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Do we need different aircraft noise metrics to predict annoyance for different groups of people?

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ABSTRACT

In the literature, LAeq and Lden are the dominating noise exposure metrics for calculating the relationship between noise and annoyance. However, alternative metrics such as the number of events above a threshold (NAT), LAmax or Emergence are rarely considered, although they may have the potential to explain additional variance. This seems necessary because a WHO-Review pointed out that the average relationship between aircraft noise levels and annoyance raw scores is .44 which represents an explained variance of only 19.36%. Here, we present a post-hoc analysis of the NORAH data set and aim to evaluate the adequacy of alternative noise metrics. We calculated regression models and multilevel analyses with robust estimation algorithms (MLR) by using different noise metrics (LAeq, Lden, LAmax, Emergence, NAT). The analyses were carried out for different groups of people (children, parents, teachers) and different contexts (school: workplace or learning environment, residential environment). The calculations with different noise metrics showed that the LAeq as a single noise metric can best predict annoyance. However, for aircraft noise annoyance of children and teachers there was a significant increase in explained variance by including the NAT criterion as a second noise metric in the models (maximum R^2 = .684).

Keywords: Aircraft noise, different metrics, Annoyance

1. INTRODUCTION

Environmental noise annoyance is a psychological response to noise and can be viewed as a multi-faceted stress response (1). Besides sleep disturbances, annoyance is one major burden of disease effect of environmental noise, according the WHO (2). Concerning annoyance, different responses to noise are distinguished including physiological, emotional, cognitive, and behavioral responses (3).

Guski et al. (4) showed in their WHO-Review that the average association between aircraft noise levels and annoyance raw scores is .44 (range .21 to .74) which represents an explained variance of 19.36%. This indicates a comparatively low explanation of variance across all the studies included. It was shown that the association between aircraft noise and annoyance is greater compared to other traffic noise sources (4) Previous reviews with focus on children also showed differences in the level of relationships for different groups of people (e.g., 5). Accordingly, children rate themselves as less annoyed by traffic noise compared to adults (6). For teachers, on the other hand, there was a much stronger association between aircraft noise and annoyance (7).

To improve explained variance of aircraft noise annoyance, two perspectives of measurement can be considered: First, studies could consider adaptions in the measurement of annoyance. Second, studies could use alternative acoustic metrics.

Although transportation noise annoyance is understood as a multi-facetted response, it is currently predominantly measured with a single item, the so-called ICBEN item – “Thinking about the last (12 months or so), when you are here at home, how much does noise from [noise source] bother, disturb, or annoy you?” - with the verbal marks “not at all,” “slightly,” “moderately,” “very,” “extremely” (8). In order to achieve a better variance explanation, possibilities of a better annoyance measurement are discussed (9-11); however, in the field of method development and improvement the focus is mainly on adults.

Current approaches in the field of annoyance measurement consider the multidimensional construct of annoyance. Thus, Schreckenberg et al. (12) suggest the multi-item noise annoyance scale (MIAS) as a reliable, valid, theory-driven measure to assess annoyance as a response to transportation noise, with a slightly improved variance explanation compared to the ICBEN measurement. Within the framework of the NORAH study work package three, annoyance was measured by several items and aggregated to annoying factors. These factors had a high composite reliability (CR between .83 and .93) and average variance extracted (AVE between .64 and .73). For this reason, we currently see no possibility of improving the variance explanation for the NORAH "children" data in this area.

For these reasons, we focus on the perspective of acoustics parameters in order to improve variance explanation. Most studies analysed the associations between aircraft noise and annoyance with weighted and unweighted acoustic averaging levels (Lden, LAeq), but less with alternative metrics (but see for a current alternative approach (13)). This neglect may fail to use a potential source for more variance detection, which we will review with our post-hoc analysis of the NORAH data.

Here, we present a further analysis of the NORAH data set, aiming to evaluate the adequacy of different noise exposure metrics (LAeq, Lden, LAmax, Emergence, NAT55 to NAT80) for analyzing the association between aircraft noise and annoyance. We focus on differences in the level of relationships for different groups of people (children, parents, and teachers) and for different contexts (school: workplace or learning environment, residential environment).

2. METHOD

2.1 Participants

A total of 1,243 second-graders and 84 class teachers (78 female) from 29 primary schools participated in the NORAH study (14). From a total of 297 schools, 29 schools were selected based on 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-priori direct matching to avoid potential confounding factors (e.g., socioeconomic status = SES). The schools were matched by indicators of the pupils´ SES, migration background, and German language proficiency, according to the headmasters´ reports. For annoyance due aircraft noise at school, complete data were available for 84 teachers (78 female) and 1,090 children. Mean age for children was 8 years and 4 months (*SD* 5 months).

2.2 Assessment of Noise Exposure

Average aircraft noise levels (school: LAeq, 08-14; home: LAeq, 06-22, Lden, 00-24), maximum sound levels (school: LAmax, 08-14; home LAmax, 06-22), difference between LAmax and LAeq (emergence) and number above thresholds (school: NAT, 08-14: home: NAT, 06-22) for bands of five dB(A) were calculated for the time period of 12 months before data collection was conducted. Exposure levels were calculated on the basis of radar data from the Flight Track and Aircraft Noise Monitoring System (FANOMOS) provided by German Air Traffic Services (for details, see (15)). Road traffic and railway noise levels were estimated using a combination of information (e.g., traffic flow data, quantity of train runs) provided by local authorities. Classroom reverberation and insulation were assessed through screening procedures (15).

2.3 Materials and Procedure

The following description of the procedure has been published elsewhere (e.g. 14, 16). The questioning of the children was performed in groups of whole classes. Each statement was carefully explained to the children and practiced with examples. All statements were read aloud by the experimenter and a combination of picture and number represented the statement. The children were given a questionnaire to be completed at home by their parents, which contained questions concerning the annoyance and potential confounding factors (e.g., SES). The teacher questionnaire was given to the teachers before the children's testing session and collected immediately after it.

Teachers' noise annoyance was assessed by a scale (factor) with five statements focused on annoyance due to aircraft noise at school (composite reliability, CR = .93; average variance extracted, AVE = .73; Cronbach's α = .94). The additional statements addressed concrete effects of aircraft noise on the quality of instruction (e.g., "Due to aircraft noise, I have to interrupt my talk/the discourse for a short time") and ranged from "not at all annoyed" [1] to "severely annoyed" [5].

Parental noise annoyance was assessed by three statements and a 4-point rating scale ranging from "strongly disagree" to "strongly agree" (CR = .85; AVE = .66; Cronbach's α = .82).

Children's annoyance due to aircraft noise at school was assessed through a four-item scale (e.g., "When learning at school, I am bothered by aircraft noise"). The same applies to the annoyance judgements for annoyance due to aircraft noise at home. The reliability was good for both scales (school: CR = .88, Cronbach's α = .81; home: CR = .83, Cronbach's α = .80). Explained variance was relatively high (school: AVE = .64; home: AVE = .71). More details concerning the procedure, the questionnaires, and statistical examination of psychometrics are provided by Klatte et al. (14, 17).

2.4 Statistical Analyses

To analyze the impact of aircraft noise exposure on annoyance, regression models and multilevel models (MLA) were realized using Mplus 8 and IBM SPSS 25. Regression analyses were performed for teacher´s and parents´ annoying judgements and for children's annoying due aircraft noise at home. For children's annoying du aircraft noise at school, we conducted MLA in order to deal with the hierarchical structure of the data and avoid misspecifications of parameters (e.g., underestimation of standard errors) (18). Regression models were adjusted for confounding factors on individual level, hierarchical models for both levels (level 1: individual, level 2: classes).

3. RESULTS

3.1 Aircraft Noise Exposure

Descriptive statistics for the different noise metrics are shown in Table 1. The aircraft noise exposure is shown separately for school and home address. A period from 8 a.m. to 2 p.m. is reported for school (08-14) and a period from 6 a.m.to 10 p.m. for the residential address (06-22).

Table 1 – Descriptive statistics for the different noise metrics (NORAH Study)

		Daytime at school (08-14)			Daytime at home (06-22)		
		M	*SD*	*Range*	*M*	*SD*	*Range*
LAeq	dB (A)	49.52	6.12	39.10-58.90	49.15	6.16	36.40-60.80
Lden, 00-24	dB (A)	-	-	-	51.74	6.00	40.80-63.60
LAmax	dB (A)	64.12	7.18	50.00-80.00	67.12	7.73	51.00-83.00
Emergence	dB (A)	14.92	2.66	9.20-21.30	17.96	2.89	11.20-24.60
NAT (bands)	≥55 <60 dB (A)	22.60	17.15	0.67-66.33	55.28	42.26	0.07-187.00
	≥60 <65 dB (A)	18.01	17.72	0.03-58.77	45.52	46.52	0.04-165.23
	≥65 <70 dB (A)	9.95	14.27	0.00-63.61	28.77	42.75	0.01-180.37
	≥70 <75 dB (A)	3.72	5.55	0.00-22.80	11.60	18.34	0.00-121.21
	≥75 <80 dB (A)	1.48	3.45	0.00-14.47	3.90	8.18	0.00-40.73

Notes. Emergence school: LAmax (08-14) minus LAeq (08-14) at school; Emergence home LAmax (06-22) minus LAeq (06-22) at home.

3.2 Effects of Aircraft Noise on Children at School and at Home

Multilevel analyses revealed significant associations between aircraft noise exposure at school and children's aircraft noise annoyance. Only for NAT ≥ 55 < 60 the association was not significant. The MLA results for the school context are depicted in Table 2. It can be seen that the size of associations (unadjusted models) strongly vary from β = .235 to .629 depending on the aircraft noise metrics.

Systematic differences between the annoyance judgements at class level (level 2) were 34% (intraclass correlation, *ICC* = .34). This means that 34% of the variance in the class average annoyance judgements is due the class membership. An R^2 of .396 as in LAeq (unadjusted model) means that 39.6% of 34% can be explained by LAeq - an absolute variance explanation of 13.46%.

The results for the home context are depicted in Table 3. The explained variance was slightly higher than in the school context, but not for the NAT ≥70 <75 metric. Here, R^2 can be read directly because it addresses regression models on individual level. Therefore, the explained variance of the LAeq is for example R^2 = .186.

Table 2 - Multilevel Model Parameter Estimates for Effects of Aircraft Noise at School on Children's Ratings of Noise Annoyance at School

	unadjusted					adjusted				
	β	***b (SE)***	***p***	***95% CI***	***R²***	**β**	***b (SE)***	***p***	***95% CI***	***R²***
LAeq	.629	.052 (.008)	< .001	.037/.069	.396	.626	.052 (.009)	< .001	.032/.073	.454
LAmax	.603	.039 (.007)	< .001	.025/.053	.364	.604	.039 (.009)	< .001	.022/.056	.442
Emergence	.358	.069 (.023)	< .01	.025/.114	.128	.362	.070 (.023)	< .01	.026/.114	.265
NAT ≥55 <60	.235	.007 (.003)	< .01	.002/.013	.055	.146	.004 (.003)	> .05	.000/.010	.160
NAT ≥60 <65	.253	.007 (.003)	< .01	.002/.012	.064	.186	.005 (.003)	< .05	.001/.010	.173
NAT ≥65 <70	.439	.016 (.003)	< .001	.009/.023	.193	.448	.016 (.004)	< .001	.009/.023	.310
NAT ≥70 <75	.802	.073 (.007)	< .001	.059/.087	.643	.832	.075 (.009)	< .001	.058/.092	.724
NAT ≥75 <80	.614	.091 (.008)	< .001	.075/.107	.377	.749	.110 (.017)	< .001	.078/.143	.541

Notes. *SE* = Standard Error; *b* = unstandardized coefficient; *β* = standardized coefficient; 95% *CI* = 95% confidence interval. Adjusted for age, gender, socioeconomic status (SES), class SES, class size, classroom insulation, road-traffic and railway noise at school. *ICC* = .34 (ICC = intraclass correlation); $R^2 = R^2$ for Level 2.

Table 3 - Effects of Aircraft Noise at Home on Children's Ratings of Noise Annoyance at Home

	unadjusted					adjusted				
	β	***b (SE)***	***p***	***95% CI***	***R²***	**β**	***b (SE)***	***p***	***95% CI***	***R²***
LAeq	.411	.077 (.005)	< .001	.068/.087	.168	.429	.081 (.006)	< .001	.070/.012	.186
Lden	.406	.078 (.005)	< .001	.068/.088	.164	.425	.082 (.006)	< .001	.071/.093	.182
LAmax	.393	.059 (.004)	< .001	.051/.067	.154	.404	.060 (.004)	< .001	.051/.069	.166
Emergence	.179	.072 (.011)	< .001	.050/.094	.031	.172	.066 (.012)	< .001	.042/.089	.036
NAT ≥55 <60	.149	.004 (.001)	< .001	.003/.006	.022	.171	.005 (.001)	< .001	.003/.006	.034
NAT ≥60 <65	.244	.006 (.001)	< .001	.005/.007	.059	.259	.006 (.001)	< .001	.005/.008	.073
NAT ≥65 <70	.261	.007 (.001)	< .001	.006/.009	.068	.273	.007 (.001)	< .001	.006/.009	.079
NAT ≥70 <75	.316	.020 (.002)	< .001	.017/.023	.099	.310	.019 (.002)	< .001	.015/.023	.103
NAT ≥75 <80	.318	.045 (.004)	< .001	.037/.052	.100	.310	.042 (.004)	< .001	.033/.050	.098

Notes. *SE* = Standard Error; *b* = unstandardized coefficient; *β* = standardized coefficient; 95% *CI* = 95% confidence interval. Adjusted for age, gender, SES, road-traffic noise, and railroad noise at home. $R^2 = R^2_{\text{corrected}}$ (corrected by the number of predictors and sample size).

Overall, for the group of children, we found no consistent evidence that other exposure measures than LAeq could better clarify the annoyance judgments. The results are independent of the context (school vs. home).

3.3 Effects of Aircraft Noise on Parents

Adjusted and unadjusted regression models were conducted to test the relationship between different aircraft noise metrics and annoyance (see Table 4). All noise metrics showed significant associations with aircraft noise annoyance (all *p's* < .001). The explained variance was significantly higher than in the models calculated for children (ΔR^2 = .11 for LAeq) and also higher (ΔR^2 = .07) than reported by Guski et al. (4). As for children, it was shown for parents that LAeq is the most adequate noise metric for predicting aircraft noise annoyance in the private context.

Table 4 - Effects of Aircraft Noise at Home on Parent's Ratings of Noise Annoyance at Home

	unadjusted					**adjusted**				
	β	***b (SE)***	***p***	***95% CI***	***R²***	**β**	***b (SE)***	***p***	***95% CI***	***R²***
LAeq	.528	.071 (.003)	< .001	.064/.078	.278	.513	.071 (.004)	< .001	.063/.078	.292
Lden	.517	.072 (.004)	< .001	.065/.078	.267	.504	.071 (.004)	< .001	.063/.079	.283
LAmax	.514	.055 (.003)	< .001	.049/.060	.264	.493	.053 (.003)	< .001	.047/.081	.273
Emergence	.259	.074 (.008)	< .001	.058/.090	.066	.232	.064 (.009)	< .001	.047/.081	.088
NAT ≥55 <60	.201	.004 (.001)	< .001	.003/.005	.040	.184	.004 (.001)	< .001	.002/.005	.068
NAT ≥60 <65	.295	.005 (.001)	< .001	.004/.006	.086	.298	.005 (.001)	< .001	.004/.006	.123
NAT ≥65 <70	.281	.005 (.001)	< .001	.004/.006	.078	.298	.006 (.001)	< .001	.004/.006	.122
NAT ≥70 <75	.392	.018 (.001)	< .001	.015/.020	.153	.377	.017 (.001)	< .001	.014/.019	.178
NAT ≥75 <80	.480	.048 (.003)	< .001	.043/.053	.230	.457	.045 (.003)	< .001	.039/.050	.233

Notes. *SE* = Standard Error; *b* = unstandardized coefficient; *β* = standardized coefficient 95% *CI* = 95% confidence interval. Adjusted for age, gender, SES, road-traffic, and railroad noise at home. $R^2 = R^2_{corrected}$ (corrected by the number of predictors and sample size).

3.4 Effects of Aircraft Noise on Teachers

Again, to test the relationship between different aircraft noise metrics and annoyance, we calculated adjusted and unadjusted regression models (see Table 5). All noise metrics (except for NAT ≥55 <60) showed significant associations with aircraft noise annoyance (all *p's* < .001). The explained variance was markedly higher (ΔR^2 = .41) than reported by Guski et al. (4). Overall, the NAT ≥70 <75 and the LAeq were the most adequate noise metrics for predicting teachers annoyance due aircraft noise exposure at school (adjusted model).

Table 5 - Teachers' Aircraft Noise Annoyance (School Workplace)

	unadjusted					**adjusted**				
	β	***b (SE)***	***p***	***95% CI***	***R²***	**β**	***b (SE)***	***p***	***95% CI***	***R²***
LAeq	.770	.134 (.012)	< .001	.109/.158	.589	.821	.144 (.015)	< .001	.114/.175	.593
LAmax	.732	.098 (.010)	< .001	.078/.118	.530	.764	.101 (.012)	< .001	.077/.125	.541
Emergence	.412	.164 (.040)	< .001	.084/.244	.160	.420	.160 (.042)	< .001	.077/.244	.225
NAT ≥55 <60	.286	.018 (.006)	< .01	.005/.030	.071	.191	.011 (.007)	> .05	-.003/.025	.089
NAT ≥60 <65	.544	.032 (.006)	< .001	.021/.043	.288	.482	.031 (.006)	< .001	.018/.044	.298
NAT ≥65 <70	.610	.045 (.006)	< .001	.032/.058	.364	.612	.050 (.007)	< .001	.035/.064	.450
NAT ≥70 <75	.773	.146 (.013)	< .001	.120/.173	.593	.771	.146 (.015)	< .001	.116/.176	.604
NAT ≥75 <80	.606	.184 (.027)	< .001	.131/.238	.359	.670	.196 (.033)	< .001	.130/.261	.384

Notes. *SE* = Standard Error; *b* = unstandardized coefficient; *β* = standardized coefficient; 95% *CI* = 95% confidence interval. Adjusted for class size, classroom insulation, road traffic, and railway noise, noise sensitivity of the teacher. $R^2 = R^2_{corrected}$ (corrected by the number of predictors and sample size).

3.5 Combined Models

In the models aimed to combine the different acoustic metrics, we found that only the inclusion of the NAT metric leads to a significantly higher variance explanation. The models (see Table 6) revealed that the NAT metric served as a significant predictor of children's annoyance as a response to aircraft noise over and above LAeq. However, this only holds for the NAT ≥70 <75 dB(A) criterion as exemplified by the comparison between combined model 1 and combined model 2. The inclusion of the NAT metric leads to an explained variance of R^2 = .727. Compared to the sole calculation with LAeq, this corresponds to an increase in explained variance at the class level of ΔR^2 = .273. Including the *ICC* of .34, this corresponds to an absolutely explained variance of R^2 = .247 = 24.7% (only LAeq R^2 = .15 = 15%).

Table 6 - Fully-adjusted Multilevel Models with Inclusion of a Second Aircraft Noise Metric: Effect of Aircraft Noise Exposure at School on Children's Aircraft Noise Annoyance at School

		β	*b (SE)*	*p*	*95% CI*	R^2
children at	**Combined Model 1**					**.456**
school	LAeq	.595	.050 (.017)	< .01	.017/.083	
	NAT ≥65 <70	.044	.002 (.007)	>.05	-.012/.015	
	Combined Model 2					**.727**
	LAeq	.010	.001 (.009)	> .05	-.017/.019	
	NAT ≥70 <75	.826	.074 (.012)	< .001	.051/.097	

Notes. *SE* = Standard Error; *b* = unstandardized coefficient; *β* = standardized coefficient; 95% *CI* = 95% confidence interval. Adjusted for age, gender, socioeconomic status (SES), class SES, class size, classroom insulation, road-traffic, and railway noise at school. *ICC* = .34 (*ICC* = intraclass correlation); $R^2 = R^2$ for Level 2.

The models depicted in Table 7 revealed that the NAT metric served as a significant predictor of teacher annoyance due to aircraft noise over and above LAeq. The statistical significance for the prediction of annoyance by NAT ≥70 <75 compared to LAeq is quite similar (βLAeq = .466; βNAT ≥70 <75 = .460). The inclusion of NAT ≥70 <75 leads to an explained variance of R^2 = .684, which corresponds to an increase inexplained variance of ΔR^2 = 9.1%, compared to the sole calculation with LAeq.

Table 7 – Combined Fully Adjusted Regression Models with a Second Aircraft Noise Metric: Teachers' Aircraft-Noise Annoyance (School Workplace)

		β	*b (SE)*	*p*	*95% CI*	R^2
teacher	Combined Model 1					
	LAeq	.649	.114 (.021)	< .001	.071/.156	**.611**
	NAT ≥65 <70	.210	.017 (.009)	< .05	.001/.034	
	Combined Model 2					
	LAeq	.466	.082 (.019)	< .001	.017/.083	**.684**
	NAT ≥70 <75	.460	.087 (.019)	< .001	.012/.162	

Notes. *SE* = Standard Error; *b* = unstandardized coefficient; *β* = standardized coefficient 95% CI = 95% confidence interval. Adjusted for class size, classroom insulation, road traffic, and railway noise, noise sensitivity of the teacher. $R^2 = R^2_{corrected}$ (corrected by the number of predictors and sample size).

4. DISCUSSION AND CONCLUSION

In line with prior studies, the NORAH study (14, 16) revealed a significant association between aircraft noise exposure and aircraft noise annoyance, but with a markedly higher explained variance ($\Delta R^2 = .41$) than that reported by Guski et al. (4). In the NORAH and other studies in this field, LAeq was used as parameter of noise exposure. The current study aimed to evaluate the incremental value of other daytime noise exposure metrics for predicting effects of aircraft noise on annoyance for different groups of people and contexts. Our analyses confirmed that alternative noise metrics, for example LAmax, Emergence, and NAT, are significant single predictors of the harmful effects of aircraft noise exposure. For each of these metrics, exposure was significantly associated with noise-induced annoyance for children and teachers during the lessons and also for children and parents at home. However, further analyses revealed that only the NAT metric served as a second (unique) significant predictor over and above daytime LAeq. This supports the idea that, when assessing effects of aircraft noise on annoyance, both the average of noise intensity (as mirrored by the LAeq) and the number of flight events above a certain noise threshold (NAT) should be taken into account. However, this incremental effect was only apparent for the school context, both for teachers and children, and was highest when the number of flight events in a band of 70 to 75 dB (A) increased. For studies with residents (children, parents), however, we could not find incremental value of other daytime exposure metrics We therefore conclude that for assessments of aircraft noise annoyance of teachers and children, the NAT criterion should be included in future studies, to improve the prediction of annoyance, at least in the school context.

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REFERENCES

1. Guski R, Felscher-Suhr U, Schuemer R. The concept of noise-annoyance: How international experts see it. Journal of Sound and Vibration 1999; 223(4):513–27.
2. World Health Organization. Burden of disease from environmental noise. Quantification of healthy life years lost in Europe. WHO: Bonn, Germany; 2011.
3. Stallen PJM. A theoretical framework for environmental noise annoyance. Noise Health 1999; 1(3):69–80.
4. Guski R, Schreckenberg D, Schuemer R. WHO environmental noise guidelines for the European region: A systematic review on environmental noise and annoyance. Int J Environ Res Public Health 2017; 14(12).
5. Van Kamp I, Davies H. Noise and health in vulnerable groups: a review. Noise Health 2013; 15(64):153–9.
6. Babisch W, Schulz C, Seiwert M, Conrad A. Noise annoyance as reported by 8- to 14-year-old children. Environment and Behavior 2012; 44(1):68–86.
7. Ko NWM. Responses of teachers to aircraft noise. Journal of Sound and Vibration 1979; 62(2):277–92.
8. Fields JM, Jong RG de, Gjestland T, Flindell IH, Job RFS, Kurra S et al. Standardized general-purpose noise reaction questions for community noise surveys: Research and a recommendation. Journal of Sound and Vibration 2001; 242(4):641–79.
9. Taylor SM. A path model of aircraft noise annoyance. Journal of Sound and Vibration 1984; 96(2):243–60.
10. Nguyen TL, Yano T, Yokoshima S, Morihara T. Comparing causal structures of aircraft noise annoyance in Ho Chi Minh City, Hanoi and Da Nang using structural equation analysis. Proceedings of the 11th ICBEN Congress on Noise as a Public Health Problem, 1–5 June 2014; Nara, Japan, 2014,

11. Brink M, Schreckenberg D, Vienneau D, Cajochen C, Wunderli J-M, Probst-Hensch N et al. Effects of scale, question location, order of response alternatives, and season on self-reported noise annoyance using ICBEN scales: A field experiment. Int J Environ Res Public Health 2016; 13(11).
12. Schreckenberg D, Belke C, Spilski J. The Development of a Multiple-Item Annoyance Scale (MIAS) for Transportation Noise Annoyance. Int J Environ Res Public Health 2018; 15(5).
13. Brink M, Schäffer B, Vienneau D, Foraster M, Pieren R, Eze IC et al. A survey on exposure-response relationships for road, rail, and aircraft noise annoyance: Differences between continuous and intermittent noise. Environ Int 2019; 125:277–90.
14. Klatte M, Sqilski J, Mayerl J, Möhler U, Lachmann T, Bergström K. Effects of aircraft noise on reading and Quality of life in primary school children in Germany: Results from the NORAH study. Environment and Behavior 2017; 49(4):390–424.
15. Möhler U, Liepert M, Mühlbacher M, Beronius A, Nunberger M, Braunstein G, Bartel, R. Verkehrslärmwirkungen im Flughafenumfeld: Erfassung der Verkehrsgeräuschexposition [Effects of traffic noise in areas surrounding airports: Report of methods of noise exposure assessment]. Retrieved from http://www.laermstudie.de/ergebnisse/basismodul-akustik/. 2014). Available from: URL: www.laermstudie.de/ergebnisse/basismodul-akustik.
16. Bergström K, Spilski J, Mayerl J, Möhler U, Lachmann T. & Klatte M. 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. Proc Euronoise 2015, 31 May – June 3 Maastricht, Holland, 2015.
17. Klatte M, Bergström J, Spilski J, Mayerl J, & Meis M. Wirkungen chronischer Fluglärmbelastung auf kognitive Leistungen und Lebensqualität bei Grundschulkindern Endbericht. NORAH Verkehrslärmwirkungen im Flughafenumfeld–Endbericht, Bd, 1. et al. [Effects of chronic aircraft noise exposure on cognitive performance and quality of life in primary school children Final report. NORAH Traffic noise effects in the airport environment Final report. Volume 1]. 2014.
18. Hox JJ. Quantitative methodology series: Multilevel analysis: Techniques and applications. 2nd ed. New York, USA: Routledge; 2010.