Effects of aircraft noise on annoyance and quality of life in German children near Frankfurt/Main airport: Results of the NORAH (noise-related annoyance, cognition, and health)-study

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Summary
Prior research has shown that chronic exposure to aircraft noise is associated with annoyance and decreased quality of life in children. In the framework of the NORAH-study, the effects of aircraft noise on children's annoyance, well-being at school and health-related quality of life were investigated in 1.058 German second-graders from 29 schools in the vicinity of Frankfurt/Main Airport. Outcome variables were assessed via structured interviews of the children in the classrooms, and parents and teacher questionnaires. Potential confounding factors such as socioeconomic status, classroom insulation and exposure to road traffic and railway noise at school were also assessed. Although aircraft noise levels at children's homes did not exceed 61 dB and were thus considerably lower than in prior studies, multilevel analyses revealed small but significant detrimental effects of aircraft noise on children's well-being at school, health-related quality of life, and sleep quality. Teachers from noise-exposed schools consistently reported severe impairments of school lessons due to interruptions of discourse and obvious distraction of the children in case of overflights. These impairments could not only account for reduced well-being at school, but also contribute to the association between aircraft-noise and reading impairments found in NORAH and in prior studies.

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1. Introduction

Pior studies proved negative effects of aircraft noise exposure on children's quality of life, noise annoyance, and cognition [1, 2, 3, 4]. In the West London Schools Study, children in high noise schools had higher scores in psychological morbidity, particularly hyperactivity, compared to children in low noise schools after adjustment for age, main language spoken and social deprivation [1]. Other studies failed to link aircraft noise exposure to mental health problems [2, 3]. In the multicentric RANCH-study, aircraft noise was not associated with the children's overall mental health, but with higher scores on the hyperactivity subscale of the conducted questionnaire [3, 4]. There is evidence for detrimental effects of aircraft noise on sleep quality in adults (for review, see

[10]). For children, an exposure-effect association between road traffic noise and reduced sleep quality was found [11]. Some researchers consider sleep disturbance as one possible factor underlying the association between noise and health problems [10].

2. The present study

In the framework of the NORAH-study (noise-related annoyance, cognition and health), the effects of aircraft noise on children's annoyance, quality of life, and reading abilities were investigated in second-graders living in the vicinity of Frankfurt/Main Airport in Germany. This paper focuses on the effects of aircraft noise on children's well-being at school, health-related quality of life, and sleep quality. In addition, teachers´ reports concerning the effects of aircraft noise at school on instructional quality are presented. The effects of aircraft noise on reading and it´s precursors are presented in a separate EURONOISE 2015 paper [5].

3. Methods

3.1. Participants

Participants were 85 teachers (78 female) and 1243 second-grade children from 29 primary schools near Frankfurt/Main Airport. From a total of 297 schools, 29 schools were selected by extent of aircraft noise exposure. Those schools exposed to the highest amounts of aircraft noise were selected first. The remaining schools were selected using a combination of criteria. The schools were matched by indicators of the pupils´ socioeconomic status, migration background, and German language proficiency, according to the headmasters´ reports. Schools whose headmasters reported high levels of road traffic or railroad noise were excluded.
We obtained approval for the study from the Hessian Ministry of Education, and written parental consent. In this paper, the data of 1058 children aged 7 to 10 years (mean age 8 years 4 months; 545 girls, 513 boys; 60% with a migration background) are reported, as full data from the parent questionnaires and the children´s survey were required for inclusion in the statistical analysis.

3.2. Noise exposure assessment

The children´s aircraft noise exposure at school and at home was assessed by means of radar data provided by "Deutsche Flugsicherung GmbH" (DFS, German Air Traffic Services). Road traffic and railway noise were calculated using a combination of information (e.g., traffic flow data, street types, proportion of heavy traffic and traffic census data; quantity of train runs, speed and lengths of the trains).
Noise exposure during the time period of 12 months before data collection was assessed for each individual child by linking the school and home addresses to the modeled aircraft, road traffic and railway noise levels computed for different times of day (school: 08-14h, home: 06-18h, 20 – 06h). Classroom insulation was assessed using a combination of variables (e.g., glazing. wall thickness). Aircraft noise levels were treated in the statistical analyses as continuous variables in dB(A): $L_{pAS,eq,08\text{-}14}$ at school and $L_{pAS,eq,06\text{-}18}$ and $L_{pAS,eq,20\text{-}06}$ at home. Road traffic and railway noise levels were entered as classed variables into the final model.

3.3 Procedure

Data collection took place from April to June 2012. The questioning of the children was performed in groups of whole classes. The experimenter shortly introduced the research team and affirmed that the questionnaire data were for the researchers and not for the parents or teachers. Each statement was read aloud by the experimenter. The children marked their response on answer sheets equipped with age-appropriate pictorial rating scales (e.g., never – sometimes – often, see Figure 1).

Figure 1. Pictorial rating scale representing the categories never – sometimes - often. Each line (1 to 5) represents a specific questionaire statement.

Table I. Outcome variables concerning children's well-being at school and health-related quality of life.

Outcome Variable	Questions	Aircraft noise
Index "Well-being at school" Cronbach´s α = 0.78)	I am looking forward to learning new things. After the holidays, I look forward to going to school again. Without school, everything would be better. I feel fine at school. At school, we learn exciting things.	Aircraft noise at home (08 – 14 h)
Physical well-being (single variables)	Last week I had a headache and stomach ache. Last week I felt ill. Last week I felt sluggish and tired. Last week I could sleep well.	Aircraft noise at home (06 – 18 h) Aircraft noise at home (20 – 06 h)
Psychological well-being (single variables)	Last week I laughed a lot and had a lot of fun. Last week I was bored. In the last week I felt good at home.	Aircraft noise at home (06 – 18 h)

The parents were given questionnaires in order to assess socioeconomic status (SES, based on the parents' education and income), and further variables which were not used in the analyses reported here (e.g., main language spoken at home, housing). The teacher questionnaires were filled out by the class teachers during the testing session.

3.4 Child questionnaire

The scales of the child questionnaire comprised health-related quality of life (KINDL-R [6]), home environment and noise at home [7], noise in the schools [8], and children's social and emotional attitudes towards school (class climate, relation to teachers)[9].

For items of the index "well-being at school", answers were reported on a 4-point scale (*strongly disagree, disagree, agree, strongly agree*). For items concerning health-related quality of life (see Table 1), children gave their responses using a 3-point scale (*never, sometimes, often*).

3.5 Teacher questionnaire

Five statements from the teacher questionnaire focused on impairments of school lessons through aircraft noise: (1) Due to aircraft noise, I have to interrupt my talk/the discourse for a short time, (2) During the lessons, the children are distracted by aircraft noise, (3) During the lessons, aircraft noise is audible even when the windows are closed, (4) Due to aircraft noise, I keep the windows closed even when the weather is warm (5) Due to aircraft noise, I undertake fewer outdoor activities with the children. For statements 1 to 3, a 5-point rating scale was used (*never, seldom, sometimes, often, very often*). For statements 4 and 5, a 4-point rating scale was used (*strongly agree, agree, disagree, strongly disagree*).

3.6 Statistical analyses

Principal axis analyses were carried out on the items from the children's survey. Only the index "well-being at school" with an internal consistency of Cronbach´s α = 0.78 could be calculated (see Table I). For the other outcome variables from the children's survey, aggregation of items was not justified by the data. Thus, analyses were based on single items.

In order to account for the hierarchical structure of the data (Level 1: children; Level 2: classes), the associations between aircraft noise exposure and the children´s reports were assessed through multilevel analyses (MLAs). The unadjusted model contained only aircraft noise exposure. The final (fully adjusted) model was adjusted for the Level 1 (L1)-variables age, gender, and SES, and for the L2-variables sound insulation, road traffic noise, and railway noise. Aircraft noise was always included as continuous variable. The coefficients (b), standard errors and p-values are reported in Table III.

With respect to the teachers´ reports, analyses of variance (ANOVAs) were performed in order to analyze the effects of aircraft noise at school on instruction. For this aim, the teachers were assigned to one of three groups according to the aircraft noise levels at school: low exposure (< 47 dB), medium exposure (47 dB to < 55 dB) and high exposure (≥ 55 dB). Outcome variable was an index representing the intensity of disturbance of school lessons through aircraft noise, based on the 5 items from the teacher questionnaire described above (Cronbach´s α = 0.94).

4. Results

4.1. Aircraft noise exposure

Aircraft noise levels at school and at home are given in Table II. Strong correlations were found between aircraft noise at school and at home (r = .96, p < .001), and between daytime and nighttime aircraft noise exposure at home (r = .95, p < .001).

Table II. Aircraft noise exposure at school and at home.

Daytime exposure at school ($L_{pAS,eq,A,08-14}$)	
Mean (*SD*)	49.52 (6.12)
Median (Range)	50.60 (39.10-58.90)
Daytime exposure at home ($L_{pAS,eq,A,06-18}$)	
Mean (*SD*)	49.39 (6.17)
Median (Range)	50.00 (40.00-60.90)
Nighttime exposure at home ($L_{pAS,eq,A,20-06}$)	
Mean (*SD*)	44.79 (5.99)
Median (Range)	45.58 (34.1-56.60)

4.2. Effects of Aircraft noise on children's well-being at school and health-related quality of life

Aircraft noise exposure at school was significantly associated with a decrease in children's well-being at school after full adjustment for age, gender, SES, sound insulation, road traffic noise and railway noise at school (see Table III). As aircraft noise at school increased by 10 dB, children's school-related well-being decreased linearly by 0.130 marks on the 4-point scale (see Figure 1 for the exposure-response curve).

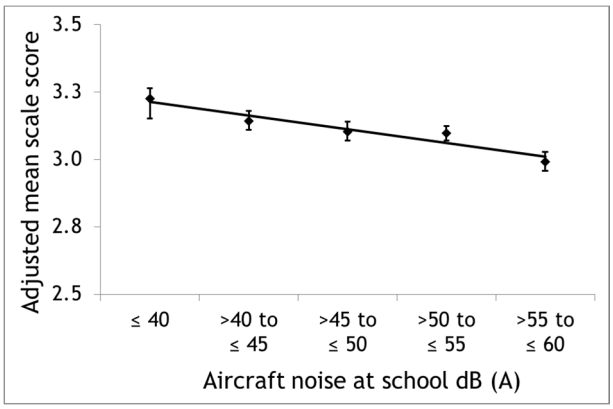

Figure 1. Exposure-response curve for children´s well-being at school: Adjusted mean scale score (95% CI) for 5 dB bands of aircraft noise at school.

Linear exposure-response-relationships were also found between aircraft noise at home and children´s health-related quality of life. With respect to physical well-being, a 10 dB increase in aircraft noise at home was associated with an increase of 0.07 marks for head and stomach ache, and with a decrease of 0.08 marks for sleep quality on a 3-point scale. No significant effects were found for feeling ill and feeling tired (see Table III). For concreteness, Figure 2 shows the relative frequencies of *never*, *sometimes*, and *often*-answers concerning the occurrence of head and stomache ache with respect to aircraft noise exposure at home (low exposure: < 47 dB, medium exposure: 47 dB to < 55 dB, and high exposure: ≥ 55 dB). In each of the three noise exposure groups, the majority of the children reported *never* having had a headache or stomach ache last week. However, when compared to low exposed children, in highly exposed children the percentage of *never*-answers is decreased, and the percentage of *sometimes*-answers is increased. Concerning sleep quality, in each of the three noise

Table III. Multilevel model parameter estimates for aircraft noise on the children's outcome variables for school-related and health-related quality of life, separately for the unadjusted and fully adjusted model.

Outcome Variable	Unadjusted Model		Fully adjusted Model	
	b (SE)	*p*	*b (SE)*	*p*
School-related well-being	-0.011 (0.006)	.087	-0.013 (0.006)	.044
Physical well-being				
head and stomach aches	0.006 (0.003)	.041	0.007 (0.003)	.034
felt ill	-0.003 (0.003)	.307	-0.002 (0.003)	.605
felt sluggish and tired	0.004 (0.004)	.383	0.004 (0.004)	.307
slept well	-0.006 (0.004)	.087	-0.008 (0.004)	.031
Psychological well-being				
bored	0.014 (0.004)	<.001	0.014 (0.004)	<.001
laughed/had fun	-0.004 (0.003)	.221	-0.006 (0.004)	.078
felt good at home	-0.003 (0.003)	.414	-0.004 (0.004)	.312

exposure groups, more than 50% of the children reported to sleep well *very often*, but the percentage of *never*-answers is higher and the percentage of *often*-answers is lower in the highly exposed group (see Figure 3).

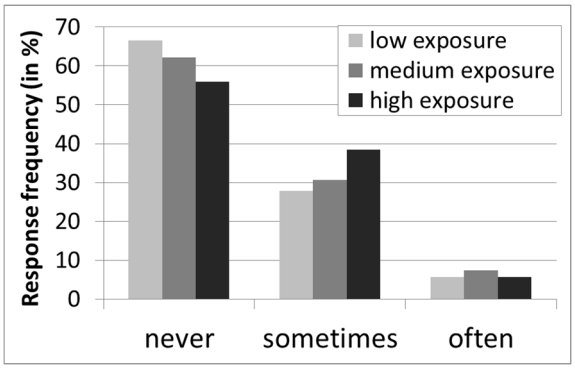

Figure 2. Children's reports concerning head and stomach aches.

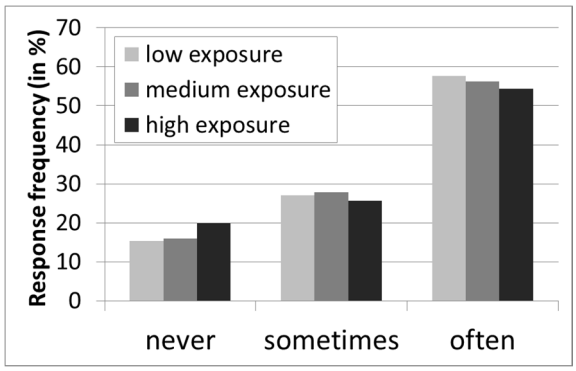

Figure 3. Children's reports concerning good sleep quality.

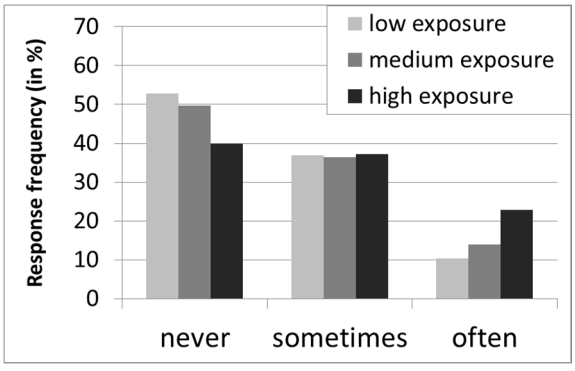

Figure 4. Children's reports concerning beeing bored.

Concerning psychological well-being, a 10 dB increase in aircraft noise at home was significantly associated with a linear increase of 0.14 marks for feeling bored on a 3-point scale. No significant effects were found for having fun and feeling good at home (see Table III). Concerning boredom, Figure 4 shows that the percentage of "*never*"-answers is lower and the percentage of "*often*"-answers is higher in highly exposed when compared to low exposed children.

4.3. Teachers reports concerning impairments of school lessons through aircraft noise

The teachers in the three exposition groups did not differ in respect to age, gender and teaching experience (all F<1). Concerning teachers´ ratings of disturbances of school lessons through aircraft noise, a main effect of exposure group was found, $F(2.81) = 82.89$, $p < .001$. Teachers from highly exposed schools reported stronger disturbances when compared to teachers from medium and low exposed schools (M = 4.52, SD=0.16; M=2.68, SD=0.18, and M=1.26, SD = 0.08, respectively). Disturbance ratings and aircraft noise levels at school were highly correlated (r = .77).

Inspections of single-item answer frequencies proved that more than 50 % of the teachers from highly exposed schools reported frequent interruptions of discourse and frequent distractions of the children due to aircraft noise (see Figure 4). Furthermore, 76 % of the highly exposed teachers reported that aircraft noise is frequently audible in the classroom even when the windows are closed. 86 % reported keeping the windows closed even in warm weather due to aircraft noise. Finally, 38% of the highly exposed teachers confirmed the statement "Due to the aircraft noise, I undertake fewer outdoor activities with the children".

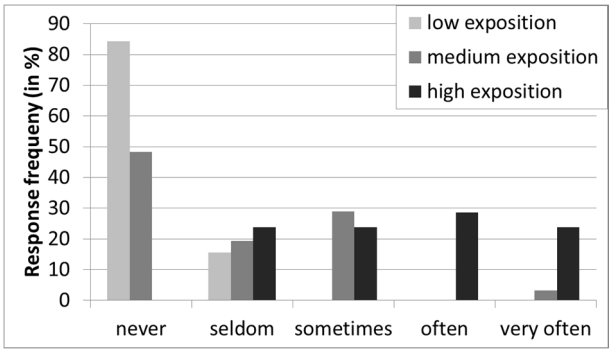

Figure 5. Teacher's reports concerning interruptions of discourse due to aircraft noise.

5. Discussion

In this study, the effects of aircraft noise on well-being at school and health-related quality of life were assessed in German second-graders living in the vicinity Frankfurt/Main Airport in Germany. Although aircraft noise levels at children's homes

did not exceed 61 dB and were thus considerably lower than in prior studies [e.g., 1, 3, 4], multilevel analyses revealed small but significant detrimental effects of aircraft noise on children's well-being at school, physical and psychological well-being, and sleep quality. In view of the small effect sizes and the overall positive evaluations of the children's well-being, the impact of aircraft noise seemed to be small. However, nothing is known on the long-term effects of enduring exposure to aircraft noise.
Teachers from highly noise-exposed schools consistently reported severe impairments of school lessons due to interruptions of discourse and noticeable distractions of the children due to aircraft noise. The strong correlation between the teachers´ ratings and the aircraft noise levels at school underpin the validity and seriousness of the teacher's judgments. These findings are consistent with results from the RANCH project, where detrimental effects of aircraft noise and road traffic noise on student communication, concentration, performance and quality of work were reported by the teachers [12]. Such impairments are especially unfavorable for primary school children. The ability to control attention improves until the teenage years, and young children exhibit difficulties to redirect attention back to the task after interruptions. Furthermore, young children are less able than older children and adults to understand speech in noisy conditions.
From the viewpoint of educational psychology, efficient utilization of the lessons time is an important criterion for instructional quality. The teachers´ reports indicate that, under conditions of aircraft noise, part of the lessons time is lost. Furthermore, aircraft noise affects the range of educational activities, as teachers abandon outdoor activities with the children. The reduction of instructional quality due to aircraft noise might reduce the children´s well-being at school, and contribute to the negative associations between aircraft noise and children´s reading found in NORAH and in prior studies [3, 5]. The current study provides further evidence for negative effects of aircraft noise on children, and is thus of relevance for policy of noise and child health.

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