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The association between residential quality of life and aircraft noise annoyance around Frankfurt Airport

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A large field study on aircraft noise annoyance with 2310 residents living within a radius of 40 km around Frankfurt Airport was performed in 2005 between the announcement (1998) and implementation of the airport extension (4th runway, anticipated 2010). For the address of each participant aircraft noise levels were calculated. This study concentrates on results with regard to the relationship between perceived – not aircraft noise-related – residential situation (i.e. infrastructure, attractiveness of the area, insulation/quietness) and aircraft noise annoyance. Furthermore the impact of actual perceived residential situation and the expected future situation after airport extension on noise annoyance before the change in aircraft noise exposure occurs is compared.
The results indicate that noise annoyance is associated with perceived quality of residential live and much stronger with the expected change of the personal residential situation. Furthermore, homeowners were found to be more annoyed than tenants.

1 Introduction

It is well known from the literature that beside noise load non-acoustical factors affect noise reactions [1]. These non-acoustical factors comprise personal factors like noise sensitivity, fear, attitudes towards the noise source and the (perceived) context of the noise situation, e.g. cultural and visual aesthetic context, availability of quite façades or green areas, ambient noise, etc.

One of the ideas of investigating the context of the living environment of residents exposed to the environmental stressor 'noise' is that a supportive 'healthy' environment is important for restoration and compensation of the impacts of environmental stress [2-4]. In the area of community noise the soundscape concept came up in about the last 10 years as a comprehensive approach to study and improve the relationship between humans, noise and the contextual environment [2, 5].

The compensatory effect of a perceived supporting environment in the sense of reduced noise reactions was shown in several studies [e.g. 3, 6-8]. Accordingly, evidence of an association between residential satisfaction and noise reactions like annoyance was often found (e.g. 9-11].

When residents experience changes in noise exposure, e.g. due to extension of the traffic infrastructure (opening of new streets, new railway lines, new runways, etc.), they often show a shift in noise reactions ['overreaction', 12], that is they report stronger reactions than in situations with no change in noise exposure at comparable noise level. This increase in noise reaction can even occur before the change in noise exposure occurs and after residents are informed about the forthcoming change [14]. In this case expectations regarding future residential situation seem to play a significant role.

This study focuses on the role of residents' perception of and satisfaction with the actual quality of the residential area around an international airport in a period between the announcement and the planned implementation of an airport extension (construction of a new runway). The impact of the satisfaction with the residential quality on aircraft noise annoyance is analysed and compared with the influence of the expectation about the future residential situation of noise annoyance.

2 Methods

2.1 Procedure

In a large field study 2312 residents living within a 40 kilometres distance from Frankfurt Airport were interviewed with regard to their residential situation, health-related quality of life, annoyance and disturbances due to noise, in particular to aircraft noise. For each address individual aircraft noise levels were calculated on the base of flight movements of the 6 busiest months of the year 2005. 66 residential areas within 40dB(A)-$L_{Aeq,6\text{-}22h}$ noise contour were selected with regard to acoustical, structural and social criteria. Within these areas residents were chosen by random for participation in the field study. For sampling address data were provided by local registry offices. In a letter preceding the interview all selected residents were informed about the study and were asked for participation. The interviews were *done* by trained interviewer at the home of the participants. The interview study was carried out in 2005, in a period between the announcement in 1998 and the planned implementation of an airport extension at Frankfurt Airport (planned for 2011).

2.2 Measurements

Noise level was indicated by the equivalent noise level for daytime ($L_{Aeq,16h}$) calculated for the address of each participants on the base of flight movements of the 6 busiest months of the year 2005.

Aircraft noise annoyance during the last 12 months preceding the interview were assessed using the verbal 5-point scale according to the recommendations of the International Commission on Biological Effects of Noise (ICBEN) [Fields et al 2001, ISO/TS 15666].

The *perception of the actual environmental and social quality* in the residential area was ascertained with a list of 14 items describing the satisfaction with several attributes of the residential areas (RS). The factor analysis of these items revealed 3 factors and 2 single items explaining altogether 61% of variance (Table 1). The first three factor scores were calculated by averaging the rating values of the respective items. Further, all items were averaged to a global score of residential satisfaction (RS global).

Scale (Factor)	Satisfaction with …	Factor loading
1. Infrastructure Cronbach's $\alpha = 0.79$	Shopping facilities	0.76
	Public transport	0.75
	Schools	0.70
	Leisure vacilities	0.68
	Distance to the city	0.66
	Supraregional transport connection	0.56
2. Insulation/Quietness Cronbach's $\alpha = 0.76$	Noise insulation of windows	0.90
	Noise insulation of house façades	0.88
	Quietness in the residential area	0.55
3. Attractiveness Cronbach's $\alpha = 0.63$	Appearance	0.72
	Possibility of recreation	0.71
	Neighbours	0.68
Item 13	Distance to work	--
Item 14	Quality of dwelling	--

Table 1 Resulting factors of a factor analysis (principle component analysis with varimax rotation) of items ascertaining the satisfaction with several attributes of the residential area

For the assessment of the expectation regarding the future residential situation after airport extension one question about how the personal residential situation of the respondents would change after the airport extension was used in this study. The participants could respond with 'It will become better.', 'It will become worse.' or 'No changes of my residential situation will occur'.
Furthermore *socio-demographic variables* like age, gender, house ownership were assessed.

Scale (Factor)	Expectations concerning future situation after airport extension	Factor loading
1. Negative expectations	Damages in nature	0.65
	Decrease in house prices	0.73
	Reduction of staying outdoor	0.81
	More awakenings in the morning	0.89
	Disturbances in the evening	0.88
	No quiet sleep anymore	0.87
2. Positive expectations	More attractive destinations	0.74
	Improved services at the airport ('Airport City')	0.74
	Improvement of quality of life	0.79
3. Expectations with regard to economy	Prosper development of the region	0.81
	New jobs	0.78
Item 3	Worsening neighbourhood relationships	--
Item 14	More profit for tourism	--

Table 2 Resulting factors of a factor analysis (principle component analysis with varimax rotation) of items ascertaining the satisfaction with several attributes of the residential area

3 Results

3.1 Noise exposure, residential satisfaction and noise annoyance

Table 3 indicates that the satisfaction with the infrastructure in the residential area is not associated with aircraft noise level , the satisfaction with the attractiveness of the area is although significant on a rather low level ($r < .10$) related to the noise level. Both factors of residential satisfaction (infrastructure, attractiveness) correlate with aircraft noise annoyance on a significant but low level ($r < .02$). Most of all – as expected – satisfaction with noise insulation at home and quietness in the area correlates with aircraft noise level as well as with aircraft noise annoyance. This suggests

that this factor of perceived residential quality is at least partly a reaction to aircraft noise. Accordingly, as this part of perceived environmental quality concerning insulation/quietness is included in the total score of residential satisfaction the latter is associated with aircraft noise annoyance and noise level, too.

Residential satisfaction concerning …	Aircraft noise annoyance	Aircraft noise level $L_{Aeq,06\text{-}22h}$
infrastructure	**-0.122**	0.015
insulation/quietness	**-0.475**	**-0.313**
attractiveness	**-0.170**	**-0.096**
global	**-0.295**	**-0.145**
Noise annoyance		**0.454**

n= 2237-2240; **bold:** p < .000

Table 3 Pearson correlation coefficients between aircraft noise annoyance, residential satisfaction and aircraft noise level ($L_{Aeq,\ 06\text{-}22h}$)

Because age and house-ownership were found to be weakly but significantly correlated with annoyance and satisfaction with the three aspects of the environmental and social quality of life in the residential area these two demographic factors were included in further analyses.

3.2 Impact of perceived quality of the residential area on aircraft noise annoyance

In order to assess the impact of perceived environmental and social quality of the residential area on aircraft noise annoyance General Lineal Models (COANOVA) was used with the three factors noise level (5 $L_{Aeq,6\text{-}22h}$-noise level groups), residential satisfaction (2 groups of either RS infrastructure, attractiveness, insulation/quietness), house ownership (owner, tenant) and aircraft noise annoyance as the dependent variable was used. To adjust for age effects age in years was included as a covariate in all models. Results of the COANOVAs are shown in table 4 (model 1-3) and 5.

In all models in Table 4 noise level and house ownership as well as the residential satisfaction – either with regard to infrastructure, attractiveness or insulation/quietness – have an impact on noise annoyance. The results indicate an increase in aircraft noise annoyance with increasing aircraft noise level, higher noise annoyance in the group of house owners in comparison to tenants and in the group of residents being less satisfied with the perceived environmental and social quality of their residential area. This is as expected in particular true for the aspect of house insulation/quietness in the residential area. Noise level interacts with house ownership in model 2 and 3, indicating that differences in aircraft noise annoyance between homeowners and tenants are higher in the highest noise level class ($L_{Aeq,6\text{-}22h} \geq$ 60 dB) than in the lower noise level classes. This interaction has not become significant in model 1 on a preassigned level of significance of 1% (p < .01). The interaction RS-i*HO in model 1 indicate that the satisfaction with the residential infrastructure has an impact on aircraft noise annoyance in particular in the group of tenants and far less in the group of home owners.

No.	Factors	df	F	p	η_p^2
1	Noise level $L_{Aeq,6\text{-}22h}$ (NL)	4	159.6	.000	.227
	RS infrastructure (RS-i)	1	14.8	.000	.007
	House ownership (HO)	1	88.2	.000	.039
	NL*RS-i	4	1.7	.146	.003
	NL*HO	4	2.9	.020	.005
	RS-i*HO	1	7.9	.005	.004
	NL*RS-i*HO	4	.1	.985	.000
2	Noise level $L_{Aeq,6\text{-}22h}$ (NL)	4	133.2	.000	.196
	RS attractiveness (RS-a)	1	22.0	.000	.010
	House ownership (HO)	1	86.0	.000	.038
	NL*RS-a	4	1.0	.432	.002
	NL*HO	4	3.5	.008	.006
	RS-i*HO	1	1.5	.228	.001
	NL*RS-i*HO	4	.6	.666	.001
3	Noise level $L_{Aeq,6\text{-}22h}$ (NL)	4	106.2	.000	.163
	RS insulation (RS-i/q)	1	25.5	.000	.103
	House ownership (HO)	1	142.8	.000	.061
	NL*RS-i/q	4	4.6	.001	.008
	NL*HO	4	4.0	.003	.007
	RS-i/q*HO	1	.2	.702	.000
	NL*RS-i/q*HO	4	2.3	.056	.004

df total: 2201; df error: 2180

Table 4 Results of COANOVAs with noise level, residential satisfaction (either with regard to infrastructure, attractiveness or insulation/quietness), house ownership as independent variables, age as the covariate and aircraft noise annoyance as the dependent variable.

The interaction of satisfaction with the noise insulation at home and quietness in the residential area and aircraft noise level may suggest that satisfying insulation at home could be an indicator of a successful coping with the noise leading to decreased aircraft noise annoyance.

House ownership	$L_{Aeq,6-22h}$ [dB]	Means		Standard deviation	
		high	low	high	low
		RS – infrastructure			
Owner	< 45	2.13	2.27	1,04	0,92
	45 - 50	2.46	2.75	1,16	1,20
	50 - 55	3.27	3.13	1,21	1,23
	55 - 60	3.70	3.65	1,16	1,17
	>= 60	4.24	4.26	0,97	0,85
Tenant	< 45	1.75	2.10	0,84	1,12
	45 - 50	1.74	2.31	0,95	1,16
	50 - 55	2.56	2.84	1,40	1,20
	55 - 60	3.14	3.38	1,24	1,28
	>= 60	3.27	3.59	1,24	1,13
		RS – attractiveness			
Owner	< 45	2.00	2.32	1,02	0,95
	45 - 50	2.47	2.73	1,21	1,15
	50 - 55	2.97	3.36	1,28	1,15
	55 - 60	3.44	3.80	1,21	1,12
	>= 60	4.06	4.36	1,07	0,79
Tenant	< 45	2.00	1.84	0,83	1,02
	45 - 50	1.96	2.03	1,14	1,07
	50 - 55	2.38	2.80	1,26	1,30
	55 - 60	3.02	3.37	1,29	1,24
	>= 60	3.17	3.47	1,43	1,11
		RS - insulation/quietness			
Owner	< 45	2.07	2.55	1,01	0,83
	45 - 50	2.30	3.21	1,09	1,13
	50 - 55	2.79	3.68	1,18	1,10
	55 - 60	3.14	4.08	1,14	1,01
	>= 60	3.64	4.44	1,09	0,75
Tenant	< 45	1.75	2.00	0,93	0,99
	45 - 50	1.78	2.33	1,03	1,09
	50 - 55	2.11	3.08	1,16	1,25
	55 - 60	2.60	3.76	1,12	1,13
	>= 60	2.40	3.70	1,18	1,04

Table 5 Means and standard deviation of aircraft noise annoyance by residential satisfaction (median split; either with regard to infrastructure, attractiveness or insulation/quietness), noise level and house ownership

3.3 Impact of the expectation about future situation after airport extension

The participants were asked whether they expect an improvement, a worsening or no change of their residential situation after the extension of the airport. For the analysis on the impact of the expectation on noise annoyance the answers of the participants were allocated to two categories: (1) improvement, no change of residential situation, (2) worsening of the residential situation. As Fig. 1 and 2 show this expectation has a strong influence on the aircraft noise annoyance judgments ($F[1;1886]= 465.0$; $p < .000$; $\eta_p^2 = .20$) both for tenants and home owners.

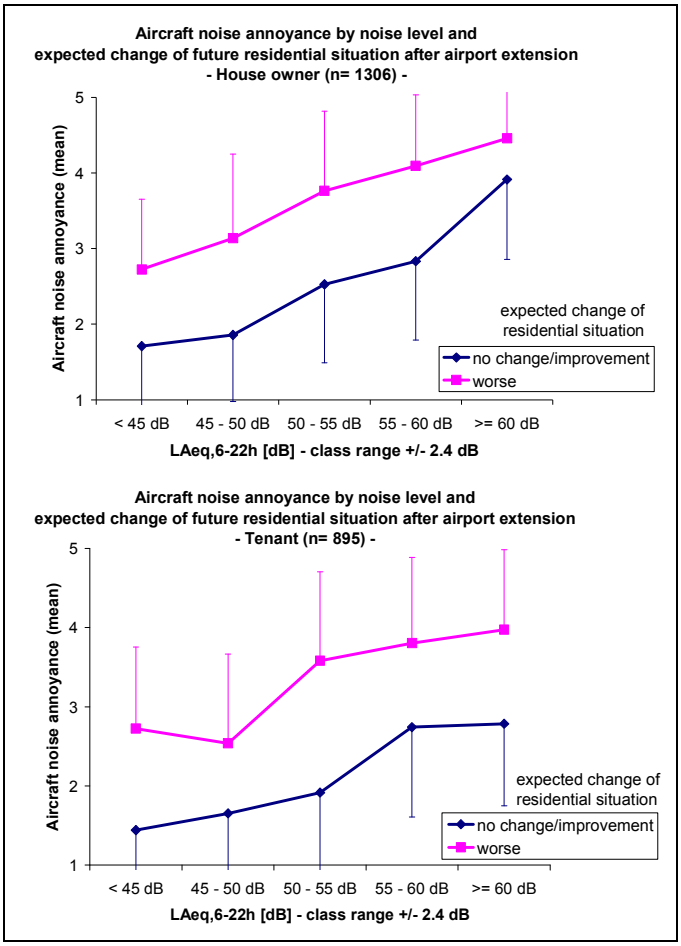

Fig.1a+b Means and standard deviation of aircraft noise annoyance of (a) house owners and (b) tenants by noise level and expectations about future residential situation after airport extension

The different effect sizes (η_p^2) of the actual satisfaction with the residential quality and the expectations with regard to the situation after airport extension indicate a stronger effect of expectations on aircraft noise annoyance in comparison to the factors of actual residential satisfaction. This is confirmed by results of a multiple regression analyses with expectation, factors of residential satisfaction and noise level ($L_{Aeq,06-22h}$) as predictors and aircraft noise annoyance as criterion (Table 6). According to the results of the regression analysis expectation concerning the future residential situation, satisfaction with insulation/quietness, noise level and house ownership explain in descending order 51% of variance of aircraft noise annoyance.

Factors	beta	p
$R^2 = 0.51$		
Expectation	-0.361	0.000
RS insulation/quietness	-0.333	0.000
LAeq3,6-22h	0.324	0.000
House ownership	-0.181	0.000
RS attractiveness	0.028	0.149
RS infrastructure	-0.022	0.201

Table 6 R^2 and beta coefficients of the linear multiple regression model with noise annoyance as criterion and noise level (LAeq,06-22h), expectation and factors of residential predictors.

4 Conclusion

2312 residents living within a radius of 40 km around Frankfurt Airport were interviewed among others with regard to their aircraft noise annoyance, satisfaction with several aspects of residential quality and expected changes of the future residential situation. It was assumed that a perceived enhanced residential quality could decrease aircraft noise annoyance. Furthermore, it was expected that those residents believing that the residential situation after airport extension would get worse report higher aircraft noise annoyance than those residents, which expect no change or an improvement of their residential situation.

The results show that – in descending effect size - above-average residential satisfaction with regard to noise insulation/quietness, the attractiveness of the area and – far less – with regard to the infrastructure in the residential area led to lower aircraft noise annoyance than residential satisfaction below average. This is true both for homeowners (concerning satisfaction with insulation/quietness and attractiveness) and tenants (concerning all three aspects of residential quality), although homeowners tended to be more annoyed than tenants at comparable noise exposure. Expectations regarding future residential situation after airport extension were found to have a stronger effect. Homeowners and tenants, who believed that their residential situation would become worse, reported higher aircraft noise annoyance than those expecting no change or an improvement of their future situation.

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