



Lebensqualität  
Gesundheit  
Entwicklung

# Effects of aircraft noise on children's reading and quality of life

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# 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

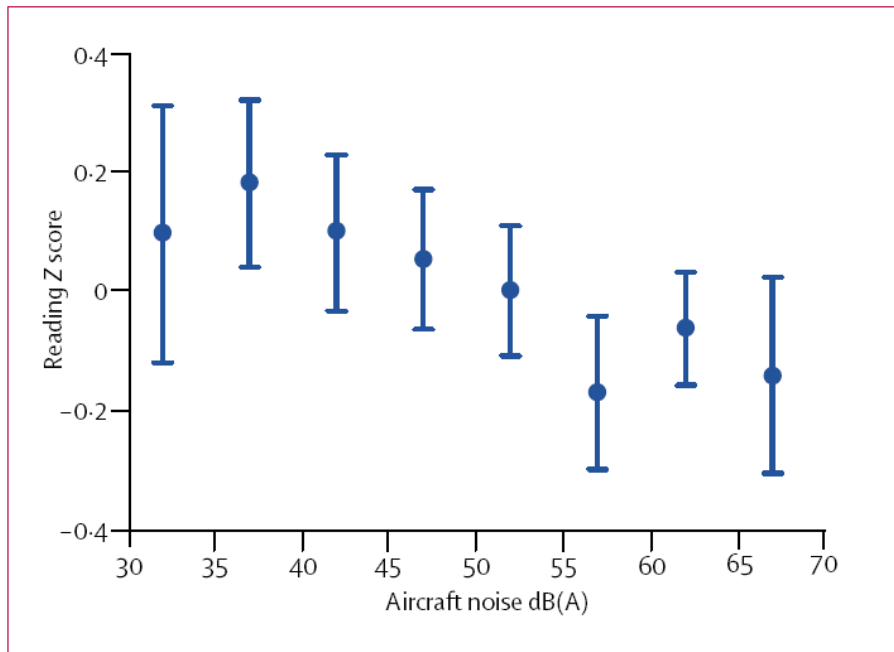
*Evans, 2006; Haines et al., 2001, 2002*

- 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)

*Stansfeld et al., 2005, The Lancet; 365: 1942-1949.*

# 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

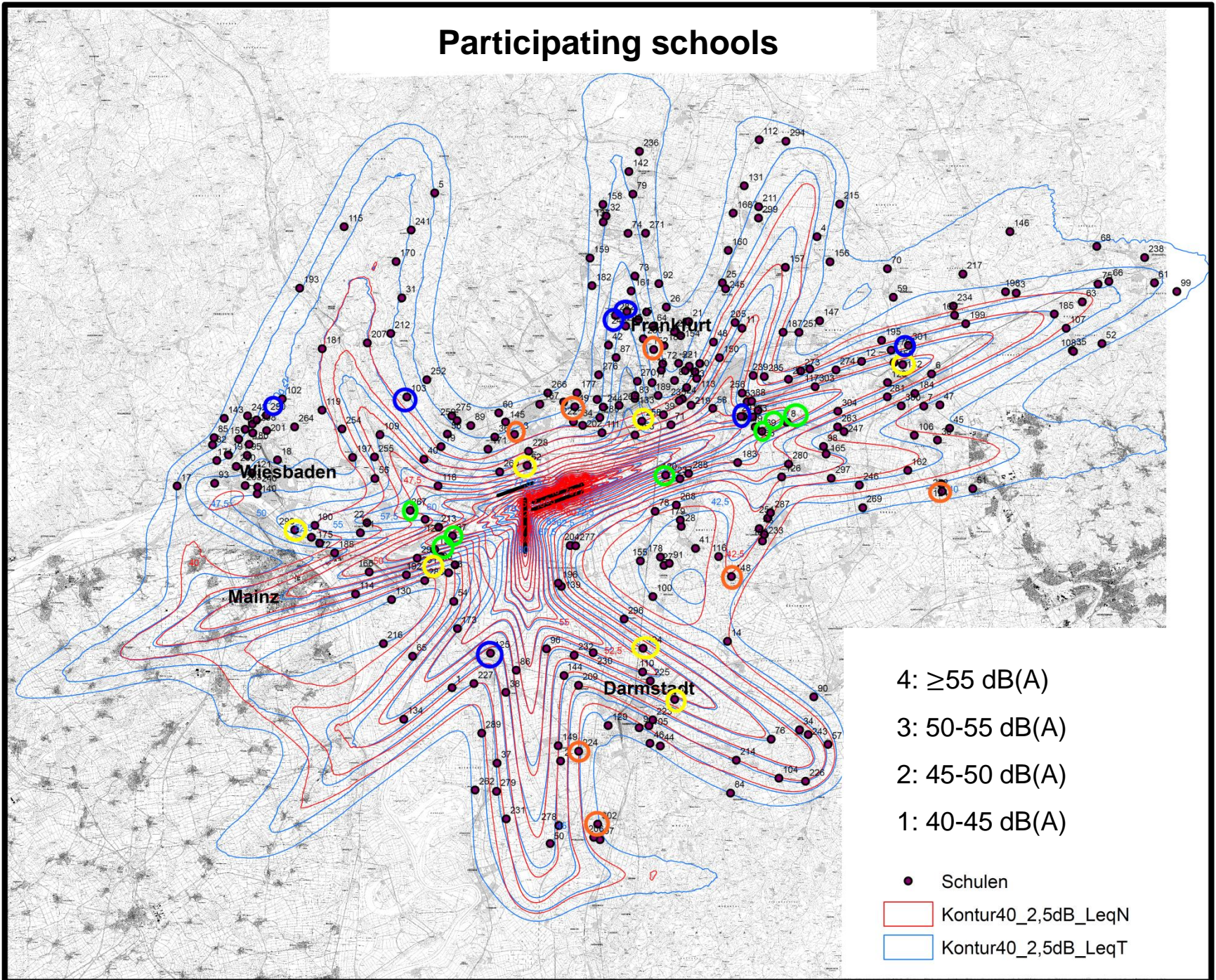
# Method: Participants

- **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.*

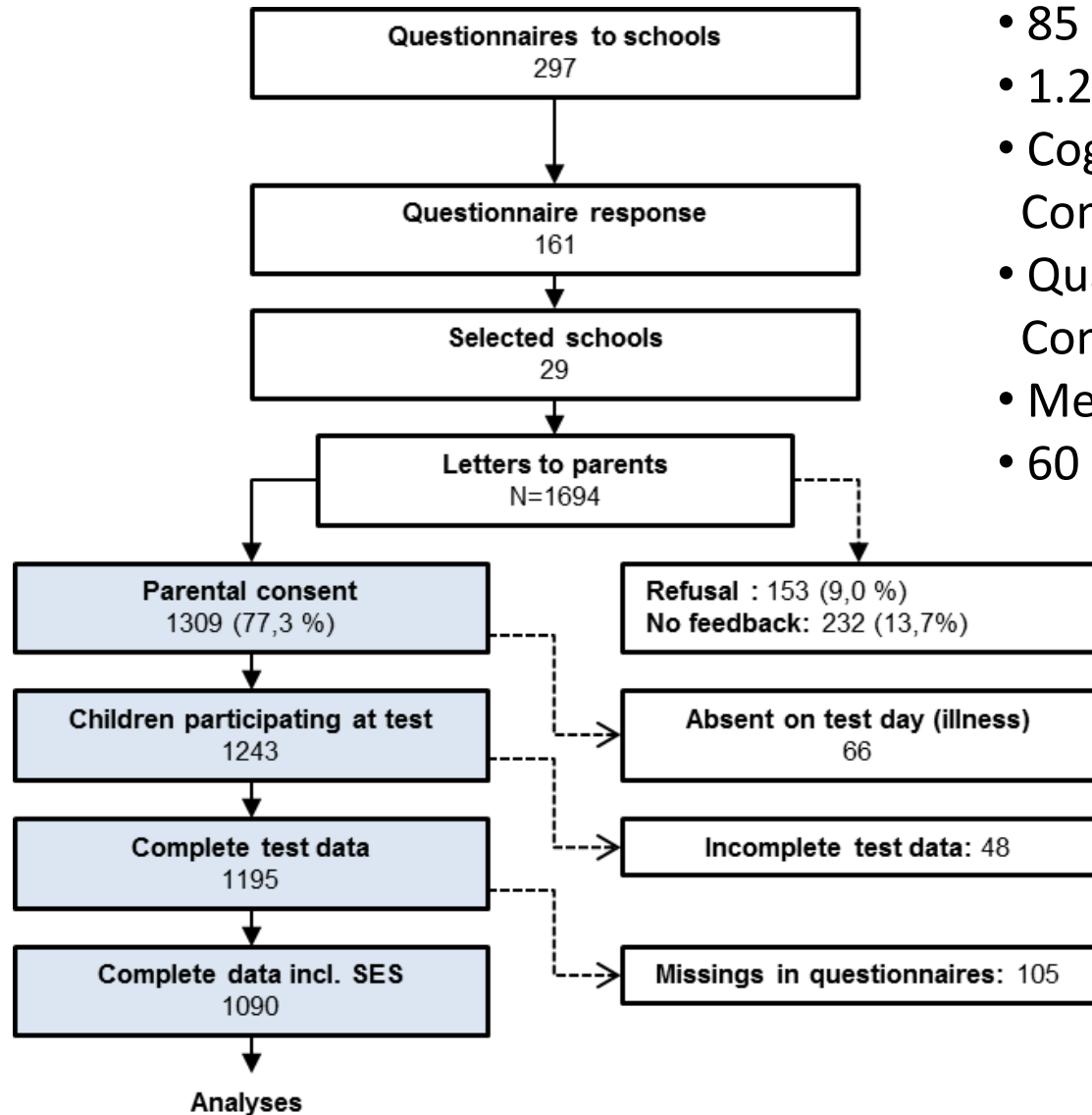


# Participating schools





# 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

# Test Battery

## Complex Cognitive Tasks

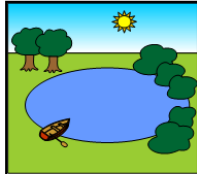

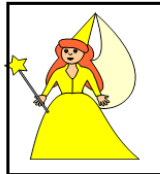



























Reading	Standardized German Reading Test ( <i>Lenhard 2006</i> )
Story memory	Answering questions about a story heard before <i>Grob, A.; Meyer, C.S. &amp; Hagmann-von Arx, P. (2009)</i>
Nonverbal abilities	Ravens colored progressive matrices (CPM), short form <i>(Bulheller &amp; Häcker 2002)</i>



Auto  
Flugzeug  
Fahrrad  
Pferd



## Verbal Precursors of Reading

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

<b>SES</b> <i>Lange et al. (2007), Schenk et al. (2007)</i>	<ul style="list-style-type: none"> <li>Composite score calculated from education, current position, income</li> </ul>
<ul style="list-style-type: none"> <li>Physical well-being</li> <li>Mental well-being</li> </ul>	<ul style="list-style-type: none"> <li>Self-made items</li> <li>KINDL-R</li> </ul>

## Teacher questionnaire

<ul style="list-style-type: none"> <li>Annoyance due to aircraft noise at school</li> <li>Effects of aircraft noise at school on students and instruction</li> </ul>	<ul style="list-style-type: none"> <li>Adaptations from prior studies (Klatte, 2010)</li> <li>Self-made items</li> </ul>
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\* Translated in 9 languages

Physical well-being						
In the last four weeks....		never	rarely	sometimes	often	almost always
1.	... <u>my</u> child felt sick.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2.	... <u>my</u> child had headaches or stomach aches.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

# 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

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

- 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

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

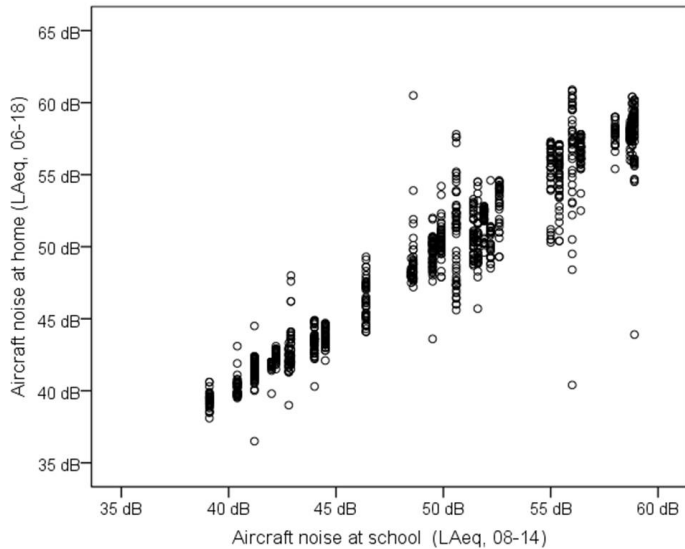
## Strong correlations were found

- between aircraft noise at school and at home ( $r = .96, p < .001$ ),
- between daytime and nighttime aircraft noise at home ( $r = .95, p < .001$ )

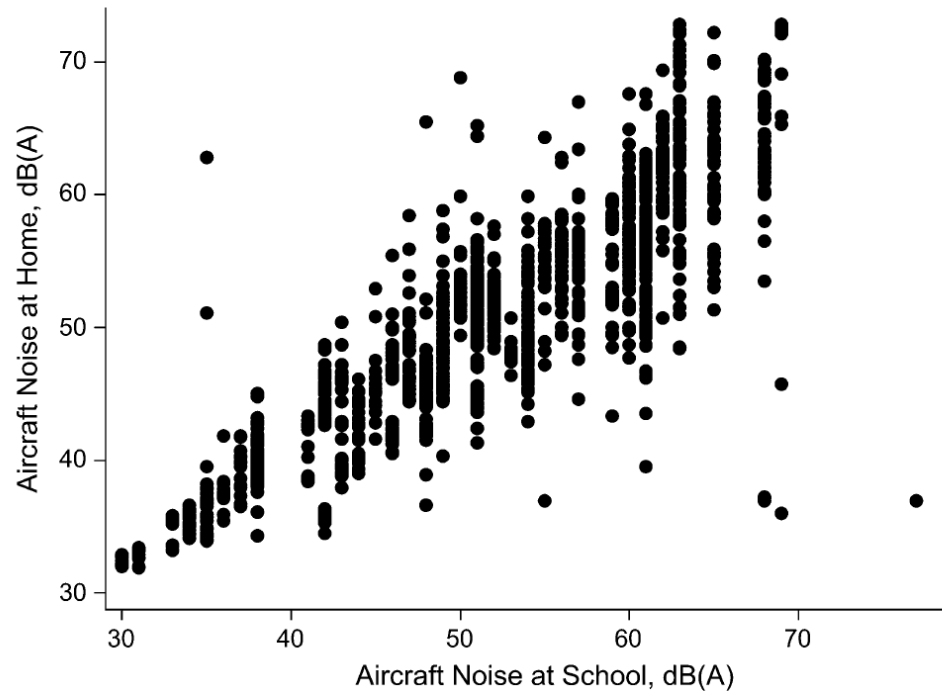


# Correlation between aircraft noise levels at school and at home

... 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

<u>Unadjusted model</u>	Partially adjusted model	Fully adjusted model
Aircraft noise at school	Aircraft noise at school	Aircraft noise at school
	Level 1	Level 1
	Age	Age
	Gender	Gender
	SES	SES
	Migration background	Migration background
	<u>German language proficiency</u>	<u>German language proficiency</u>
	Number of books at home	Number of books at home
	<u>Nonverbal abilities</u>	<u>Nonverbal abilities</u>
	<u>Story comprehension</u>	<u>Story comprehension</u>
	<u>Access to phon. repr.</u>	<u>Access to phon. repr.</u>
	<u>Phonological awareness</u>	<u>Phonological awareness</u>
	Level 2	Level 2
	Class SES	Class SES
	<u>Class migration</u>	<u>Class migration</u>
	<u>Class size</u>	<u>Class size</u>
	<u>Parental involvement</u>	<u>Parental involvement</u>
		<u>Classroom insulation</u>
		Road traffic noise at school
		<u>Railroad noise at school</u>

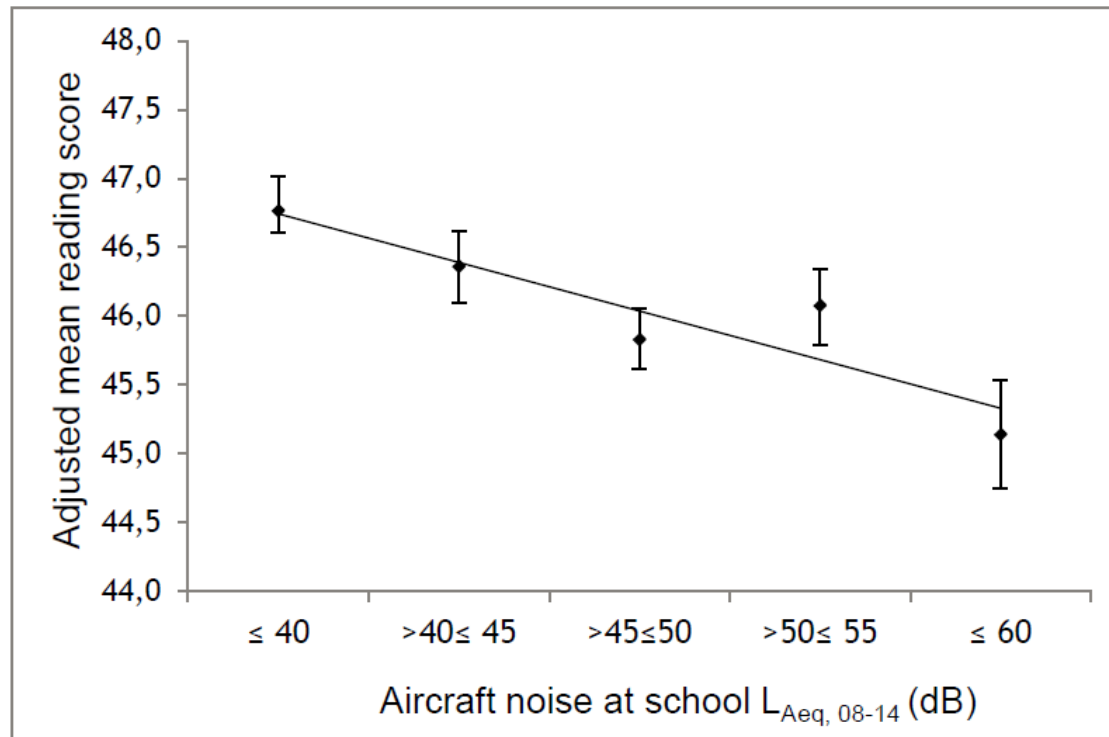
# Results: Global Reading Score

N=1,090 ICC=0.081	unadjusted model			partially adjusted model			fully adjusted model		
	<i>b</i> (SE)	$\beta$ (SE)	<i>p</i> ( <i>b</i> )/ <i>p</i> ( $\beta$ )	<i>b</i> (SE)	$\beta$ (SE)	<i>p</i> ( <i>b</i> )/ <i>p</i> ( $\beta$ )	<i>b</i> (SE)	$\beta$ (SE)	<i>p</i> ( <i>b</i> )/ <i>p</i> ( $\beta$ )
Intercept	46.92 (0.384)			45.97 (0.543)			45.94 (0.534)		
Aircraft noise school (Level 2)	-0.081 (0.064)	-0.190 (0.156)	0.103 / 0.113	-0.103 (0.049)	-0.346 (0.169)	0.018 / 0.020	-0.097 (0.050)	-0.327 (0.172)	0.027 / 0.029
Level 1									
Age				-0.101 (0.041)	-0.060 (0.024)	0.013 / 0.014	-0.100 (0.041)	-0.060 (0.024)	0.014 / 0.015
Gender				0.085 (0.467)	0.005 (0.026)	0.855	0.082 (0.467)	0.005 (0.026)	0.860
SES household				0.121 (0.053)	0.066 (0.029)	0.022	0.120 (0.053)	0.065 (0.029)	0.024
Migration background				1.164 (0.614)	0.090 (0.034)	0.009	1.649 (0.617)	0.092 (0.035)	0.008
Language proficiency				1.686 (0.337)	0.146 (0.030)	<0.001	1.723 (0.337)	0.150 (0.030)	<0.001
Number of children's books				0.663 (0.206)	0.097 (0.030)	0.001	0.673 (0.205)	0.099 (0.030)	0.001
Nonverbal abilities				0.583 (0.218)	0.066 (0.025)	0.007 / 0.008	0.581 (0.218)	0.066 (0.025)	0.008
Story comprehension				1.094 (0.191)	0.124 (0.022)	<0.001	1.087 (0.191)	0.123 (0.022)	<0.001
Access to phon. repr.				3.116 (0.280)	0.355 (0.030)	<0.001	3.111 (0.278)	0.354 (0.029)	<0.001
Phonological awareness				2.018 (0.241)	0.227 (0.027)	<0.001	2.002 (0.239)	0.225 (0.027)	<0.001
Level 2									
Class SES				-0.165 (0.210)	-0.217 (0.270)	0.431 / 0.422	-0.188 (0.212)	-0.247 (0.273)	0.376 / 0.366
Class migration background				-2.349 (2.205)	-0.295 (0.267)	0.287 / 0.270	-1.805 (2.136)	-0.227 (0.263)	0.398 / 0.388
Class size				0.123 (0.108)	0.178 (0.152)	0.255 / 0.241	0.078 (0.110)	0.114 (0.157)	0.476 / 0.470
Parental Involvement				0.219 (0.680)	0.062 (0.192)	0.747 / 0.746	0.069 (0.687)	0.020 (0.195)	0.920
Classroom insulation							0.009 (0.038)	0.037 (0.155)	0.809
Road traffic noise at school							-0.270 (0.149)	-0.285 (0.157)	0.070
Railroad noise at school							0.320 (0.342)	0.138 (0.148)	0.349 / 0.351
R <sup>2</sup>									
Level 1 (Within Level)				0.441			0.441		
Level 2 (Between Level)	0.036			0.120			0.208		

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

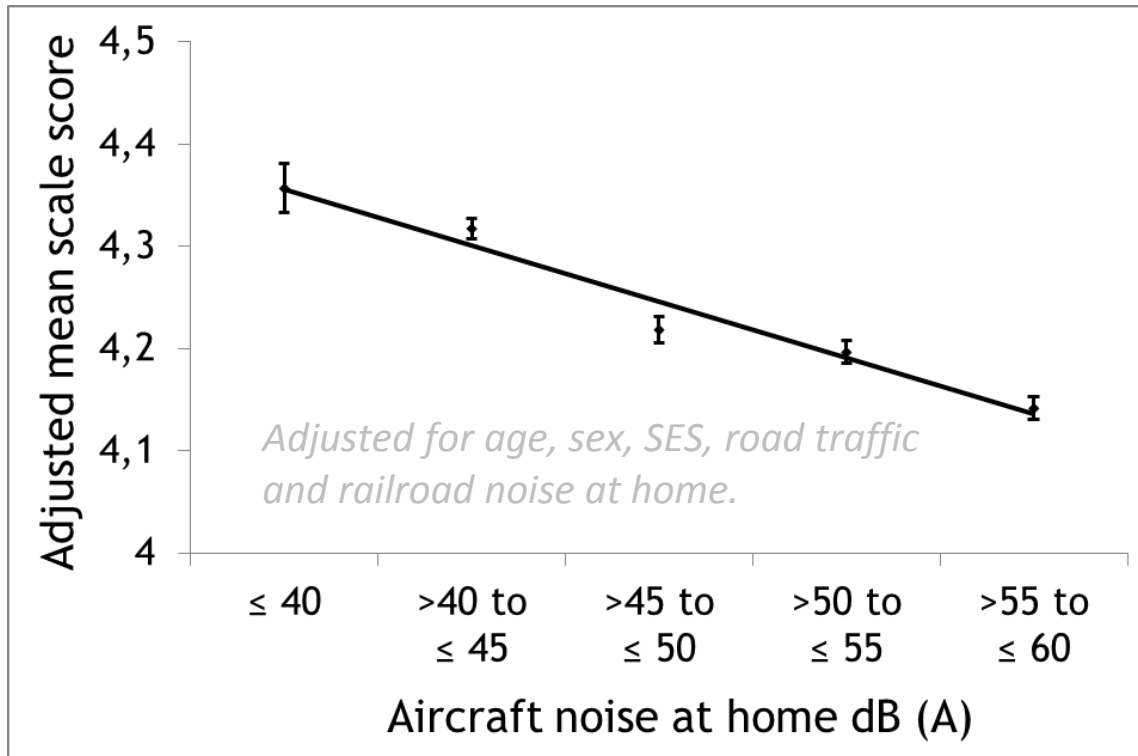


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Parents questionnaire

Physical well-being						
<i>In the last four weeks....</i>		never	rarely	sometimes	often	almost always
1.	... <u>my</u> child felt sick.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2.	... <u>my</u> child had headaches or stomach aches.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

# Parents' ratings of children's physical well-being



## During the last four weeks..

- ... my child had stomachache or headache
- ... my child felt sick.
- ... my child felt sluggish and tired .

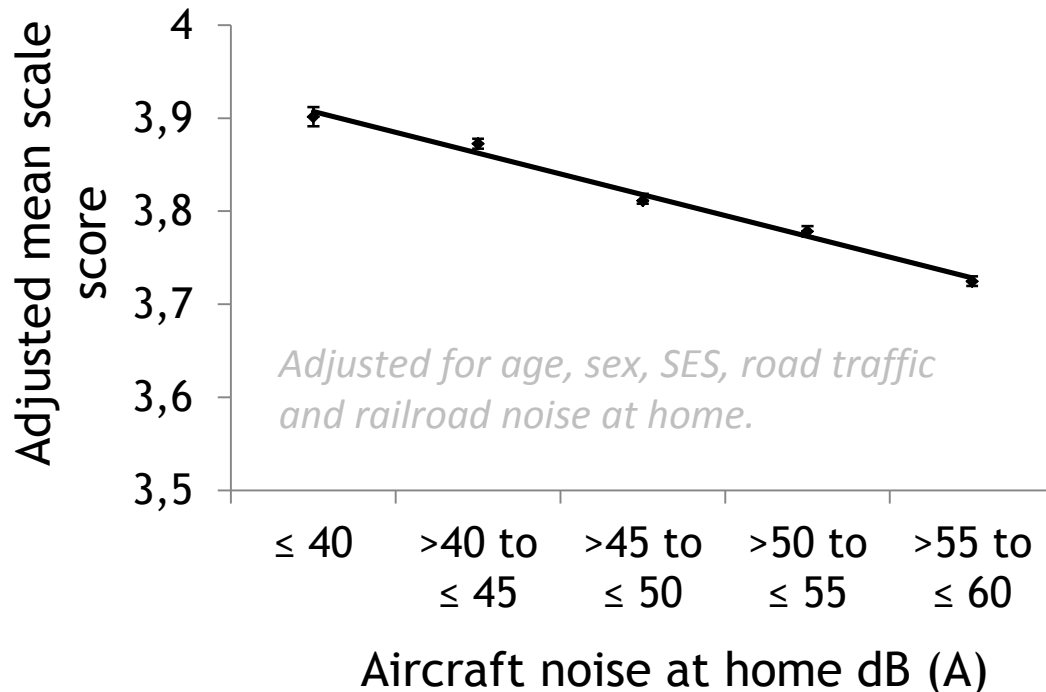
5-point rating-scale:

„never“ to „almost everytime“

Cronbach's  $\alpha = .77$

- **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.

# Parents' ratings of children's mental well-being



## During the last four weeks..

- ... my child was grumpy and bad-tempered.
- ... my child got angry easily.
- ... my child got bored with everything.
- ....

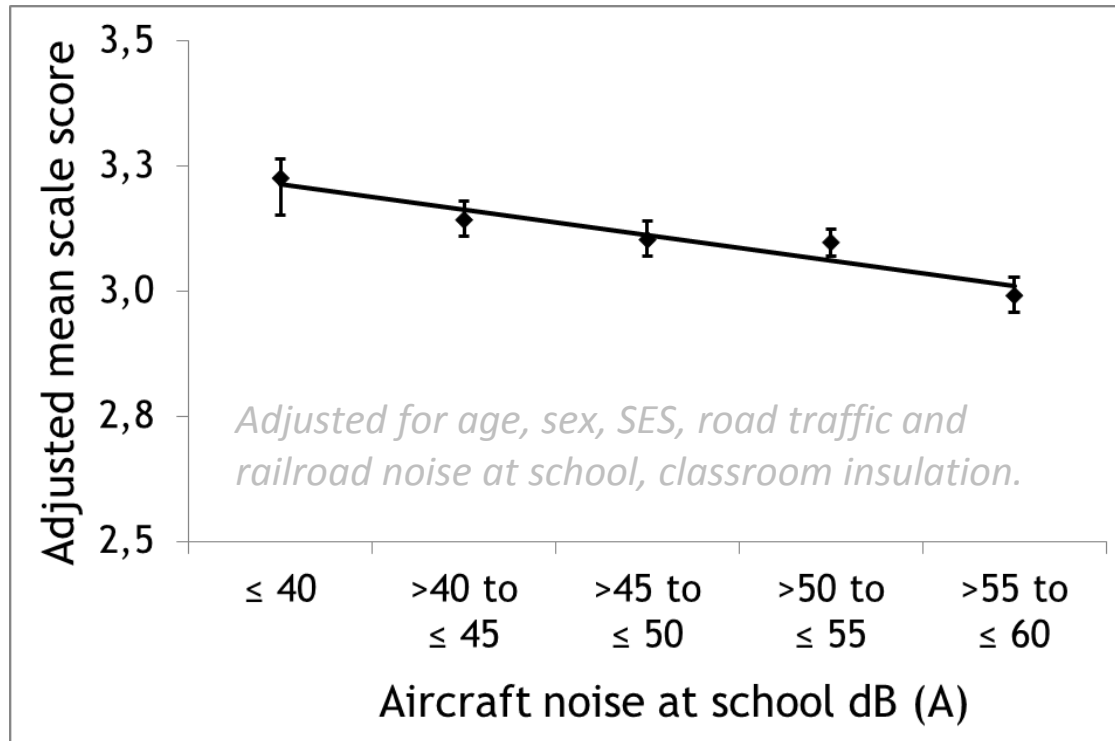
5-point rating-scale:

„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.

# Children's ratings of well-being at school



- 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“

Cronbach's  $\alpha = .79$

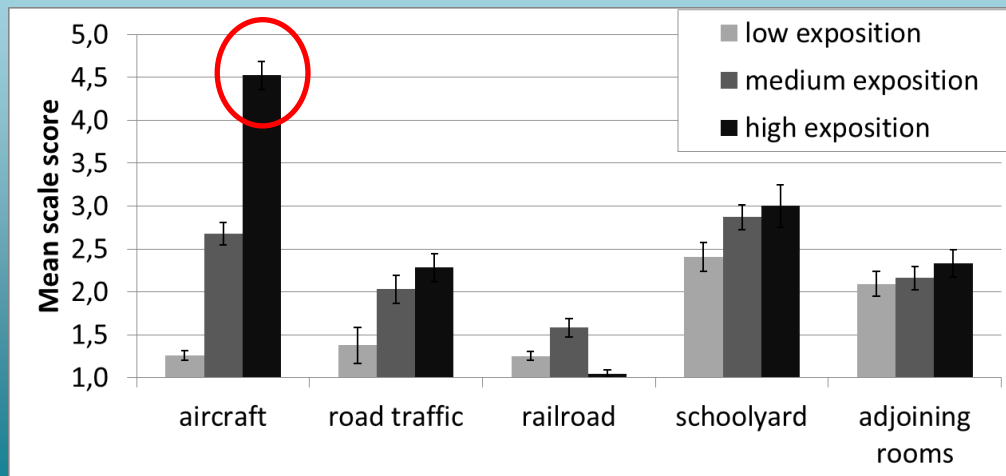
- **Overall, ratings are positive:** Score 4 represents best-possible answer!
- **Significant effect of aircraft noise after full adjustment**  
Linear exposure-response-relationship
  - 20 dB increase in aircraft noise is associated with a decrease in rating scores by 1/4 points on the scale.



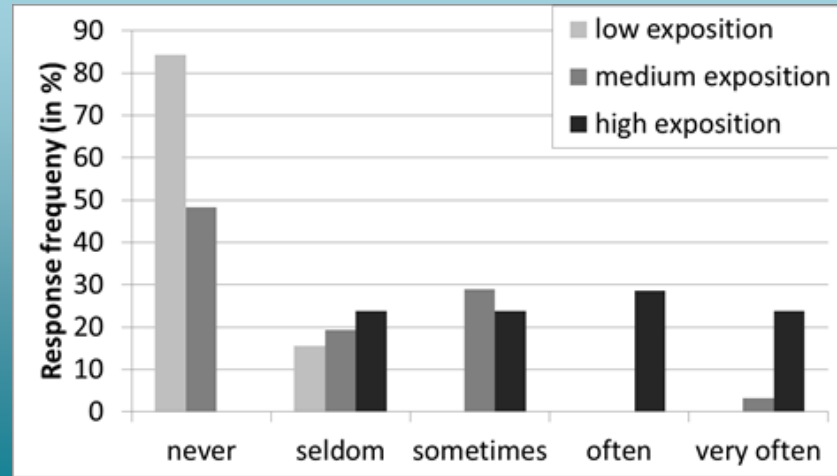
# Effects of aircraft noise on instruction at school

- 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, 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**

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Jochen Mayerl

**NORAH Konsortium**

Dirk Schreckenber

Rainer Guski

Andreas Seidler

**NORAH Scientific**

**Advisory Board**

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