Analyzing effects of aircraft noise on cognition and quality of life in German children near Frankfurt Airport in the NORAH-study: An overview of design and methods

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In order to get more insight into the effects of transportation noise, the state-owned Environment & Community Center (ECC) of the Forum Airport and Region (FFR) commissioned the authors of this contribution to conduct a noise effects monitoring program at Frankfurt Airport. This program includes a study on noise effects on children. Based on prior findings, the current study aims to explore the effects of chronic aircraft noise exposure on reading and its precursors in primary school children who are instructed in German language. Variables known to affect reading acquisition such as teachers´ methods of reading instruction, children´s SES and language spoken at home are assessed via teacher and parent questionnaires. In addition to cognitive tasks, children´s quality of life is assessed via standardized interviews of the children and parent questionnaires.

1 INTRODUCTION

Since the announcement in 1998 there have been discussions in the Rhine Main area among stakeholders about the expansion of Frankfurt Airport, including the construction of the 4th runway (opened in October 2011), and about the health-related effects of aircraft noise in relation to other noise sources. In order to get more insight into the effects of transportation noise, the state-owned Environment & Community Center (ECC) of the Forum Airport and Region (FFR) commissioned the authors of this contribution to develop and conduct a noise effects monitoring program at Frankfurt Airport and comparative studies at other German airports. The study started in April 2011. The subject matters of this study, called NORAH study (noise-related annoyance, cognition and health) are

- noise annoyance and health-related quality of life (HQoL; including reported diagnosed health diseases): Aircraft noise annoyance and HQoL before and after the opening of the 4th runway in comparison to annoyance at other airports; comparison of HQoL and annoyance due to aircraft, railway and road traffic noise; effects of combined transportation noise exposure on annoyance and HQoL;
- effects of transportation noise on hypertension and cardio-vascular diseases and the causal structure of noise exposure, noise reactions, and health effects;
- effects of changing nocturnal noise exposure at Frankfurt Airport on sleep;
- noise effects on cognitive performance and quality of life (QoL) in children.

In this contribution, the design and methods of the study on noise effects on children are presented.

2 RESEARCH INTEREST

Prior studies indicate that chronic exposure to aircraft noise may have harmful effects on children´s cognitive development.[1-3] In these studies, reading acquisition and basic cognitive functions such as attention, long-term memory, and working memory were assessed in children differing in noise exposure. Consistently, reading performance was found to be poorer in highly noise-exposed children. With respect to attention and memory, the results are contradictory: In some studies, noise exposure was associated with poorer performance[2-3], whereas in other studies, no effect[1] or even a reversed effect of noise (better performance in noise-exposed children) was found.[4]

The relationship between aircraft noise exposure and reading performance has to be interpreted with caution, since aircraft noise may be confounded with socioecomomic status (SES). Areas with high levels of aircraft noise tend to be occupied to a higher degree by families with low SES, which in turn is strongly related to reading ability in children. Accordingly, in some studies, the relationship between reading and noise was abolished when SES was controlled. However, in the cross-national RANCH-study – the hitherto largest epidemiologic study undertaken of noise exposure and children's cognition and health - the harmful effect of aircraft noise was evident despite careful control of socioeconomic status variables[3].

Some researchers have argued that the effect of noise on reading is mediated by noise effects on phonological processing abilities representing precursors of reading acquisition[5]. These abilities comprise speech perception, verbal short-term memory, and phonological awareness. Several studies

have shown negative effects of acute noise on children´s performance in tasks relying on these functions [6-8]. Furthermore, children who were exposed to high levels of indoor noise in classrooms over years were found to perform worse in phonological tasks when compared less noise-exposed controls[9-10], indicating that chronic noise exposure impairs the development of phonological abilities. In view of this evidence, phonological processing tasks are included in the current study in order to explore the underlying mechanisms of noise effects on reading.

Concerning attention, prior studies used classical paper-and-pencil tests requiring rapid identification (cancellation) of target symbols in complex visual arrays. Such tests are supposed to assess selective attention and concentration via measures of processing speed, errors, and quality of performance. In the RANCH-study[3] and in the Munich-study[2], performance in such tests was unrelated to aircraft noise exposure. However, later studies with other tests found significant effects of childrens´ noise exposure on performance.[11] For the current study, a new paper-and-pencil cancellation test was constructed, in which the target items are defined by phonological (not visual) characteristics. We hypothesize that auditory-verbal abilities are most sensitive for negative effects of chronic noise exposure. Thus, tasks relying purely on visual search processes might not be suitable for uncovering such effects.

Primary school children who experienced two years of reading instruction at the time of the study (second-graders, 8 years old) served as participants in the current study. Earlier studies, e.g. RANCH, used older children. The reason for this difference is that learning to read proceeds faster in German when compared to English, since the German orthography is consistent (i.e., in the majority of cases, one grapheme corresponds to one speech sound) whereas English is exceptionally inconsistent (i.e., one phoneme has different spellings, and one grapheme can be pronounced in multiple ways). We hypothesize that noise effects are more evident during reading acquisition, when reading is not yet automatized, but effortful and attention-demanding.

3 METHOD

3.1 Recruitment of participants

Children were recruited via primary schools in the Rhine-Main-Region located within the 40 dB(A) envelope contour of the equivalent sound levels of aircraft noise for daytime.

As a first step, the respective noise levels were computed for each of the 297 schools in the relevant area. The schools were than clustered into four 5-dB-classes of aircraft noise exposure (40 to less than 45 dB; 45 to less than 50 dB, 50 to less than 55 dB, 55 dB and higher).

We aimed to include schools which differ in aircraft noise exposure, but are roughly comparable with respect to other factors affecting reading acquisition, such as percentage of second-grade students with non-German mother language, SES in the school district etc. Furthermore, schools which were highly exposed to other noise sources (e.g., road traffic, railways, building sites, industry) and schools with less than 40 second-grade students were to be excluded. In order to collect the respective information, a questionnaire was sent to each of the 297 schools in August 2011. Based on the questionnaire data, 7 to 8 schools were selected for participation in each of the four 5-dB-classes. Only few schools refused to participate; these were substituted by appropriate alternates. Subsequently, written information was given to the parents of the second-graders, and parent evenings were arranged in the schools by the researchers. All information materials were translated

in several languages in order to include parents with weak knowledge of German. Written consent was thus obtained by 77 % of the parents addressed. The resulting sample consists of 1.300 second-grade children from 29 schools with aircraft noise levels (LAeq for daytime) ranging from 40 to 62 dB.

3.2 Tasks and Materials

3.2.1 Cognitive tasks

Reading

Reading abilities were assessed by means of a standardized German reading test[12]. The test consists of three subtests measuring reading speed and accuracy on the level of single words, sentences, and short paragraphs.

Long-term memory

The subtest "auditory memory" from the German version of the "Intelligence and Development Scales"[13] was adapted and modified for the current study. In the original subtest, which was designed for individual testing, a short story about a boy and a dog is read to the child. After a delay filled with other tasks, the child is asked to recall the story orally as precisely as possible. In order to make this test suitable for execution in groups of children, free verbal recall was replaced by a recognition paradigm. For this aim, questions relating to central and marginal aspects of the story content were constructed. For each question, the children had to select the correct answer out of three alternatives which were read out loud by the experimenter (e.g. How did the dog´s coat look like? Was it *black*, or *white*, or *white with black spots*?). The response alternatives were illustrated by pictures shown on a screen in front of the classroom. The children had to mark the appropriate answer on their response sheets. Two test versions with 11 questions each were constructed. One version was presented immediately after presentation of the story. The second version was performed after a 2 hours delay filled with other tasks, standardized interviews, and breaks.

Nonverbal abilities

In order to control for general intellectual abilities, a short form of the Coloured Progressive Matrices was used.[14] Incomplete visual patterns are presented to the children. The children have to select the missing item from 6 alternatives.

Attention

Answer sheets printed with an array of 96 pictures of common objects (e.g., bed, dog, tree, knife) are given to the children. The task is to cross out objects representing words which start with the phoneme /b/, and to mark all objects representing other words with a circle. Performance is assessed via the number of items correctly marked in two minutes.

Speech perception

Speech perception was assessed by means of a word-to-picture matching task requiring identification of noise-masked words[8-9]. Lists of three similar-sounding common and concrete German nouns were created (e.g. *Fee* [fe:], *Reh* [re:], *See* [se:]). Each item was represented by a

simple and easy-to-name picture. In each trial, three pictures representing the similar-sounding words were presented to the children. Two seconds after onset of this slide, a spoken word corresponding to one of the three pictures was presented in a multitalker speech noise with an S/N of about -4 dB. The level of the speech noise was adjusted in pilot studies in order to achieve a medium difficulty for second graders. The children had to mark the appropriate picture on prepared answer sheets. Prior to the task, all pictures were shown to the participants and named by the experimenter.

Verbal short-term memory

Verbal short-term memory was assessed via storage of pseudowords. In each trial, a pair of pseudowords was presented to the children. The pseudowords were constructed according to the phonological rules of the German language and differed in length between 3 and 7 syllables. In 9 of the 24 pairs, the pseudowords were equal, in 15 trials, the second pseudoword differed from the first. Different pairs were constructed by substituting or deleting one or two phonemes of the target word, or by reversing the order of two adjacent syllables. In each pair, the first pseudoword was spoken in a female voice, and the second was spoken in a male voice. This was done in order to ensure that the pseudowords are encoded at the phonological (rather than acoustical) level of representation[15]. For instruction, the task was embedded in a story about a fairy who is teaching magic spells to her assistant. The children had to decide whether or not the assistant was successful in repeating what the fairy said. Response sheets were prepared in which each trial was represented by a smiling face ("same") and a sad face ("different").

Phonological awareness

In this task, the children had to decide which of three pseudowords differed from the others with respect to the initial sound. This is a standard task in the assessment of phonological processing in children called 'odd one out'[16-17]. In each trial, three CVC-syllables were presented to the children with an interstimulus-interval of 700 msec. The position of the 'odd' syllable in the sequence had to be marked on prepared response sheets. Prior studies have shown that performance in this task is closely related to reading and spelling, and that the task is highly sensitive to negative effects of acute noise[6].

3.2.2. Recording of the speech materials

The speech materials used in the auditory tests (story, words, pseudowords, syllables) were pre-recorded in a sound-attenuated laboratory at the university of Kaiserslautern. The materials were read by trained speakers and recorded on hard disc with a sampling rate of 44100 Hz and 16-bit-resolution. The recordings were converted to .wav-files and processed with standard sound editing software.

3.2.3 Questionnaires

Children´s noise annoyance and quality of life were assessed by means of questionnaires. All statements were read aloud by the experimenter. For each statement, the children marked their response on answer sheets printed with symbols representing the rating categories (e.g., never – sometimes – often). The scales comprised health-related quality of life (KINDL-R[18]), home

environment and noise at home[19,] noise in the schools[9], and children's social and emotional attitudes towards school (class climate, relation to teachers)[20].

The parents-questionnaire contained questions concerning SES, main language spoken at home, parental support in school work[21], the child´s physical health, and health-related quality of life[18], learning disorders, home environment, and annoyance due to different noise sources.

The teachers-questionnaire contained questions concerning methods of reading instruction[21] , class climate[20], and noise in the schools[9]. Furthermore, for children with migration background, individual ratings of language competence in German were obtained from the class teachers.

3.3 Acoustical Data

Noise exposure is assessed for each child by linking the school and home addresses to modelled aircraft, road traffic, and railway noise levels computed for different times of day (morning, afternoon, evening, night). Sound insulation (e.g., glazing in the windows) and reverberation times in the children´s classrooms were obtained via screening methods. Noise levels were measured continuously during the test sessions. Acoustical events during the test sessions such as overflights, railways passing, or sounds from adjoining classrooms were recorded in writing by the research assistants.

3.4 General Procedure

3.4.1. Data acquisition

All data were collected within a period of 8 weeks in (April to June 2012). The tasks were performed in groups of whole classes. The pupils' desks were arranged in four to five rows in each classroom. Paper boards were placed between adjacent seats in order to avoid distraction due to recognizing the neighbour's answers. The pictures were presented via a notebook and a low-noise beamer on a screen in front of the classroom. The speech materials were presented va wireless headphones designed for children, at a comfortable listening level signal adjusted in pilot studies. The headphones were used in order to ensure perfect signal quality at each working place in the classroom, and thus to eliminate acute effects of classroom reverberation and noise from outside.

In each task except the reading test, pictures of the children's response sheets were shown on the screen, with an arrow indicating the line representing the actual trial. The presentation of the pictures and sounds was controlled by means of standard presentation software. Each task was carefully explained to the children and practiced with examples. The experimenter and two assistants ensured that all children followed the instructions. In the first session, the experimenter shortly introduced the project and affirmed that the questionnaire data were for the researchers and not for the parents or teachers.

3.4.2. Data analysis

To investigate the effect of aircraft noise exposure on children´s cognitive performance, multi-level analyses will be carried out. Multilevel modeling takes into account the hierarchical structure of the data (children in schools) and allows including effects at the level of school and child simultaneously in the same model. In all models, aircraft noise at school and at home will be the main dependent variables, included as continuous variable. Indicators of SES, language competence in German,

methods of reading instruction, classroom acoustics and other noise sources will be included as potential confounders. Like in the RANCH-study[3], exposure-effect relations between aircraft noise and the outcome variables (cognition and health) will be investigated. Furthermore, the underlying mechanisms of potential noise effects on reading will be analyzed.

4 ACKNOWLEDGEMENTS

We thank our research assistants Constanze Schmuck, Christian Geyer, Benjamin Klein, Katharina Schürmann, and Maria Evotschko for their commitment in data collection in the schools. Special thanks also to the children, teachers and parents, and to the Hessen Federal Ministry for Education for cooperation and support in this study.

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