Effects of aircraft noise on children’s reading and quality of life

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Cognitive and Developmental Psychology
Prior Findings

Prior studies on the effects of chronic aircraft noise exposure proved...

• Lower reading performance in highly exposed children
  Stansfeld et al. 2005; Haines et al., 2001; Hygge et al., 2002
  • Small effect sizes, in some studies confined to most difficult test items.
• Inconsistent findings concerning effects on attention and memory
  • Adverse effects
    Stansfeld et al., 2005; Hygge et al., 2002
  • No effects
    Haines et al., 2001; Stansfeld et al. 2005
• Confound: High aircraft noise exposure is associated with lower SES
  Evans, 2006; Haines et al., 2001, 2002
  • Low SES is a risk factor in children’s health, cognition, and academic achievement, esp. reading.

➤ When comparing performance in children differing in aircraft noise exposure, careful control of SES and SES-related variables is needed.
The RANCH-Study

- Investigated 2,844 children from schools in the vicinity of international airports London-Heathrow, Amsterdam-Schiphol, and Madrid-Barajas.
- Main Result: Increasing aircraft noise level at school is associated with lower reading scores.

**Linear exposure-effect relationship:**
A 20 dB increase in aircraft noise is associated with a reading score decrement of 1/5 to 1/8 SD.

*Figure 1: Adjusted mean reading Z score (95% CI) for 5 dB bands of aircraft noise (adjusted for age, sex, and country)*

Why running a further study?

- **Situation at Frankfurt/Main Airport differs from prior studies**
  - Children’s aircraft noise exposure is lower when compared to prior studies!
    - *Aircraft noise levels at school in RANCH reached 77 dB(A)*
    - *Aircraft noise levels at school in NORAH reached 59 dB(A)*
  - Reading acquisition in German language

- **Further contribution to our knowledge on aircraft noise effects**
  - Effects on verbal precursors of children’s reading acquisition
  - Effects on quality of classroom instruction
  - Control of potential confounders on individual and class level
Method: Participants

• **Selection of Schools**
  • Questionnaires were send out to all 297 public primary schools in the NORAH study area.
  • Positive responses from 160 schools
  • Selection of 29 schools for participation
    • *Schools with highest exposure levels were selected first*
    • *Matched for socioeconomic status and migration background*
    • *Schools reporting extreme levels of noise from other sources were excluded.*
Participating schools

- 4: ≥55 dB(A)
- 3: 50-55 dB(A)
- 2: 45-50 dB(A)
- 1: 40-45 dB(A)
Method: Participants

- 85 second-grade classes
- 1,243 children tested
- Cognitive tests:
  - Complete data from 1,090 children
- Quality of life:
  - Complete data from 1,058 children
- Mean age 8;4
- 60% migration background

Flowchart:

1. Questionnaires to schools
   - 297
2. Questionnaire response
   - 161
3. Selected schools
   - 29
4. Letters to parents
   - N=1694
5. Parental consent
   - 1,309 (77.3%)
6. Children participating at test
   - 1,243
7. Complete test data
   - 1,195
8. Complete data incl. SES
   - 1,090

Refusal:
- 153 (9.0%)
- No feedback: 232 (13.7%)

Absence:
- Absent on test day (illness): 66
- Incomplete test data: 48
- Missings in questionnaires: 105

Analyses
# Test Battery

## Complex Cognitive Tasks

| Reading                          | Standardized German Reading Test  
(Lenhard 2006) |
|----------------------------------|----------------------------------|
| Story memory                     | Answering questions about a story heard before  
Grob, A.; Meyer, C.S. & Hagmann-von Arx, P.  
(2009) |
| Nonverbal abilities              | Ravens colored progressive matrices (CPM), short form  
(Bühlheller & Häcker 2002) |

## Verbal Precursors of Reading

| Phonological awareness + storage | Categorizing Speech Sounds  
(Bradley & Bryant, 1985) |
|---------------------------------|--------------------------|
| Nonword Recognition             | Identifying Words in Noise  
(Klatte et al., 2010) |
| Rapid access to phonological representations in LTM | Speed test: Cross out all pictures representing words with initial sound /b/!  
(Klatte et al., 2014) |
### Parents questionnaire*

<table>
<thead>
<tr>
<th>SES</th>
<th>Composite score calculated from education, current position, income</th>
</tr>
</thead>
</table>
| • Physical well-being | • Self-made items  
| • Mental well-being | • KINDL-R  

### Teacher questionnaire

| Annoyance due to aircraft noise at school | Adaptations from prior studies (Klatte, 2010)  
| Effects of aircraft noise at school on students and instruction | Self-made items |

* Translated in 9 languages

### Physical well-being

<table>
<thead>
<tr>
<th>In the last four weeks....</th>
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<th>sometimes</th>
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Noise Levels

• Aircraft noise exposure at school and at home during the time period of 12 months before data collection were calculated for each individual child on the basis of radar data provided by German Air Traffic Services (Deutsche Flugsicherung, DFS).

• Calculations were performed for different times of day
  School: 08-14h on work days, Home: 06-18h, 20 – 06h.

• Further acoustic data were included and controlled in the analyses:
  ➢ Road traffic and railroad noise levels
  ➢ classroom insulation and reverberation
Data Acquisition in Schools

• 3 to 4 lessons per class
• Wireless headphones were used for the auditory-verbal tests, in order to rule out potential effects of classroom reverberation, seat position, and noise from outside.
## Results: Noise Levels

<table>
<thead>
<tr>
<th></th>
<th>Mean (SD)</th>
<th>Median (Range)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Daytime exposure at school</strong> (L&lt;sub&gt;pAS, eq,A, 08-14&lt;/sub&gt;)</td>
<td>49.52 (6.12)</td>
<td>50.60 (39.10-58.90)</td>
</tr>
<tr>
<td></td>
<td>49.39 (6.17)</td>
<td>50.00 (40.00-60.90)</td>
</tr>
<tr>
<td><strong>Daytime exposure at home</strong> (L&lt;sub&gt;pAS, eq,A, 06-18&lt;/sub&gt;)</td>
<td>44.79 (5.99)</td>
<td>45.58 (34.1-56.60)</td>
</tr>
</tbody>
</table>

- Children’s socioeconomic status was unrelated to aircraft noise levels at home and at school ($r = - .027; p < .38$; and $r = -.036, p < .24$).
- Matching of schools according to SES was successful.
Results: Noise Levels

<table>
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<th>Mean (SD)</th>
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<td></td>
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<td>($L_{pAS,eq,A,20-06}$)</td>
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<td>45.58 (34.1-56.60)</td>
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Strong correlations were found
- between aircraft noise at school and at home ($r = .96, p < .001$),
- between daytime and nighttime aircraft noise at home ($r = .95, p < .001$)
Correlation between aircraft noise levels at school and at home

... in NORAH

... in RANCH

➢ Studies do not allow conclusions concerning differential effects of noise at school and noise at home.
Results: Reading Performance

Standardized German Reading Test (Lenhard & Schneider, 2006)

3 Subtests:
• Words
• Sentences
• Short texts

• Global Score

Reading Measure: T-Scores
Mean 50, SD 10
T-Scores between 40 and 60 represent average range
Multilevel Models for Reading as Outcome Variable

<table>
<thead>
<tr>
<th>Unadjusted model</th>
<th>Partially adjusted model</th>
<th>Fully adjusted model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aircraft noise at school</td>
<td>Aircraft noise at school</td>
<td>Aircraft noise at school</td>
</tr>
<tr>
<td>Level 1</td>
<td>Level 1</td>
<td>Level 1</td>
</tr>
<tr>
<td>Age</td>
<td>Age</td>
<td>Age</td>
</tr>
<tr>
<td>Gender</td>
<td>Gender</td>
<td>Gender</td>
</tr>
<tr>
<td>SES</td>
<td>SES</td>
<td>SES</td>
</tr>
<tr>
<td>Migration background</td>
<td>Migration background</td>
<td>Migration background</td>
</tr>
<tr>
<td>German language proficiency</td>
<td>German language proficiency</td>
<td>German language proficiency</td>
</tr>
<tr>
<td>Number of books at home</td>
<td>Number of books at home</td>
<td>Number of books at home</td>
</tr>
<tr>
<td>Nonverbal abilities</td>
<td>Nonverbal abilities</td>
<td>Nonverbal abilities</td>
</tr>
<tr>
<td>Story comprehension</td>
<td>Story comprehension</td>
<td>Story comprehension</td>
</tr>
<tr>
<td>Phonological awareness</td>
<td>Phonological awareness</td>
<td>Phonological awareness</td>
</tr>
<tr>
<td>Level 2</td>
<td>Level 2</td>
<td>Level 2</td>
</tr>
<tr>
<td>Class SES</td>
<td>Class SES</td>
<td>Class SES</td>
</tr>
<tr>
<td>Class migration</td>
<td>Class migration</td>
<td>Class migration</td>
</tr>
<tr>
<td>Class size</td>
<td>Class size</td>
<td>Class size</td>
</tr>
<tr>
<td>Parental involvement</td>
<td>Parental involvement</td>
<td>Parental involvement</td>
</tr>
<tr>
<td>Classroom insulation</td>
<td>Classroom insulation</td>
<td>Classroom insulation</td>
</tr>
<tr>
<td>Road traffic noise at school</td>
<td>Railroad noise at school</td>
<td>Railroad noise at school</td>
</tr>
</tbody>
</table>
Results: Global Reading Score

<table>
<thead>
<tr>
<th></th>
<th>N=1,090</th>
<th>unadjusted model</th>
<th>partially adjusted model</th>
<th>fully adjusted model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>b (SE)</td>
<td>β (SE)</td>
<td>p (b)/p (β)</td>
<td>b (SE)</td>
</tr>
<tr>
<td>ICC=0.081</td>
<td>46.92 (0.384)</td>
<td>45.97 (0.543)</td>
<td>-0.103 (0.049) -0.346 (0.169) 0.018 / 0.020</td>
<td>-0.097 (0.050) -0.327 (0.172) 0.027 / 0.029</td>
</tr>
<tr>
<td>Aircraft noise school (Level 2)</td>
<td>-0.081 (0.064) -0.190 (0.156) 0.103 / 0.113</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>-0.101 (0.041)</td>
<td>-0.060 (0.024) 0.013 / 0.014</td>
<td>-0.100 (0.041) -0.060 (0.024) 0.014 / 0.015</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>0.085 (0.467)</td>
<td>0.005 (0.026) 0.855</td>
<td>0.082 (0.467) 0.005 (0.026) 0.860</td>
<td></td>
</tr>
<tr>
<td>SES household</td>
<td>0.121 (0.053)</td>
<td>0.066 (0.029) 0.022</td>
<td>0.120 (0.053) 0.065 (0.029) 0.024</td>
<td></td>
</tr>
<tr>
<td>Migration background</td>
<td>1.164 (0.614)</td>
<td>0.090 (0.034) 0.009</td>
<td>1.649 (0.617) 0.092 (0.035) 0.008</td>
<td></td>
</tr>
<tr>
<td>Language proficiency</td>
<td>1.686 (0.337)</td>
<td>0.146 (0.030) &lt;0.001</td>
<td>1.723 (0.337) 0.150 (0.030) &lt;0.001</td>
<td></td>
</tr>
<tr>
<td>Number of children’s books</td>
<td>0.663 (0.206)</td>
<td>0.097 (0.030) 0.001</td>
<td>0.673 (0.205) 0.099 (0.030) 0.001</td>
<td></td>
</tr>
<tr>
<td>Nonverbal abilities</td>
<td>0.583 (0.218)</td>
<td>0.066 (0.025) 0.007 / 0.008</td>
<td>0.581 (0.218) 0.066 (0.025) 0.008</td>
<td></td>
</tr>
<tr>
<td>Story comprehension</td>
<td>1.094 (0.191)</td>
<td>0.124 (0.022) &lt;0.001</td>
<td>1.087 (0.191) 0.123 (0.022) &lt;0.001</td>
<td></td>
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<tr>
<td>Access to phon. repr.</td>
<td>3.116 (0.280)</td>
<td>0.355 (0.030) &lt;0.001</td>
<td>3.111 (0.278) 0.354 (0.029) &lt;0.001</td>
<td></td>
</tr>
<tr>
<td>Phonological awareness</td>
<td>2.018 (0.241)</td>
<td>0.227 (0.027) &lt;0.001</td>
<td>2.002 (0.239) 0.225 (0.027) &lt;0.001</td>
<td></td>
</tr>
<tr>
<td>Level 2</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Class SES</td>
<td>-0.165 (0.210)</td>
<td>-0.217 (0.270) 0.431 / 0.422</td>
<td>-0.188 (0.212) -0.247 (0.273) 0.376 / 0.366</td>
<td></td>
</tr>
<tr>
<td>Class migration background</td>
<td>-2.349 (2.205)</td>
<td>-0.295 (0.267) 0.287 / 0.270</td>
<td>-1.805 (2.136) -0.227 (0.263) 0.398 / 0.388</td>
<td></td>
</tr>
<tr>
<td>Class size</td>
<td>0.123 (0.108)</td>
<td>0.178 (0.152) 0.255 / 0.241</td>
<td>0.078 (0.110) 0.114 (0.157) 0.476 / 0.470</td>
<td></td>
</tr>
<tr>
<td>Parental Involvement</td>
<td>0.219 (0.680)</td>
<td>0.062 (0.192) 0.747 / 0.746</td>
<td>0.069 (0.687) 0.020 (0.195) 0.920</td>
<td></td>
</tr>
<tr>
<td>Classroom insulation</td>
<td>0.009 (0.038)</td>
<td>0.037 (0.155) 0.809</td>
<td></td>
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<tr>
<td>Road traffic noise at school</td>
<td>-0.270 (0.149)</td>
<td>-0.285 (0.157) 0.070</td>
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<tr>
<td>Railroad noise at school</td>
<td>0.320 (0.342)</td>
<td>0.138 (0.148) 0.349 / 0.351</td>
<td></td>
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</table>

R²
- Level 1 (Within Level): 0.441
- Level 2 (Between Level): 0.036

SE = standard error;

Significant association between aircraft noise at school and lower reading scores after full adjustment.
Results: Global Reading Score

Linear Exposure-Effect Relationship

- A 20 dB increase of aircraft noise at school was associated with a decrease in children’s global reading scores by 1/5 of a SD, i.e. 2 points on the T-score scale.
- Replication of the RANCH result.
Further Results: Reading

• Significant effects of aircraft noise were found for the *global reading score*, and for the subtests *word reading* and *text reading*.

• In terms of learning time, a 10 dB increase in aircraft noise corresponds to a reading delay of about one month (one point on the T-score scale).

➢ Statistically, the most exposed children in the Rhine-Main region lag 2 months behind their least exposed peers.

• **Separate analyses in children with and without a migration background**
  • In children with a migration background, the effect of aircraft noise was in the same direction, but did not reach significance.
    • Problem of statistical power due to an accumulation of risk factors in this group?
  • In children without a migration background, a 20 dB increase in aircraft noise level was associated with 2.8-point decrement in the global reading scores, corresponding to a reading delay of about 3 months.

• **Analyses of story comprehension and phonological abilities**
  • No effects of aircraft noise were found.
Results: Children´s quality of life

Standardized interview in groups of whole classes

Parents questionnaire

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Parents’ ratings of children’s physical well-being

During the last four weeks:
- ... my child had stomach ache or headache
- ... my child felt sick.
- ... my child felt sluggish and tired.

5-point rating-scale:
“never” to “almost everytime”

Cronbach’s α = .77

• **Overall, ratings are positive:** Score 5 represents best-possible answer!
• **Significant effect of aircraft noise after full adjustment**
  Linear exposure-response-relationship
  • 20 dB increase in aircraft noise is associated with a decrease in physical health ratings by 1/4 points on the scale.
During the last four weeks:
- my child was grumpy and bad-tempered.
- my child got angry easily.
- my child got bored with everything.
- 
  5-point rating-scale: „never“ to „almost everytime“

Cronbach’s $\alpha = .76$

- Overall, ratings are positive: Score 5 represents best-possible answer!
- Significant effect of aircraft noise after full adjustment
  Linear exposure-response-relationship
  - 20 dB increase in aircraft noise is associated with a decrease in rating scores by 1/5 points on the scale.
I feel fine at school
At school, we learn exciting things
After the holidays, I look forward to going to school again.

4-point rating-scale: „absolutely wrong“ to „absolutely true“

Overall, ratings are positive: Score 4 represents best-possible answer!

Significant effect of aircraft noise after full adjustment
Linear exposure-response-relationship

- 20 dB increase in aircraft noise is associated with a decrease in rating scores by 1/4 points on the scale.

Cronbach’s $\alpha = .79$
Effects of aircraft noise on instruction at school

- 20 out of 21 teachers from schools with aircraft noise levels exceeding 55 dB reported severe disruptions of classroom instruction due to aircraft noise (\(M = 4.52, \text{SD} 0.16\), on a 5-point scale).
- Disruption ratings were strongly correlated with aircraft noise levels (\(r = .85\)).
- More than 50% of these teachers reported frequent interruptions of discourse and noticeable distractions of the children due to aircraft noise.

Ratings of impairments of instruction due to different noise sources

Teacher ratings of frequency of discourse interruptions due to aircraft noise
Discussion (1)

- The NORAH study proved adverse effects of aircraft noise on children’s reading acquisition after full adjustment for potential confounders on both individual and class level.
- In combination with prior studies, esp. RANCH, this is strong evidence for a causal effect of aircraft noise on reading.
- Although small in statistical effect size, in terms of learning time, the effects correspond to reading delays of 2 to 3 months in the most exposed when compared to the least exposed children.
- In our second-graders, 2 to 3 months constitute 10 to 15% of the total time of instruction at school.
Discussion (2)

• Nothing is known concerning long-term effects on reading and QoL. Children’s exposure will endure, or even increase.
• **Mechanisms** between aircraft noise and reading are still unclear.
• Teachers’ reports indicate severe impairments of classroom instruction due to aircraft noise. These may contribute to the effect on reading.
• Such adverse conditions are present throughout the lessons time, not only during reading instruction!
  ➢ Future studies should include other domains of academic achievement, e.g., spelling and math.
Thank you!

Kirstin Bergström
Jan Spilski
Jochen Mayerl

NORAH Konsortium
Dirk Schreckenberg
Rainer Guski
Andreas Seidler

NORAH Scientific Advisory Board
Jürgen Hellbrück
Irene van Kamp

Children, teachers, and parents from 29 primary schools participating in the NORAH-study