Sleep disturbance by traffic noise: after-effects on brain activity

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Introduction

Current data point out that perceptive and motor functions in humans are less impaired by noise than functions relating to memory load and/or mental operations. For example, traffic noise has usually no effect on vigilance [1, 3], choice-reaction time [5], spatial perception [1]. On the contrary, following mental functions seems to be impaired by noise: short-term-memory [1], mental arithmetic [1], recall of task-irrelevant information [6].

All these findings suggest that subjects make additional efforts to compensate the noise-induced deficits mainly by increasing concentration on a task. Obviously, such a strategy requires additional physiological costs. For example, under noise conditions the heart rate acceleration and decrease of heart rate variability were obtained [3].

Another important question is whether noise can exert its effect on cognitive functions indirectly, through noise-induced sleep disturbances. It is well known, that traffic noise worsens both objective and subjective sleep quality (e.g. reduces REM-sleep, increases sleep complaints). However, the performance decrement after noisy night is not observed necessarily. In addition, no after-effects on heart rate or heart rate variability were found, which could be linked with cognitive deficits.

It should be noted, that cardiovascular or electrodermal measures are not fast enough to reflect changes of neuronal mechanisms underlying information processing. Fast alternations can be registered with event-related brain potentials (ERP). Using this method it is possible to explore impairments in the brain after noisy nights, even if performance decrement is not evident.

Hockey and Hamilton [6] reported the noise-induced deficit in recall of task-irrelevant information. The recall is an important precondition for flexible switching between actions. This finding suggests the behavior inflexibility as an after-effect of noise exposure. We propose that such an inflexibility may be a result of deficient functioning of the so-called "executive system" of the brain [7]. This system provides planning, implementing, and stopping of action. The frontal lobes of the brain are the main structures of this system. In our study we especially interested in whether there were noise-induced impairments in initiation and stopping of an action.

Method

Twenty-three subjects had to perform a Go-Nogo task after a quiet night and after three noisy nights when subjects were exposed to railway noise during eight hours in bed with a maximum level of 62 dB(A), 68 dB(A), and 74 dB(A). In the Go-trials (words "STOP" or "press") they had to press a button, in the Nogo-trials (words "PRESS" or "stop") they had to refrain from response (Table 1). The task contained 200 stimuli presented visually. Each of four stimuli was occurred equiprobably and randomly for 300 ms. The interstimulus interval was 1650 ms. The EEG at frontal, central, and parietal sites was recorded during the whole test to obtain the event-related potentials. The EEG-sweeps were averaged for Go and Nogo trials in each experimental condition. ERP analyses were performed with Brain Vision program (Brain Products GmBH, Germany).

Stimulus type	**Stimulus presented**	**Reaction required**	**Error type**
Go	"STOP" or "press"	Press a button!	No response – miss
Nogo	"PRESS" or "stop"	Don't press!	Response – false alarm

Table 1. Go-Nogo task description.

Statistical analyses were performed with SPSS 11.5. Dependent variables were: reaction times to GO trials, missing and false alarm errors, amplitudes and peak latencies of N2 (defined as negative maximum in 250-350 ms after stimulus onset) and P3 (defined as positive maximum in 350-500 ms after stimulus onset).

Results

The errors in Nogo trials (false alarms) were more often than in Go trials (missing errors). Thus, the Nogo trials were more difficult to perform than Go ones. However, no effects of noise on reaction times or false alarm rate were obtained.

For Go trials there were no significant differences in N2 and P3 components between Baseline and Noise conditions. On the contrary, for Nogo trials the significant reduction of N2 and P3 components after nocturnal noise was found.

Discussion

We obtained neurophysiological evidence of noise-related cognitive deficits, although the overt performance was not affected by noise. Keeping in mind that there were no differences between experimental conditions in Go-N2 and Go-P3 amplitudes, we can conclude that both action preparation and implementation mechanisms seem to be not impaired by noise-induced sleep disturbances. But we found reduced amplitudes of N2 and P3 in Nogo trials suggesting that physiological costs for stopping an action is increased after a noisy night.

Current studies have been demonstrated that the electrical sources of inhibition-related neural activity are located in orbitofrontal cortex [2]. That indicates that both components reflect functioning of "frontal executive system" relating to action inhibition. However, the functional role of each of these components is somewhat different. Nogo-N2 has been considered as an index of modality specific inhibition, whereas the Nogo-P3 seems to indicate to a more general and high-order inhibition mechanism [4]. Processes underlying Nogo-P3 are possibly related to transfer of inhibitory influence to all low-order brain systems are involved into action stopping. The greater the P3 amplitude, the more local brain systems are involved into this process. Thereby the action stopping will be facilitated. Future studies are required to specify the functional role of both inhibitory ERP-components.

Conclusions

- Traffic noise can exert its effect on cognitive functions indirectly, through noise-induced sleep-disturbances.
- After-effects of noise can be observed at the neurophysiological level, even if there is no overt performance decrement.
- The action preparation and implementing (Go-responses) are easier to realize than action inhibition (Nogo-responses).
- Inhibitory processes are impaired by noise-induced sleep-disturbances whereas action preparation and implementing are not.
- The Nogo-N2 and Nogo-P3 components of event-related potentials are sensitive indicators of noise-induced impairment of inhibitory functions.

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