of noise on focused attention tasks and reduced hit-rate on detection tasks (Smith, 1988, 1991). A speed to accuracy trade – off effect was also detected in a selective attention task. Subjects worked faster during exposure to noise but with lower accuracy compared to a silent control (Hygge et al 2003). Other researchers have studied interactive effects of multiple stressors on cognitive performance. For example, students who have to cope with the demands of exams and papers at the end of their semester had greater psychophysiological stress and significant slower reaction time when they executed a dual task during a noise condition. (Evans et al 1996). Gomes et al (1999) found similar results that showed memory impairment after exposure to low frequency noise.

Less is understood about post-exposure effects generated by noise. Glass and Singer (1972) were among the first to demonstrate post-exposure effects on mental performance. They found that predictability and the possibility of the individual controlling the noise reduces these effects; other researchers have also found similar results (Bullinger et al 1999; Evans and Johnson, 2000).

*Reprinted, with permission from the Journal of Low Frequency Noise, Vibration & Active Control

Cohen et al (1980) investigated these effects in school children, and the results showed that children from noisy schools are more likely to fail on cognitive tasks and appear to give up before they complete their task than children from quiet schools. Haines and colleagues (Haines et al 2001a; Haines et al 2001b) revealed the same effects in studies on school children who had been exposed to aircraft noise from a local airport. Aircraft noise had an impairing effect on reading comprehension, and generated higher levels of annoyance and perceived stress. Another study conducted in the field by Lindström and Mäntysalo (1981) indicated similar results when measuring post-exposure effects from industrial noise, before, in the middle of, and after, a work-shift using reaction time task. Results indicated a trend towards decrements in reaction time after being exposed to noise during the work-shift.

Post-exposure effects on cognitive functioning due to noise need to be more closely examined. Large numbers of people regularly work in environments with intermittent exposures to noise of varying intensity and duration. Thus it is important to understand not only the effects during exposure, but also following or in between. The aim of the study was to examine the post-exposure effect of a low frequency noise on spatial skills.

We hypothesized that reaction time and number of errors would increase after exposure to noise compared to a control condition, and that participants exposed to more intense noise would exhibit greater impairment.

2. METHOD

2.1 SUBJECTS

Fifty-four participants, (27 men and 27 women) with a mean age of 25 years (ranging from 19 to 30), participated in the study. They were tested individually and were reimbursed 300 Swedish crowns (approximately 30 USD) for their participation. All subjects reported good physical health and were tested for normal hearing, <20 dB HL. The study was reviewed by the ethics committee at Umeå University.

2.2 PHYSICAL STIMULI

The noise condition consisted of a sound from a helicopter played at 21 Hz and was emitted from a loudspeaker positioned 60 cm behind the participants. The noise was registered with an integrating sound level meter (Brüel & Kjær 2237). No experimental noise was used during the control condition which consisted simply of the background noise in the laboratory, which remained steady at 60 dB (A).

2.3 PROCEDURE AND TASK

The spatial test was a part of a large data collection exercise, but the following presentation focuses on post-exposure effects of noise on a mental rotation task.

The subjects received both written and verbal instructions about the tests and procedures and written consents were collected. The study applied a mixed model design where the participants were randomly assigned to one of three groups: low-intensity exposure (77 dB (A)), medium-intensity exposure (81 dB (A)), and high-intensity exposure (86 dB (A)). All participants

Table I. Environmental stimulus levels for the three intensity groups

	Intensity levels		
Environmental exposures	Low group n = 17	Medium group n = 19	High group n = 18
Noise	77 dB (A)	81 dB (A)	86 dB (A)
Control	–	–	–

were tested in both the noise and control condition, see Table I, for a design overview.

The participants were instructed to sit in an upright position. A familiarizing phase started the session. The mental rotation task was introduced and all subjects were allowed to practice the test until they had successfully completed 10 trials without error. Feedback was provided on the screen during the practice session indicating whether the participant had responded correctly or not. The participants were also briefly introduced to the noise stimulus. The experimental test session started with noise exposure or a quiet condition for twenty minutes, the order of which was randomized over participants. During the exposure they completed an unrelated short-term memory task, and after each exposure the mental rotation task was conducted for five minutes. Between the noise and control exposures, there was a five minutes break.

The spatial orientation task consisted of three letters that were presented either normally or mirrored and rotated at one of the positions (0°, 60°, 120°, 180°, 240° or 300°) on a monitor. The participants had two hand-held, thumb-operated response buttons, one marked YES and one NO. The subject's task was to respond as quickly and accurately as possible pushing the "YES" marked response button if the letters were normal and rotated and the "NO" marked response button if the letters were mirrored and rotated. Half of the participants had the YES button in their significant dominant hand and the other half in the non-dominant. Reaction time and numbers of errors were measured as dependent variables.

3. RESULTS

An initial inspection of data showed that the reaction time data was skewed negatively, and was therefore logarithmically transformed. An analysis of the reaction time during the control condition revealed that the three intensity level groups differed in their baseline performance, see Table II, Direct comparisons between the groups where therefore difficult. Reaction time were then recalculated for each individual into difference scores by dividing the reaction time during the noise exposure with the silent control. A value of 1 would represent the case where there was no change in the reaction time during the noise condition compared to the control condition. For the statistical tests, an alpha level of .05 was used.

Reaction time data were analyzed for significant differences between the control and noise condition by testing each group's difference ratios with the hypothesized result of 1 using one-sample t-test. The results showed significantly slower reaction time in the noise condition for the participants in the medium intensity group (t = 2,151, df = 18, p < .05). Neither of the other intensity levels generated any significant effect, when comparing noise and quite condition, see Figure 1. Analyses of the number of errors

Table II. Means and standard deviations for reaction time in the noise and control condition for the intensity groups

	Control		Noise	
Intensity levels	**Mean**	**SD**	**Mean**	**SD**
Low intensity	732,0	153,8	718,7	167,2
Medium intensity	729,8	148,1	777,8	170,7
High intensity	776,3	156,9	770,1	158,1

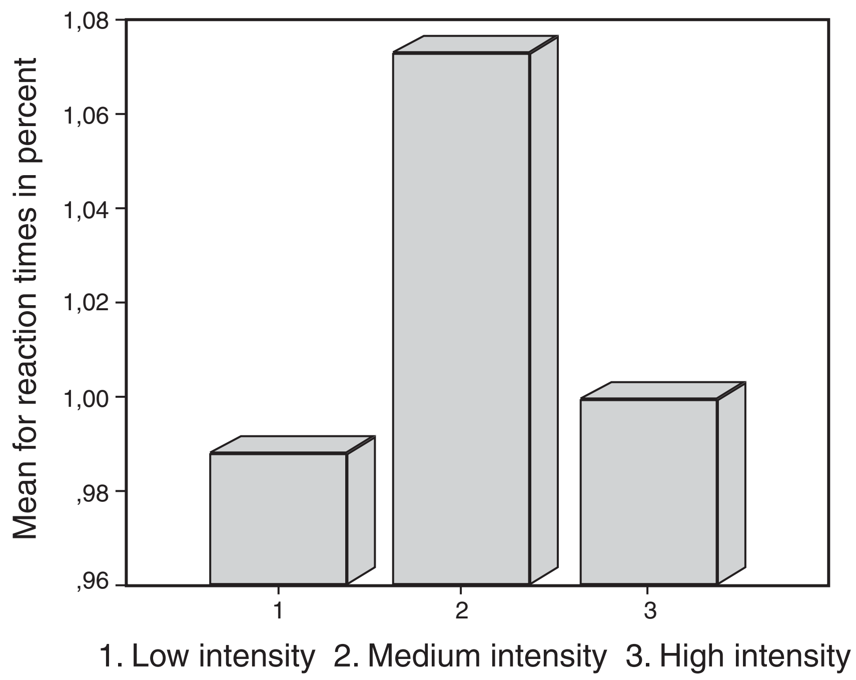

Figure 1 Mean reaction time ratios for the mental rotation task obtained at different exposure levels. For more information, see text.

committed in each condition revealed no statistically significant effects.

DISCUSSION

The results from this experiment showed a post-exposure effect generated from noise at the medium intensity level, but not at the low or high intensity levels. These results indicate that at the intensity levels investigated here, there is not a direct relationship between intensity and post-exposure performance in a mental rotation task. The fact that there was no significant differences in the number of errors made between a control condition and the noise condition for any of the groups indicate that the observed differences in reaction time wasn't a result of different strategies in speed/accuracy tradeoff. While gender and age were controlled in this experiment, preference and noise sensitivity was not. Weinstein (1978) has observed that people differ in their sensitivity to noise intensity. It may be the case that the middle intensity group tested here contained in overrepresentation of individuals who are more sensitive for noise in general.

The predictability of the noise and individuals possibility to control the noise have in earlier experiments been shown to be variables that influence post-exposure effects generated from noise (Glass & Singer, 1972). Noise with a more informative character and more complex cognitive tasks has also been show to have stronger predictability. Further investigations where these factors are included in the design might help to better understand the post-exposure effects of noise exposure.

REFERENCES

1. Bullinger, M., Hygge, S., Evans, G. W., Meis, M., & von-Mackensen, S. *The psychological cost of aircraft noise for children*. Zbl Hyg Umweltmed. 1999, 202, 127-138.

2. Cohen, S., Evans, G. W., Krantz, D. S., & Stokols, D. Physiological, motivational and cognitive effects of aircraft noise on children. *Am Psychol.* 1980, 35(3), 231-243.

3. Evans, G. W., Allen, K. M., Tafalla, R., & O¢meara, T. Multiple stressors: performance,

psychophysiological and affective responses. *J Environ Psychol.* 1996, 16, 147-154.

4. Evans, G. W., & Johnson, D. Stress and open-office noise. *J Appl Psychol.* 2000, 85(5), 779-783.

5. Glass, D. C., & Singer, J. E. *Urban stress: Experiments on noise and social stressors.* 1972, New York: Academic Press.

6. Gomes, L. M. P., Martinho Pimenta, A. J. F., & Castelo Branco, N. A. A. Effects of occupational exposure to low frequency noise on cognition. *Aviat Space Environ Med.* 1999, 70(3), 115-118.

7. Haines, M. M., Stansfeld, S. A., Job, R. F., Berglund, B., & Head, J. A follow-up study of effects of chronic aircraft noise exposure on child stress responses and cognition. *Int J Epidemiol.* 2001, 30(4), 839-845.

8. Haines, M. M., Stansfeld, S. A., Job, R. F., Berglund, B., & Head, J. Chronic aircraft noise exposure, stress responses, mental health and cognitive performance in school children. *Psychol Med.* 2001, 31(2), 265-277.

9. Hygge, S., Boman, E., & Enmarker, I. The effect of road traffic noise and meaningful irrelevant speech on different memory systems. *Scand J Psychol.* 2003, 44(1), 13-21.

10. Lindström, K., Mäntysalo, S. Attentive behavior after exposure to continuous industrial noise. In G. Salvendy & M. J. Smith (Ed.), Mach pac Occup Stress. London: Taylor & Francis. (pp. 91-96), 1981.

11. Smith, A. P. Acute effects of noise exposure: an experimental investigation of the effects of noise and task parameters on cognitive vigilance tasks. Int Arch Occup Environ Health. 1988, 60, 307-310.

12. Smith, A. P. Noise and aspects of attention. *Brit J Psychol.* 1991, 82, 313-324.

13. Weinstein, N. D. Individual differences in reactions to noise: a longitudinal study in a college dormitory. *J Appl Psychol.* 1978, 63(4), 458-466.

noise notes

SILENT AIRCRAFT INITIATIVE

A new international project to reduce aircraft noise is building on pioneering research by UK engineers. The Cambridge-MIT Institute's Silent Aircraft Initiative (SAI) aims to design an aircraft that will make much less noise than conventional aeroplanes. To help meet its objectives, the project will use noise-modelling techniques devised by engineers at Cambridge University with funding from the Engineering and Physical Sciences Research Council (EPSRC). As well as Cambridge University, participants in the SAI include the Massachusetts Institute of Technology (MIT) and a number of other organisations. Noise is a major aviation issue that will become even more pressing in future, with a 300% increase in air traffic forecast by 2020. This could have a major impact on the quality of life of people living close to airports. The SAI represents a response to the problem. It will take an integrated approach to aircraft design and operations, and investigate radically different aircraft configurations that could lead to dramatic reductions in noise.