First results of the development of a multiple-item annoyance scale (MIAS)

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ABSTRACT

The international standardized questions and response scales recommended for the assessment of noise annoyance by ICBEN Team#6 in 2001 have been widely accepted in the scientific community allowing for comparisons between studies. However, summarising concepts of annoyance as studied in surveys, annoyance can be seen as a multidimensional construct, including past experiences with a noise source and comprising at least three elements: (1) Experience of an often repeated noise-related disturbance and the behavioural response to cope with it, (2) an emotional/attitudinal response to the sound and its disturbing impact, (3) the perception of control of the noise situation. We followed the concept of annoyance as a multidimensional judgment. The psychometric properties of items reflecting the above mentioned three elements of noise annoyance have been explored. Analyses were conducted using data of the NORAH-Study (Noise-Related Annoyance, Cognition, and Health) and a multi-item annoyance scale has been developed by using a stepwise process (exploratory and confirmatory factor analyses). The validity of the scale was tested in a total sample of *N* = 13,491 collected at four German airports (Frankfurt, Berlin, Cologne/Bonn, Stuttgart).

1. INTRODUCTION

In 2001, the ICBEN Team#6 recommended two “multiple-purpose items” [1] for measuring noise annoyance (in the English version comprising "bother, disturb, annoy…") in community noise surveys, being one 5-point verbal scale question and one 0-10 point numeric scale question. The purposes these items were meant to fulfil were foremost to enable the comparison of study results nationally and internationally and to “provide a high-quality, reliable measure of a general reaction to a noise experienced in a residential environment” [1]. Both items have been widely accepted in the scientific community and delivered their purposes. Nonetheless, already in 1988 [2] drew a memorable picture in saying that “[N]oise-induced annoyance is a chameleon-like concept that eludes succinct definition”. Further, in some studies and articles the concept of noise annoyance is defined as a multidimensional construct, giving rise to the assumption that a single item does not represent noise annoyance accurately. [3] provide definitions of noise annoyance as used in different field and laboratory studies and show a wide range of understanding of the concept of noise annoyance. This range includes noise annoyance defined as an emotion, an attitude or knowledge as well as a result of disturbance or rational decision. The authors conclude that noise annoyance is a “psychological concept which describes a relation between an acoustic situation and a person who is forced by noise to do things he/she does not want to do, who cognitively and emotionally evaluates this situation and feels partly helpless”, therefore defining noise annoyance as a “multifaceted concept”. In a recently published WHO review [4] define annoyance as a “complex response” which consists of “an often repeated disturbance due to noise […] and is often combined with behavioral responses in order to minimize disturbances”. Also, noise annoyance is both an attitudinal and a cognitive response. In a slightly different approach [5] identified noise annoyance as one dimension of a general noise reaction. Further dimensions are activity disturbance as well as feelings of fear and anxiety.

We argue that a multi-item noise annoyance scale implies the different facets of noise annoyance as described above. Further, the multi-item scale leads to a better differentiation between the different parts of noise annoyance that might be differently associated with acoustical and non-acoustical factors [2]. In his model of noise annoyance Stallen [6] conceptualise annoyance as a psychological stress response to noise (stressor) with the primary appraisal of the degree of sound-induced disturbances and the secondary appraisal of resources to cope with noise (perceived control). Following this model one would expect the disturbance part of annoyance to be higher correlated with acoustical indicators of noise exposure and the non-acoustical factors, in particular those referring to the perception of control of the noise situation (e.g. noise sensitivity, perceived predictability of the noise, trust in authorities, perceived fairness, see [6] for a detailed discussion) to be higher correlated with the annoyance aspect of perceived control or the capacity to cope with noise. In line with this, it is assumed that changes in annoyance over time [7] and/or the impact of stepwise changes in noise exposure on annoyance [8] might be better explained by analysing changes of the different aspects included in the multi-dimensional annoyance construct that is operationalised by a multi-item annoyance scale. Still, the multi-item scale is not meant to replace the single annoyance items recommended by ICBEN [1], but is thought to be a comprehensive supplement.

We believe that the multidimensional construct of noise annoyance comprises (1) the experience of repeatedly occurring noise-related disturbances and the behavioural response to cope with it, (2) an emotional/attitudinal response to the sound and its disturbing impact, (3) the perception of loss of control of the noise situation, or in other words, the perceived lack of capacity to cope with noise. To develop a multi-item annoyance scale that is meant to assess these different dimensions of noise annoyance we conducted analyses using data of the NORAH-Study (Noise-Related Annoyance, Cognition, and Health). Within this research initiative the impact of transportation noise on noise annoyance and HQoL (Work package 1, WP1) has been studied. NORAH-WP1 includes a panel study at Frankfurt Airport (FRA) on the impact of aircraft noise on annoyance, reported sleep disturbances and HQoL with measurements before (2011) and repeatedly after (2012, 2013) the opening of a new (fourth) runway (runway Northwest) and the implementation of a ban on night flights from 11pm to 5am (both in October 2011). Furthermore, WP1 entails cross-sectional studies in the vicinity of the airports Berlin-Brandenburg (BER) in 2012, Cologne/Bonn (CGN) and Stuttgart (STR), the latter two in 2013.

2. METHODS

2.1. Study design and samples

The study area around Frankfurt Airport was curtailed by the "envelope" of the 40 dB contours of the continuous aircraft sound levels for daytime ($L_{p\mathrm{Aeq},06\text{-}22h}$) and night-time ($L_{p\mathrm{Aeq},22\text{-}06h}$).

Within this area adult residents were randomly sampled from population registries in 2011 with (1) aircraft sound levels (2.5 dB classes of the maximum of $L_{pAeq,06\text{-}22h}$ and $L_{pAeq,22\text{-}06h}$ calculated for 2007) and (2) the change in aircraft sound exposure, i.e. the difference between address-related estimated $L_{pAeq,24hrs}$ as predicted for 2020 and $L_{pAeq,24hrs}$ of 2007, categorized in three groups (increase in $L_{pAeq,24hrs}$ > 2 dB, decrease in $L_{pAeq,24hrs}$ > 2 dB, change within the range of ± 2 dB) as strata. Telephone numbers available from telephone registration were assigned to the sampled residents to enable telephone interviews as the main mode of survey. The continuous sound levels used for stratum and to define the perimeter of the study region were calculated for the residential address of each participant and refer to the air traffic of the six busiest months of the year 2007. Similarly, the sound levels predicted for 2020 refer to the six busiest months in 2020. See [9] for more information about the address-related estimation of aircraft sound levels in the NORAH study.

The cross-sectional study designs for the other airports BER, CGN, and STR follow the described design at Frankfurt Airport concerning the stratified random sampling with aircraft sound levels as stratum. The airports CGN and STR belong to the category of 'low-rate-of-change' (LRC) airports, i.e. there is no indication of a step change in aircraft noise exposure three years before and after the survey [10]. The surveys at CGN and STR took place in 2013. The airport BER like the airport FRA is a 'high-rate-of-change' airport before expected changes. That is, the regional airport Berlin-Schoenefeld was expected to be extended to the international BER (new runway and terminals). In the beginning of the NORAH study, the opening of BER was expected for 2012, but for several technical and organisational reasons the new airport did not open during the whole period of the NORAH study (2011 – 2015). The 'before measurement' at the airport BER took place in 2012. Table 1 depicts the samples at the four airports.

Table 1: Samples of NORAH surveys at the airports Frankfurt (FRA), Berlin-Brandenburg (BER), Cologne/Bonn (CGN), and Stuttgart (STR)

Airport	Year of measurement / sample size			Gender	Age (in last year of measurement)			
	2011	2012	2013	% female	Min	Max	Med.	M (SD)
FRA	9244	4867	3508	53.5	20	98	54	54.6 (14.6)
BER		5548		52.1	18	100	60	57.9 (15.5)
CGN			2955	51.5	18	95	60	58.7 (16.2)
STR			1979	50.5	18	97	60	58.5 (15.7)

The development and psychometric testing of the aircraft noise annoyance scale was done with data of the FRA sample after the changes at the airport in the most recent measurement in 2013. In addition, the construct validity of the developed scale was tested with the data of the samples at the other airports. Due to item nonresponse the sample sizes for the tests of validity is n = 3459 for the FRA sample, n = 5271 for the BER sample, n = 2869 for the CGN sample, and 1892 for the STR sample (total N = 13491).

2.2. Procedure

The participants of the panel study at the airport FRA were sampled in spring 2011. The sampling of the participants at the airport BER was done in spring 2012, the sampling for CGN and STR in summer 2013. All sampled residents received a cover letter to inform about the study and invite to participate in telephone interviews or optional online surveys with the same questionnaire. The first measurement at FRA was done in summer and autumn of 2011 and finished before the opening of the runway Northwest on 21 October 2011. Repeated measurements were carried out in summer/autumn of 2012 and again in 2013 (see also [11], [12]). The measurement at BER took place from May to August 2012, the ones around CGN and STR between August and December 2013. The sampling and data management was supervised and certified by each responsible agency for data protection.

2.3. Noise exposure

The exposure to sound levels for each participant's residential address (continuous and mean maximum sound levels of aircraft, railway and road traffic) was calculated for a 12 months period from October to September for each survey wave for daytime, evening and night-time and for 24 hours. For the assessment of aircraft sound levels the German calculation method AzB 2008 was used. The average sound levels of railway and road traffic were determined based on the methods for calculation used for EU noise mapping [9]. For the analyses in this study the L_{den}, and the $L_{p\mathrm{Aeq}}$ for 24 hours, at daytime (6am – 10pm), and night-time (10pm – 6am) as indicators of aircraft sound exposure were used.

2.4. Questionnaire

In all surveys at every airport the questionnaires included the assessment of disturbances and annoyance to aircraft noise and other transportation noise (railway, road traffic), health-related mental and physical quality of life (HQoL), potential co-determinants of annoyance (e.g. noise sensitivity, attitudes towards the source), questions concerning residential conditions (e.g. sound insulation, window type and position) and demographics. In the analyses described in this contribution *aircraft noise annoyance* was assessed with the ICBEN 5-point scale according to the ICBEN recommendation [1]. Table 2 shows all items initially used in the analyses.

2.5. Statistical analyses

The multiple item aircraft noise annoyance scale was developed and tested with regard to its psychometric quality (construct validity, reliability) in a stepwise process using data of the last measurement in 2013 of the FRA panel sample. Explorative factor analysis (EFA), second order confirmatory factor analysis (CFA), and the calculation of Cronbach's alpha were conducted.

First, a list of 21 items was submitted to an initial EFA (principle axis factoring (PAF) with oblique rotation conducted in SPSS) in order to select items. The item selection aimed at maximising parsimony and achieving a number of items below 10 for the assessment of the components of noise annoyance as identified by [3] and [4]. After this step, the selected set of items was submitted to a final EFA in order to examine the factor structure.

This was followed by the conduction of second order CFA in Mplus with one, two, and three factors with and without correlated error terms. The CFA were carried out with robust maximum likelihood estimation (MLR) and imputation of missing values with the FIML algorithm (full information maximum likelihood estimation). In the second order CFA a general aircraft noise annoyance score including the sub-dimensions 'experience of aircraft noise-related disturbances', annoyance (the ICBEN annoyance item), and 'lack of coping capacity' was modelled in accordance with the definition by [3] and [4] in order to test the construct validity and reliability of the annoyance scale. Five CFA versions were modelled: (1) with one annoyance factor including all items (CFA-1), a hierarchical structure with two factors (F1 'disturbances', F2 'lack of coping capacity') (2) without error terms (CFA-2) and (3) with correlated error terms (CFA-3), and a hierarchical structure with three factors (F1 'disturbances', F2 'annoyance, ICBEN 5-point scale', F2 'lack of coping capacity'), again, (4) without (CFA-4), and (5) with correlated error terms (CFA-5). Beside the test statistics for the CFA models, model fit was evaluated using (1) the comparative fit index (CFI) for which values above .90 indicate an acceptable fit and values of .95 and higher indicate a very good fit; (2) the root mean square error approximation (RMSEA) for which values of .05 and less indicate a very close fit, values of .08 and less still an acceptable close fit; (3) the standardized root mean square residual (SRMR) for which values below .10 are recommended – see e.g. [14] for an overview of the indices. The reliability of the latent constructs (the factors F1 and F2) was assessed with the composite reliability (CR) coefficient. The internal consistency of each set of items measuring together the constructs F1 and F2, respectively, was assessed with Cronbach's alpha. The convergent validity was ascertained with the average variance extracted (AVE) and the discriminant validity was evaluated by means of the Fornell-Larcker criterion (AVE > squared correlation with any other factor). CR values ≥ 0.6 and Cronbach's alpha value ≥ 0.7 indicate acceptable reliability of the factors. AVE values should be > 0.5 for acceptable convergent validity (see [14] for a description of these indices and their recommended cut-off values).

In addition, the aircraft noise annoyance scale's construct validity was analysed by comparing the results gained with the FRA sample data with CFA results of data of the samples at the airports BER, CGN, and STR. Finally, the ICBEN annoyance item and the new developed aircraft noise annoyance score and its components were correlated with acoustical and non-acoustical factors known to be related to noise annoyance. This was done in order to evaluate the criterion validity of the annoyance assessment.

3. RESULTS

3.1. Selection of items for the aircraft noise annoyance scale

Table 2 lists the 21 items extracted from the questionnaire that were submitted to an initial EFA (principle axis factoring, PAF, with oblique rotation). The item list was pre-selected and the items preliminarily grouped by content in categories mentioned by [3] and [4]. As criteria for item selection results of the initial EFA analysis referring to measures of sample adequacy (MSA), communalities and factor loading were used in addition to selection by content. For example, during the process of item selection it was decided to only include disturbances at daytime and exclude items of reported sleep disturbances, although the EFA results would suggest including these items. One of the reasons for the exclusion was that at the different airports studied in NORAH-WP1 there are different regulations/restrictions of flight operations at night-time. Thus, an annoyance score including reported sleep disturbances would mean a different psychological concept at different airports.

Finally, a set of six items plus the ICBEN annoyance item was again submitted to an EFA. The Kaiser-Meyer-Olkin coefficient (KMO = 0.856) and the Bartlett test (χ^2 = 14523.97, df = 15, $p < .001$) indicate the adequacy of the included items. The EFA extracted one factor (eigen-value > 1) that explains 65.8% of variance. Forcing EFA to extract 2 factors (in addition the ICBEN annoyance item) revealed an explained variance of 81.1%. The two identified factors can be labelled according to the components of noise annoyance mentioned in [4] as 'experience of aircraft noise-related disturbances (F1)' and 'perceived lack of coping capacity (F2)'. Table 3 shows the factor loadings of the included items (without the ICBEN annoyance item). The EFA results suggest a hierarchical factor structure of the components of the multiple aircraft annoyance scale which is tested by means of confirmatory factor analysis (CFA).

Table 2: Initial list of 21 items for the assessment of aircraft noise annoyance

Experience of aircraft noise-related disturbances	**Affective evaluation, attitudes**	**Perception of loss in control, lack in coping capacity**
In the last 12 months aircraft noise has disturbed … I-1. during communication, when using the phone at home I-2. when listening to the radio and watching TV I-3. when reading and concentrating I-4. when having visitors at home I-5. when staying and/or recovering outdoors I-6. when falling asleep I-7. during the night I-8. when awakening (1) not at all, (2) slightly, (3) moderately, (4) very, (5) extremely	I-9. ICBEN 5-point aircraft noise annoyance Expectations concerning impact of air traffic on residential quality of life: *Response scale: agree (1) not, (2) a little bit, (3) moderately, (4) rather, (5) very* I-10. The air traffic leads to fall in value of residence and properties I-11. The air traffic spoils residents' outdoor stay in the garden, on the terrace or on the balcony. Attributes of air traffic: *Response scale: agree (1) not, (2) a little bit, (3) moderately, (4) rather, (5) very* Air traffic is … I-12. useful I-13. dangerous for me I-14. comfortable for users I-15. environmental harmful	Perceived capability to cope with noise: *Response scale: agree (1) not, (2) a little bit, (3) moderately, (4) rather, (5) very* I-16. I know that I can protect myself quite well against noise. I-17. If it is too loud outside, I simply close the windows, and then I am no longer disturbed. I-18. Sometimes, I really feel at the mercy of the noise. I-19. If it is very loud, I just mentally switch off. I-20. I do not hear the noise anymore. I-21. I have accepted the fact that the noise is here.

Table 3: Results of EFA (PAF) with forced extraction of two factors

Item	**Factor**	
	F1 - (experience of aircraft noise-related disturbances)	**F2 - (perceived lack of coping capacity)**
(F1.1) In the last 12 months, aircraft noise has disturbed during communication, when using the phone at home	0.969	
(F1.2) In the last 12 months, aircraft noise has disturbed when listening to the radio and watching TV	0.947	
(F1.3) In the last 12 months, aircraft noise has disturbed when reading and concentrating	0.799	
(F2.1) I know that I can protect myself quite well against noise (recoded)		0.847
(F2.2) If it is too loud outside, I simply close the windows, and then I am no longer disturbed (recoded)		0.747
(F2.3) Sometimes, I really feel at the mercy of the noise	0.305	0.515

3.2. CFA for aircraft noise annoyance assessed at Frankfurt Airport

Table 4 shows indices of the CFA model fit. All in all, the indices in Table 4 indicate a sufficient model fit, in particular for the models CFA-3 and CFA-5. This suggests a hierarchical structure of the multi-dimensional annoyance concept with disturbances and lack of coping capacity forming the higher order construct 'annoyance'. The best model with regard the model fit indices is CFA-3 with the two factors F1 'disturbances' and F2 'lack of coping capacity' and correlated error terms. The second best one is CFA-5 that includes the ICBEN annoyance item in addition to the items of CFA-3 and, thus, lacks in parsimony (higher AIC value compared to CFA-3).

Table 4: Fit indices of confirmatory factor analyses (CFA) – sample 'FRA' (n = 3.459)

CFA	Indicators	χ^2	df	p	CFI	RMSEA (90% CI)	SRMR	AIC
CFA-1	MIAS, 1 factor	1576.605	14	< .001	.877	.180 (.172-.187)	.074	68240.053
CFA-2	MIAS, 2 factors (F1, F2)	386.247	8	< .001	.961	.117 (.107-.127)	.038	58504.907
CFA-3	MIAS, 2 factors (F1, F2) with correlated terms of error	21.717	6	< .01	.998	.028 (.016-.040)	.008	58102.914
CFA-4	MIAS, 3 indicators (F1, annoyance, F2) without error terms	564.114	13	< .001	.957	.111 (.103-.119)	.038	66902.593
CFA-5	MIAS, 3 indicators (F1, annoyance, F2) and correlated error terms	94.562	11	< .001	.993	.047 (.038-.056)	.023	66380.843

Note. χ^2: Chi square test, df: degrees of freedom, p = probability of error, CFI: comparative fit index, RMSEA: root mean square error of approximation, 90% CI = 90% confidence interval, SRMR: standardized root mean square residual values, AIC: Akaike information criterion.

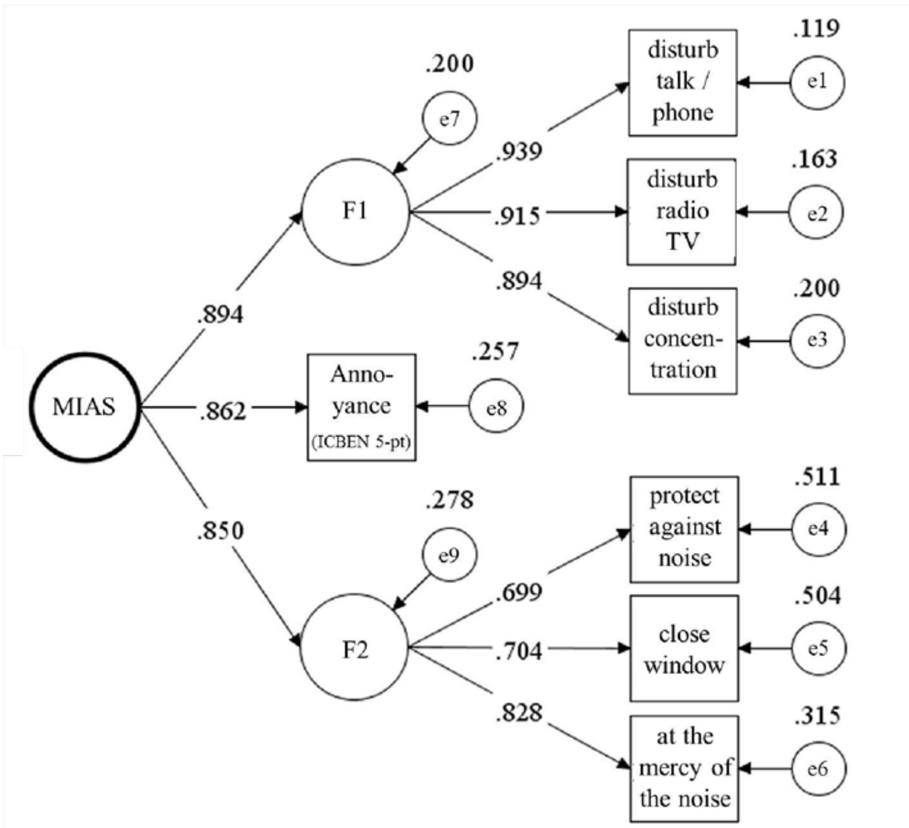

Figure 1: Confirmatory factor analysis (CFA-5) of higher order multiple item score for aircraft noise annoyance (MIAS) as measured in sample at Frankfurt Airport in 2013 (n = 3459)

The reliability scores CR and Cronbach's alpha suggest a good reliability of the constructs (CR = .76 to .92 in models with correlated error terms), the AVE a good convergent validity (AVE = .52 to .79 in models with correlated error terms). The discriminant validity of the factors F1 and F2, according to the Fornell-Larckers-criterion, is good except for F2 in particular in models with correlated error terms. However, this justifies the hierarchical structure, i.e. it indicates that both factors seem to belong to the same second order factor. Cronbach's alpha for the total MIAS (CFA-1) including items of the factors F1 and F2 and the ICBEN annoyance item is α = .91 and α = .89 without the ICBEN annoyance item.

Figure 1 depicts the model CFA-5 of multiple-item annoyance scale (MIAS) for aircraft noise annoyance including the factors F1 'disturbances', F2 'lack of coping capacity' and the ICBEN 5-point annoyance item.

3.3. Comparison of CFA results for aircraft noise annoyance at different airports

Table 5 presents an overview of model fit values for CFA-3 (model with two factors) and CFA-5 (model with two factors and ICBEN annoyance item) for the samples at the airports FRA, BER, CGN, and STR.

Table 5: Comparison of fit indices of CFA for the multiple-item aircraft noise annoyance scale (MIAS) conducted with data of the samples FRA, BER, CGN, and STR

Fit indices	FRA (n = 3459)		BER (n = 5271)		CGN (n = 2869)		STR (n = 1892)	
	CFA-3	CFA-5	CFA-3	CFA-5	CFA-3	CFA-5	CFA-3	CFA-5
χ^2	21.717	94.562	54.041	224.059	22.538	97.025	21.505	90.982
df	6	11	6	11	6	11	6	11
p	< .01	< .001	< .001	< .001	< .001	< .001	< .01	< .001
CFI	.998	.993	.996	.985	.998	.991	.996	.984
RMSEA (90% CI)	.028 (.016-.040)	.047 (.038-.056)	.039 (.030-.049)	.061 (.054-.068)	.031 (.018-.045)	.052 (.043-.062)	.037 (.021-.054)	.062 (.051-.074)
SRMR	.008	.023	.012	.036	.011	.033	.016	.032
AIC	58102.91	66380.84	86879.02	100489.00	49174.85	56669.40	30895.69	36050.09

Note. χ^2: Chi square test, df: degrees of freedom, p = probability of error, CFI: comparative fit index, RMSEA: root mean square error of approximation, 90% CI = 90% confidence interval, SRMR: standardized root mean square residual values, AIC: Akaike information criterion.

Table 6: Parameters of CFA for MIAS conducted with data of the samples FRA, BER, CGN, and STR

Estimates (factor loading)			FRA	BER	CGN	STR
F1	<---	disturb talk/phone	.939	.908	.926	.922
F1	<---	disturb radio, TV	.915	.909	.924	.919
F1	<---	disturb concentration	.894	.888	.892	.858
F2	<---	protect against noise	.699	.621	.645	.688
F2	<---	close windows	.704	.621	.652	.629
F2	<---	at the mercy of the noise	.828	.725	.800	.668
MIAS	<---	F1	.894	.883	.857	.945
MIAS	<---	Annoyance, ICBEN 5-pt.	.862	.738	.814	.737
MIAS	<---	F2	.850	.767	.834	.614

Note. p < .001 for all estimates. MIAS: multiple-item aircraft noise annoyance scale

The CFI and SRMR values suggest a very good model fit for both models at each airport. For all samples the RMSEA values indicate a very close fit for CFA-3 (RMSEA ≤ .05) and a close fit in an acceptable range for CFA-5 (RMSEA ≤ .08). This suggests that the hierarchical structure of MIAS has a satisfying construct validity beyond the sample at Frankfurt Airport, although for all models results of the χ^2-Test indicate a statistically significant deviation of the empirical covariation matrix from the modelled one. The factor loading of the items on the factors F1 and F2 and the loadings of F1, F2 and the ICBEN annoyance item on the second order factor MIAS are in a similar range in the samples at the different airports, although, in detail, some differences can be observed (Table 6).

3.4. Correlations of MIAS with acoustical, non-acoustical factors and further outcomes

Earlier studies have shown that aircraft noise annoyance is associated with long-term average aircraft sound levels and non-acoustical factors such as noise sensitivity and attitudes towards the source or towards authority (e.g. [15]) as well as with sleep disturbances and with health-related quality of life (HQoL) (e.g. [16]). Therefore, comparisons of the correlation structure of aircraft noise annoyance as measured with the ICBEN 5-point item and with MIAS as the mean score of items reflecting the factors F1, ICBEN annoyance, and F2 were made. It was decided to calculate MIAS as an unweighted mean score because (1) the factor loadings in the samples at the different airports would suggest slightly different weights and (2) the loadings of the sub-constructs F1, ICBEN annoyance item, and F2 on MIAS would suggest weights within a similar range for summarising the three sub-constructs. Thus, for reasons of generalisability the calculation of MIAS was done unweighted.

Table 7: Correlation of aircraft noise annoyance (MIAS and its components) with indicators of aircraft sound exposure (sample FRA, *n* = 3506 – 3508)

Indicators of aircraft sound exposure	MIAS - Aircraft noise annoyance score	Annoyance (ICBEN 5-pt. scale)	F1 - annoyance (disturbances)	F2 - annoyance (lack of coping capacity)
$L_{p\text{Aeq},06\text{-}22h}$	.453	.466	.499	.278
$L_{p\text{Aeq},22\text{-}06h}$	.405	.425	.455	.237
$L_{p\text{Aeq},24hrs}$	.451	.466	.498	.276
L_{den}	.444	.463	.490	.269
Disturbance falling asleep	.717	.669	.688	.563
Disturbance night sleep	.555	.502	.533	.441
Disturbance - awaken in morning	.759	.739	.710	.603
Air traffic is useful	-.328	-.294	-.271	-.303
Air traffic is dangerous for me	.554	.496	.511	.461
Air traffic is comfortable for users	-.172	-.149	-.137	-.166
Air traffic is environmental harmful	.336	.315	.275	.314
Expectations conc. impact of air traffic	-.686	-.656	-.588	-.601
Trust in authorities	-.465	-.438	-.371	-.436
Perceived procedural fairness	-.351	-.319	-.294	-.323
SF8 Physical Component Summary	-.183	-.149	-.181	-.144
SF8 Mental Component Summary	-.319	-.235	-.267	-.309
Noise sensitivity (single item)	.333	.258	.238	.361

Note. $L_{p\text{Aeq}}$ = continuous sound level averaged over 12 months, $p \leq .001$ for all correlation coefficients.

The correlations are shown in Table 7. Both, MIAS and the ICBEN annoyance item, are correlated with indicators of aircraft sound exposure in a similar range, although the correlation coefficients of the ICBEN annoyance item with the vast majority of the exposure indicators are slightly higher than those of MIAS (Table 7). Highest correlation coefficients are observed for the factor F1 'disturbances'. The correlations of F2 'lack of coping capacity' with the exposure indicators are lower compared to the other annoyance components.

Table 7 shows that MIAS and the ICBEN annoyance item correlate with non-acoustical factors with quite similar effect size. However, whereas the ICBEN annoyance item correlates a little bit higher with aircraft sound level indicators, MIAS correlates slightly higher with the non-acoustical factors than the ICBEN annoyance item. As expected, the factor F1 'disturbances' (at daytime) correlates somewhat higher with sleep disturbances than factor F2. Furthermore, F1 correlates higher with the judgment of air traffic as dangerous, and with the physical HQoL than the factor F2. The factor F2 'lack of coping capacity' correlates higher with other judgments and expectations concerning the air traffic, mental HQoL and noise sensitivity.

All in all, the correlation coefficients suggest a satisfying criterion validity of MIAS and the components F1 and F2 as in this study the structure of associations with acoustical and non-acoustical factors are altogether quite similar to that of the single ICBEN annoyance item and to what is known from literature. The differences observed in correlations of the factors F1 and F2 with acoustical and non-acoustical factors imply information that might help to improve the understanding of the concept of annoyance.

4. DISCUSSION & CONCLUSION

The study aimed at developing a multi-item noise annoyance scale in order to meet the definition of noise annoyance as a multidimensional psychological construct. Taken aircraft noise annoyance as an example, the developed scale was tested with regard to its psychometric quality. The analyses were done with data on community responses to transportation noise collected in the years 2012 and 2013 at the four German airports Frankfurt, Berlin-Brandenburg, Cologne/Bonn, and Stuttgart within the frame of the NORAH research initiative (Noise-Related Annoyance, Cognition, and Health). The intention was to develop and test a reliable and valid parsimony scale including a number of less than 10 items to allow its use in field studies. [3]-[4] defined three aspects of noise annoyance: (1) the experience of occurring disturbances and behavioural coping response, (2) an emotional/attitudinal response to the sound and its disturbing impact, (3) the lack of capacity to cope with noise. Six items plus the ICBEN 5-point annoyance item were selected and their factorial structure analysed.

The second order multiple-item aircraft noise annoyance scale (MIAS) consisting of the two factors F1 ('experience of aircraft noise-related disturbances'), F2 ('perceived lack of coping capacity') and the single ICBEN 5-point annoyance item was found to be a reliable scale of satisfying construct and criterion validity across surveys at different German airports. MIAS, modelled as one factor (CFA-1), has already a very good internal consistency according to Cronbach's alpha (α = .91). Nevertheless, results of different CFA models suggest that the model fit improves considerably, when MIAS is modelled as a second order construct. In practice, this means that scores for F1 and F2 should be calculated before summarising these scores together with the ICBEN annoyance item to MIAS. From a statistically point of view, a higher order factor of annoyance consisting of the two factors F1 and F2 would be already a reliable and valid as well as a parsimonious construct. However, to continue the internationally standardised assessment of noise annoyance the inclusion of the single annoyance item(s) suggested by ICBEN [1] is still recommended. The ICBEN annoyance item used in this study to assess aircraft noise annoyance itself fits well into the factorial structure of MIAS. Moreover, the single ICBEN aircraft noise annoyance item was found to be an assessment of noise annoyance of good criterion validity. That is, correlations of aircraft noise annoyance as measured with the single ICBEN 5-point annoyance item with acoustical and non-acoustical factors are of expected size and quite similar to those of MIAS.

MIAS fits with the concept of annoyance as a stress response to noise according to the stress concept of Lazarus as adopted by [6]. Factor F1, showing the highest correlation with exposure indicators among the components of MIAS, seem to reflect the primary appraisal of the stressor 'noise' and factor F2 (lack of coping capacity) the secondary appraisal of available coping resources. The correlation matrix concerning the non-acoustical factors suggests that the association between annoyance and the non-acoustical factors, in particularly the attitudes and noise sensitivity, refer more to the secondary appraisal, i.e. the capacity to cope with noise, which is in line with the noise annoyance model presented by [6]. The SF-8 score for physical well-being (PCS) is somewhat higher correlated with the factor F1 and the score for mental well-being (MCS) is slightly higher associated with the factor F2. This might indicate different mechanism of a mediation effect of noise annoyance (see [16]) on HQoL. Whereas repeatedly experienced sound-related disturbances might lead to physical arousals and hinder recovery from noise-induced (physiological) stress and, thus, impair, on a long-term level, physical health, mental well-being might be reduced because of the perception that one can't get rid of the noise. This might have implications for different noise control strategies either to improve mental or physical well-being. To study this in more detail is out of the scope of this contribution. Nevertheless, one of the advantage of the assessment of noise annoyance as a multiple-item second order construct is that it helps to understand the interrelations between different noise effects and, thus, might be more effective in the assessment of the impact of noise-related interventions (changes in exposure in terms of improvement due to noise abatement or worsening, e.g. due to expansion of infrastructure).

Another advantage of MIAS compared to a single annoyance item is that the association between noise annoyance and non-acoustical factors are often interpreted in terms of the non-acoustical factors engendering a response bias in annoyance judgments [2], sometimes even intentionally in order to foster activities of responsible authorities to reduce the noise. With a set of multiple items to assess annoyance this response bias is expected to be reduced and, in addition, different causes of different components of annoyance are more explicit.

The study has several limitations. First, all developmental work and analyses concerning MIAS has been done post-hoc, although theoretically driven. That is, the questionnaires and items were not developed for the construction of a multiple-item annoyance scale. In line with this, the aspect of affective reaction to the noise as mentioned by [3] could not be operationalised by items directly referring to emotional reactions as no explicit emotion-related item concerning aircraft noise was assessed. Instead, the ICBEN annoyance 5-point item was used as its own 'proxy' for an affective reaction to aircraft noise. In this study, the numerical 11-point scale recommended by ICBEN Team#6 was not used. Thus, it is unclear how this item would fit into the factorial structure of MIAS. Then, MIAS was developed only for one noise source, aircraft noise. The generalisability of MIAS to other noise sources has to be tested in future research. Finally, the items referring to the capacity to cope with noise (F2) were assessed non-source specific. As part of a source-specific annoyance assessment the items should be related to the specific noise source of interest.

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