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Aircraft noise-induced annoyance in the vicinity of Cologne/Bonn Airport

The examination of short-term and long-term annoyance as well as their major determinants

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Für Emil,

meine liebste „Lärmquelle"

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Abbreviations

AzB	Anleitung zur Berechnung von Lärmschutzbereichen [Technical Instructions on Aircraft Noise Calculations in accordance with the German Aircraft Noise Act]
cf.	compare
COSMA	Community Oriented Solutions to Minimise aircraft noise Annoyance (project title)
dB(A)	decibel, unit for (*A*-weighted) sound pressure level
DIN	Deutsches Institut für Normung [German Institute for Standardization]
DLR	Deutsches Zentrum für Luft- und Raumfahrt [German Aerospace Center]
e.g.	for example
FICON	Federal Interagency Committee on Noise
GEE	Generalized Estimating Equations
IATA	International Air Transport Association
ICBEN	International Commission on the Biological Effects of Noise
i.e.	that is
ISO/TS	International Organization for Standardization/Technical Specification
NORAH	Noise-Related Annoyance, Cognition, and Health (project title)
WHO	World Health Organization

Formula symbols

FFI	Frankfurt Aircraft Noise Index
FNI	Frankfurt Night Index
L	sound pressure level (generic term)
L_X	sound pressure level in dB(A) which is exceeded in X % of the time
L_{den}	day evening night average sound level
L_{dn}	day night average sound level
L_{eq}	equivalent sound pressure level (nearer definition by means of further indices)
L_{max}	maximum sound pressure level
log	decadic logarithm
$L(t)$	sound pressure level changing over time

MNR	maximum aircraft noise level to background noise level ratio
N_{AC}	number of aircraft fly-overs per reference period
NAT_{XX}	number of aircraft fly-overs with a maximum level above XX dB(A)
p X	personalized noise indicator X with the attenuation due to the whereabouts of the individual (indoors vs. outdoors) and the window position considered
SEL	Sound Exposure Level
SNR	Signal to Noise Ratio (in this context: aircraft noise to background noise ratio)
T	averaging time, e.g., 1 hour or 24 hours
ZFI	Zurich Aircraft Noise Index

Indices

24 h	with respect to the whole day (24 hours)
22-6	with respect to the night as it is defined in Germany: 22:00-06:00 hours
6-22	with respect to daytime as it is defined in Germany: 06:00-22:00 hours
A	*A*-weighted
AC	with respect to aircraft noise
bkgd	with respect to background noise
d	with respect to daytime (generic term)
eq	equivalent
max	maximum
n	with respect to night-time (generic term)
s	measured with the time-adjustment *slow*

Summary

In the light of a continuously growing air traffic and a presumably resulting impairment of the quality of life of airport residents, the present doctoral thesis aims at the extensive investigation and description of short-term and long-term annoyance induced by aircraft noise in the vicinity of Cologne/Bonn Airport, Germany. This thesis was written in the framework of the European project COSMA (*Community Oriented Solutions to Minimise Aircraft noise annoyance)*. A telephone study with 1,262 residents (M = 58.6 years, SD = 15.5, 61.8 % female) as well as an in-depth study in the field with further 55 residents (M = 45.7 years, SD = 14.3, 61.8 % female) were conducted. On the basis of these results, an attempt was made to identify measures to reduce community annoyance.

The telephone survey in summer 2010 focused on the examination of the status quo of community annoyance due to aircraft noise during the past 12 months (= long-term annoyance). Likewise, the study aimed at the identification of the key variables that determine the annoyance judgment in addition to the equivalent continuous noise level. A further purpose of the telephone survey was the preparation of the subsequent field study conducted in summer/autumn 2011.

The telephone survey was run in six areas exposed to an equivalent aircraft noise level between 40 and 55 dB(A). The aircraft noise exposure of the examination areas was operationalized by the A-weighted energy equivalent sound pressure level (L_{Aeq}) for the six busiest months of the year. The L_{Aeq}-values were extracted from a current noise contour map. Since at Cologne/Bonn Airport air traffic, and in particular freight traffic, is operated also at night, not only the general annoyance but the annoyance at night, i.e., between 22:00 and 06:00 hours, was examined as well. Aircraft noise-induced annoyance was assessed by means of a semantic five-point scale recommended by the International Commission on the Biological Effects of Noise (ICBEN). In addition, an open format question was applied to gain information about times of day when the aircraft noise is particularly annoying. Diverse personal and situational factors were examined regarding their effect on annoyance. In a multiple-stage process using the multiple linear regression approach, a prediction model for aircraft noise annoyance was developed both for general and night-time annoyance.

A comparison of the annoyance data obtained in the vicinity of Cologne/Bonn Airport to the European standard exposure-response curve clearly indicated an increase of the percentage of highly annoyed individuals at a given noise level. Respondents reported particular high annoyance due to aircraft noise for the late evening and night. The variables found to significantly contribute to long-term annoyance ratings comprise the L_{Aeq} as well as the following non-

acoustical predictors: a) the belief that the airport could take actions to improve the residents' situation, b) the perception of negative aspects of the local airport and air traffic, c) carrying out measures to cope with the noise, d) the general attitude towards the airport, e) the satisfaction with the residential area, f) the respondent's environmental conscience, g) the general sensitivity to noise as well as h) the degree of urbanization of the investigated areas, and i) the presence and evaluation of domestic noise insulation. Night-time annoyance was predicted by the same variables as general annoyance and the size of the effect of the single predictors was comparable. The ten predictors explained 54.8 % of the variance in the general annoyance ratings and 52.3 % of the variance in the night-time annoyance ratings.

Whereas a number of prior surveys focused on the examination of long-term annoyance due to aircraft noise, only very few studies examined short-term annoyance in the field. Therefore, the main purpose of the in-depth field study subsequent to the telephone survey was to investigate the contribution of a wide range of acoustical parameters and non-acoustical factors to aircraft noise-induced annoyance during the preceding hour. Furthermore, the field study aimed at the examination of the relation between daytime short-term annoyance, subjective sleep quality, and long-term annoyance. In addition, within the framework of the present field study, the construct *fairness* that has been investigated mostly in the organizational and legal context by now was introduced to the context of aircraft noise exposure and annoyance in the field.

The field study was run in two areas with an equivalent aircraft noise level above 50 dB(A). Over four days and nights, the sound pressure level was logged continuously. Thereby, 30 acoustical parameters could be derived. Besides prominent noise indicators, such as the L_{Aeq}, the number of aircraft noise events, or the maximum level, parameters were calculated which have not been considered thoroughly in previous field studies on annoyance. In particular, personalized parameters were included that take into account the outdoor levels as well as the attenuation due to the participant's whereabouts (outdoors vs. indoors) and different window positions. Simultaneously to the level recordings, participants repeatedly rated their annoyance due to aircraft noise in the interval of one hour. Short-term annoyance in the preceding hour was assessed at daytime between the time the individuals got up and the time they went to bed. For the annoyance assessments, the semantic five-point scale recommended by the ICBEN was used that had been implemented in a stand-alone application on a netbook. Situational factors, such as the time of day and the activity carried out in the past hour, were ascertained in the course of these hourly assessments, too. In addition, the participants rated their subjective sleep quality for each of the four study nights. Further personal and rather time-invariant variables as well as the long-term annoyance due to aircraft noise in the past 12 months were surveyed in a supplementary face-to face interview. Generalized Estimating Equations were applied to estimate the

impact of the acoustical parameters and non-acoustical factors on one-hour annoyance ratings. Several prediction models for short-term annoyance were developed and compared according to their model fit. The relation between short-term and long-term reactions to aircraft noise was assessed using the multiple linear regression approach. For the examination of fairness in the context of aircraft noise exposure, a new questionnaire was developed and evaluated. Three dimensions of the construct (distributive, procedural, and informational fairness) plus a global fairness judgment were tested on their correlation to long-term aircraft noise annoyance.

The model which predicted short-term annoyance ratings most precisely contains the personalized L_{Aeq} for aircraft noise during the past hour, the number of aircraft noise events in total, and the number of aircraft noise events above a threshold of 70 dB(A). Moreover, this model considers the activity carried out mostly during the past hour, the respondent's general sensitivity to noise, and the presence and evaluation of domestic noise insulation. A moderate relation was found between the average one-hour annoyance rating across the four study days and the general annoyance during the past 12 months. Furthermore, the field study results revealed that the contribution of the average subjective sleep quality during the study nights to long-term annoyance is equal to the contribution of the average short-term annoyance at daytime. The results of the fairness questionnaire showed that residents of Cologne/Bonn Airport perceive the allocation of aircraft noise and the airport-related decision-making as only slightly fair. The general belief that one is treated fairly with respect to aircraft noise was related higher to long-term annoyance than the score for any of the three fairness dimensions.

The findings of the telephone and field study stress the importance of the number of aircraft noise events besides the L_{Aeq} as well as the impact of personal and situational factors for the prediction of aircraft noise-induced annoyance. Whereas for long-term annoyance, the influence of the personal factors is prevailing, for short-term annoyance, the situational and acoustical variables are decisive. Furthermore, the findings suggest that the long-term annoyance rating does not reflect merely an average rating across several different noise situations. With regard to the status quo of community annoyance due to aircraft noise, the conclusion is that the current European standard dose-response curve needs to be updated as it seems to underestimate the percentage of highly annoyed residents. Moreover, the results emphasized the high contribution of nocturnal annoyance and disturbance due to aircraft noise to general long-term annoyance. For a reduction of the community annoyance, not only acoustical and operational aspects of the aircraft noise exposure should to be improved. Likewise, a candid and truthful communication between the profiteers of the air traffic and the airport residents exposed to the noise needs to be established to enhance the acceptance of the air traffic in the vicinity of the airport.

Zusammenfassung

Vor dem Hintergrund eines stetig wachsenden Flugverkehrsaufkommens und den damit einhergehenden Beeinträchtigungen der Lebensqualität von Flughafenanwohnern befasst sich die vorliegende Doktorarbeit sowohl mit der langfristigen als auch mit der kurzfristigen Belästigung durch Fluglärm im Umfeld des Flughafens Köln/Bonn. Die Arbeit wurde im Rahmen des EU-Projektes COSMA (*Community Oriented Solutions to Minimise Aircraft noise annoyance*) erstellt, wobei eine Telefonstudie mit 1.262 Anwohnern (*M* = 58,6 Jahre, *SD* = 15,5, 61,8 % weiblich) sowie eine Vertiefungsstudie im Feld mit weiteren 55 Anwohnern (*M* = 45,7 Jahre, *SD* = 14,3, 61,8 % weiblich) durchgeführt wurden. Ziel war es, basierend auf den Ergebnissen dieser zwei Studien, Ansatzpunkte für Maßnahmen zur Reduzierung der Fluglärmbelästigung zu finden.

In der im Sommer 2010 durchgeführten Telefonstudie wurde der Status quo der Belästigung durch Fluglärm in den vergangenen 12 Monaten (= Langzeitbelästigung) untersucht. Des Weiteren sollten diejenigen Variablen identifiziert werden, welche das Belästigungsurteil neben dem energieäquivalenten Dauerschallpegel im Wesentlichen bestimmen. Die Telefonstudie diente zudem der Vorbereitung auf die sich im Sommer und Herbst 2011 anschließende Feldstudie.

In sechs Gebieten mit einem Fluglärmpegel zwischen 40 und 55 dB(A) wurden Telefoninterviews geführt. Die Fluglärmbelastung war durch den *A*-bewerteten energieäquivalenten Dauerschallpegel (L_{Aeq}) für die sechs verkehrsreichsten Monate im Jahr definiert. Alle L_{Aeq}-Werte wurden einer aktuellen Lärmkonturkarte entnommen. Da am Köln/Bonner Flughafen aufgrund von Frachtverkehr nachts in der Regel eine sehr hohe Flugdichte herrscht, wurde neben dem allgemeinen Belästigungsurteil auch die Belästigung durch Fluglärm in der Nacht zwischen 22 und 6 Uhr erfragt. Die Fluglärmbelästigung wurde gemäß der Empfehlung der International Commission on the Biological Effects of Noise (ICBEN) mit Hilfe einer fünfstufigen, semantischen Antwortskala erfasst. Zusätzlich ermöglichte eine offene Frage die Erhebung jener Tageszeiten, zu denen der Fluglärm aus Sicht der Betroffenen besonders belästigend ist. Eine Vielzahl personenbezogener wie auch situativer Faktoren wurde bezüglich ihres Einflusses auf die Fluglärmbelästigung untersucht. In einem mehrstufigen Prozess wurde mittels der linearen Regressionsanalyse ein Vorhersagemodell sowohl für die allgemeine als auch für die nächtliche Belästigung durch Fluglärm entwickelt.

Ein Vergleich der Köln/Bonner Belästigungsdaten mit den durch die Europäische Standard-Dosis-Wirkungs-Kurve vorhergesagten Werten zeigte einen deutlich höheren Anteil hoch

belästigter Personen im Umfeld des Flughafens Köln/Bonn. Die Befragten fühlten sich besonders in den späten Abendstunden und während der Nacht durch den Fluglärm belästigt. Die Variablen, welche das Belästigungsurteil bestimmen, umfassen den L_{Aeq} sowie die neun nicht-akustischen Prädiktoren a) die Überzeugung, dass der Flughafen Maßnahmen ergreifen könnte, die einer Verbesserung der Situation der Flughafenanwohner dienen, b) die Wahrnehmung von negativen Aspekten des lokalen Flughafens und Flugverkehrs, c) das Ausführen von Maßnahmen, um die Lärmbelastung bewältigen zu können, d) die allgemeine Einstellung gegenüber dem Flughafen, e) die Zufriedenheit mit dem Wohnumfeld, f) das Umweltbewusstsein, g) die allgemeine Lärmempfindlichkeit sowie h) der Urbanisierungsgrad des Untersuchungsgebietes und i) das Vorhandensein von Lärmschutzfenstern in der Wohnung und die Zufriedenheit damit. Die allgemeine und die nächtliche Langzeitbelästigung durch Fluglärm werden durch dieselben Variablen beeinflusst. Die Regressionskoeffizienten der einzelnen Prädiktoren waren in beiden Modellen vergleichbar. Die zehn oben aufgelisteten Variablen erklärten 54,8 % der Varianz in den allgemeinen Belästigungsurteilen und 52,3 % der Varianz in den Belästigungsurteilen mit Bezug auf die Nacht.

Während sich eine Vielzahl bisheriger Studien auf die Untersuchung der Langzeitbelästigung durch Fluglärm konzentrierte, wurde die Kurzzeitbelästigung in der natürlichen Wohnumgebung der Betroffenen kaum erforscht. Das Hauptaugenmerk der Vertiefungsstudie im Feld lag daher auf der Analyse des Effekts verschiedener akustischer und nicht-akustischer Faktoren auf die Fluglärmbelästigung während kurzer Perioden, genauer während der vorangegangenen Stunde. Ein weiteres Ziel der Feldstudie war die Untersuchung und Beschreibung des Zusammenhangs zwischen der Kurzzeitbelästigung am Tage, der subjektiven Schlafstörung in der Nacht und der Langzeitbelästigung. Darüber hinaus wurde das Konstrukt *Fairness*, welches bis dato vorwiegend im Rahmen organisations- und justizpsychologischer Forschung behandelt worden war, im Kontext der Fluglärmbelastung und –belästigung im Feld untersucht.

Die Feldstudie wurde in zwei Gebieten mit einem energieäquivalenten Fluglärmpegel oberhalb von 50 dB(A) durchgeführt. Über vier Tage und Nächte hinweg wurde der Schalldruckpegel kontinuierlich aufgezeichnet. Anhand der Aufnahmen konnten 30 Lärmparameter berechnet werden. Neben den gebräuchlichen Lärmindikatoren wie dem L_{Aeq}, der Anzahl an Überflugereignissen und dem Maximalpegel wurden Parameter einbezogen, die in vorherigen Studien nur wenig Beachtung fanden. Dazu zählen vor allem persönliche Lärmindikatoren, welche anhand von Informationen zum Außenpegel, zum Aufenthaltsort des Individuums, zur Fensterstellung und der daraus resultierenden Schalldämmung die Lärmbelastung am Ohr des Teilnehmers beschreiben. Parallel zu den kontinuierlichen Aufzeichnungen des Schalldruckpegels bewerteten die Teilnehmer ihre Fluglärmbelästigung während der letzten Stunde. Diese Art der Kurzzeitbelästigung wurde tagsüber vom Aufstehen bis zum Zubettgehen zu jeder vollen Stunde erfasst. Die Probanden schätzten ihre Fluglärmbelästigung mit Hilfe der fünfstufigen, semantischen ICBEN-Skala ein. Hierfür wurde eine nur wenige Minuten dauernde Befragung auf einem Laptop implementiert. Neben dem Belästigungsurteil wurden auch situative Faktoren wie die Tageszeit oder die Tätigkeit in der vergangenen Stunde erhoben. Zusätzlich schätzten die Teilnehmer jeden Morgen nach dem Aufstehen ihre Schlafqualität in der zurückliegenden Nacht ein. Ein persönliches Interview erfasste in Ergänzung dazu überdauernde personenbezogene Variablen (demographische Daten, Einstellungen, Persönlichkeitseigenschaften) sowie die Langzeitbelästigung durch Fluglärm während der letzten 12 Monate. Mittels verallgemeinerter Schätzgleichungen (Generalized Estimating Equations) wurde der Effekt der einzelnen akustischen und nicht-akustischen Variablen auf die Kurzzeitbelästigung während einer Stunde analysiert. Mehrere Modelle für die Vorhersage der Kurzzeitbelästigung wurden entwickelt und hinsichtlich ihrer Anpassungsgüte verglichen. Die Beziehung zwischen subjektiven Kurzzeit- und Langzeitwirkungen des Fluglärms wurde unter Verwendung linearer Regressionsmodelle untersucht. Um das Konstrukt *Fairness* im Kontext von Fluglärmbelastung und –belästigung erheben zu können, wurde ein neuer Fragebogen entwickelt und evaluiert. Drei Fairness-Dimensionen (distributive, prozedurale und informative Fairness) sowie ein globales Fairness-Urteil wurden anhand von Korrelationsanalysen auf ihren Zusammenhang mit der Langzeitbelästigung durch Fluglärm getestet.

Das Modell, welches die Kurzzeitbelästigung durch Fluglärm am präzisesten vorhersagt, beinhaltet als akustische Prädiktoren den persönlichen Fluglärm-L_{Aeq}, die Gesamtzahl der Fluglärmereignisse und die Anzahl an Fluglärmereignissen mit einem Maximalpegel oberhalb von 70 dB(A) während der vergangenen Stunde. Darüber hinaus berücksichtigt dieses Modell als nicht-akustische Prädiktoren die Tätigkeit, die während der letzten Stunde vorwiegend ausgeführt wurde, die individuelle Lärmempfindlichkeit sowie das Vorhandensein von Schallschutzfenstern und die Zufriedenheit der Befragten mit diesen. Das für jeden Probanden über die vier Studientage gemittelte Kurzzeitbelästigungsurteil und die allgemeine Langzeitbelästigung durch Fluglärm korrelierten mittelhoch miteinander. Ferner zeigte sich, dass die über die vier Studiennächte gemittelte subjektive Schlafqualität die allgemeine Langzeitbelästigung in gleichem Maße vorhersagen kann wie die mittlere Kurzzeitbelästigung am Tage. Die Ergebnisse der Fairness-Skalen verdeutlichen, dass die Anwohner des Flughafens Köln/Bonn die Verteilung des Fluglärms sowie die Entscheidungsprozesse und Kommunikation bezüglich des Flughafens und des lokalen Flugverkehrs als nur wenig fair empfinden. Die allgemeine Überzeugung, man werde im Hinblick auf den Fluglärm gerecht behandelt, zeigte höhere Korrelationen zur Langzeitfluglärmbelästigung als der Skalenwert einer der drei Fairness-Dimensionen.

Die Ergebnisse der Telefon- und Feldstudie unterstreichen einerseits den großen Einfluss der Anzahl der Fluglärmereignisse neben dem energieäquivalenten Dauerschallpegel und andererseits den beachtlichen Effekt personen- und situationsbezogener Faktoren auf die Belästigung durch Fluglärm. Während in der Entwicklung der Langzeitbelästigung den personenbezogenen Eigenschaften eine höhere Bedeutung zukommt, wird das Kurzzeitbelästigungsurteil im Wesentlichen durch akustische und situationsbezogene Faktoren bestimmt. Die Ergebnisse der Arbeit deuten ferner darauf hin, dass die Langzeitbelästigung durch Fluglärm nicht dem bloßen Mittelwert der Kurzzeitbelästigung über mehrere unterschiedliche Fluglärmsituationen gleichzusetzen ist. Bezüglich des Status quo der Langzeitbelästigung im Umfeld des Köln/Bonner Flughafens wird geschlussfolgert, dass die derzeit von der Europäischen Kommission empfohlene Dosis-Wirkungs-Kurve den Anteil der durch Fluglärm hoch belästigten Anwohner unterschätzt. Jüngere Studien an anderen Flughäfen zeigen einen ähnlichen Trend. Eine Revision der Kurven erscheint daher erforderlich. Ferner verdeutlichen die Befunde der vorliegenden Arbeit den starken Zusammenhang zwischen nächtlicher Belästigung und Störung durch Fluglärm und dem allgemeinen Belästigungsurteil. Zudem legen die Ergebnisse nahe, dass für eine effektive Reduzierung der Fluglärmbelästigung in der Bevölkerung nicht allein die akustischen und operationellen Aspekte der Fluglärmbelastung verbessert werden müssen. Ergänzend sollte eine offene und vertrauensvolle Kommunikationskultur zwischen den Profiteuren des Flughafens einerseits und den vom Fluglärm betroffenen Anwohnern andererseits aufgebaut werden, um die Akzeptanz des Flugverkehrs in der Region zu erhöhen.

1 Introduction

Noise and noise-induced annoyance is a very old problem (Guski, 1987). But in times of continuously increasing mobility and high transportation it is more topical than ever. According to an estimation of the World Health Organization, approximately half of the citizens in European Commission countries live in “zones which do not ensure acoustical comfort to residents” (World Health Organization, 1999, p. 1). Of all transportation, air traffic is regarded as the most growing (Bundesministerium für Umwelt, 2007). In Germany, it is the second most annoying noise source after road traffic. More than 12 % of the German population are “considerably” annoyed by aircraft noise and approximately 1.5 % even “highly” annoyed (Ortscheid & Wende, 2006).

The issue aircraft noise as a community problem emerged in the early 1960s after jet-powered aircraft have been introduced in civil aviation and started its success as mass transport. At this time, aircraft were extremely loud (Smith, 1989). During the past decades, the noise emitted from single aircraft has been reduced significantly through innovative constructions of the propulsion system and the airframe of the aircraft (Dobrzynski, 2010; Neise & Enghardt, 2003). However, this does not automatically lead to a reduction of the community annoyance induced by aircraft noise as the number of aircraft noise events has increased dramatically during the same period and is assumed to still grow (IATA, 2012). For the period of 2012 to 2031, the worldwide growth of air traffic is forecasted with 4.4 % per year. For Europe, an increase of 3.4 % per annum is expected. Freight traffic is forecasted to grow even faster with 4.9 % worldwide per year in the same period (AIRBUS, 2012).

This raises the question about the effects of aircraft noise in airport communities. Of all reactions to noise, annoyance and disturbance are considered as the main consequences and the noise effects with the highest evidence (Guski, Felscher-Suhr, & Schuemer, 1999; Passchier-Vermeer & Passchier, 2000; Stansfeld & Matheson, 2003). At a given continuous aircraft noise level, surveys on community annoyance due to aircraft noise of the preceding 20 years indicated a considerable increase in annoyance ratings (Babisch et al., 2009; Janssen, Vos, van Kempen, Breugelmans, & Miedema, 2011). In contrast, there are indications that the annoyance has not risen when the increase of the number of aircraft operations is taken into account (Le Masurier et al., 2007). At the same time, recent studies show high variations in the annoyance ratings between the different airports (Janssen et al., 2011; van Kempen & van Kamp, 2005). Moreover, it is well known that annoyance ratings vary strongly between residents of the same airport community (Job, 1988). From these results, two conclusions can be drawn. Firstly, variations in annoyance ratings cannot be sufficiently explained by the equivalent sound pressure level (Job, 1988). Additional acoustical parameters, such as the number of (loud) events, maximum levels and repose times seem to have an effect on annoyance (Guski, 1999; Ising & Kruppa, 2002). Secondly, non-acoustical variables, containing situational factors (e.g., the time of day when the noise occurs), personal factors (e.g., individual attitudes or traits), and social factors (the image of the noise source), as well as the interaction of the noise authorities with the airport residents seem to contribute considerably to community annoyance (e.g., Fields, 1993; Guski, 1999; Lercher, 1996b; Miedema & Vos, 1999; Stallen, 1999). In particular, for the variables related to the communication and behavior of aircraft noise authorities, recent studies show a potential for the reduction of the feeling of annoyance and disturbance due to noise (Haugg, Kastner, & Vogt, 2003; Maris, Stallen, Vermunt, & Steensma, 2007b; Maziul & Vogt, 2002; Stallen, 1999; Vogt & Kastner, 2000).

A number of studies have examined aircraft noise-induced annoyance and disturbance from different time perspectives. In surveys, community annoyance has often been examined with regard to long periods, such as one year or several months or a general feeling of annoyance (e.g., Finke, Martin, Guski, Schuemer, & Schuemer-Kohrs, 1975; Kroesen, Molin, & van Wee, 2008; Taylor, 1984; Wirth, Brink, & Schierz, 2004). Only very few studies have focused on the examination of aircraft noise-induced annoyance during short periods in the field so far (Aasvang & Engdahl, 1999; Schreckenberg & Meis, 2006; Stearns, Brown, & Neiswander, 1983). Mostly laboratory settings were used to assess annoyance during short terms (e.g., Maris, Stallen, Vermunt, & Steensma, 2007a; Öhrström, Björkman, & Rylander, 1980; Vogt, 2005). The link between short-term and long-term annoyance analyzed in field settings, however, is not clear yet.

Based on the results of prior research on annoyance due to aircraft noise, the following research questions arise which are addressed in the present doctoral thesis:

1) What is the status quo of aircraft noise-induced annoyance in communities at major airports? As an example for such an airport with a 24 hour operation scheme, Cologne/Bonn Airport is addressed in this work.
2) Which are the crucial acoustical and non-acoustical factors determining annoyance ratings across short and long terms?
3) How is short-term and long-term annoyance due to aircraft noise related?
4) What is the perception of the local air traffic and aircraft noise authorities by the airport residents? And in this context: What is the contribution of perceived fairness of the

aircraft noise distribution, the behavior of the authorities and their communication of airport-related information to community annoyance due to aircraft noise?

5) What are starting points for annoyance-reducing measures, in particular with regard to non-acoustical factors influencing annoyance?

A telephone survey and an in-depth field study are presented hereinafter that address mainly annoyance as one important consequence of aircraft noise exposure. The effect of aircraft noise on sleep, cognitive performance, and health have been investigated elsewhere in the recent past (sleep: e.g., Basner, Glatz, Griefahn, Penzel, & Samel, 2008; Griefahn, Marks, & Robens, 2006; cognitive performance: e.g., Elmenhorst et al., 2010; Hygge, Evans, & Bullinger, 2002; Marks & Griefahn, 2007; health: e.g., Babisch et al., 2013; Black, Black, Issarayangyun, & Samuels, 2007; Jarup et al., 2008).

The present thesis emerged in the context of the European research project COSMA which was supported by a grant of the 7th framework program of the European Commission. COSMA is the acronym for ***C****ommunity* ***O****riented* ***S****olutions to* ***M****inimise Aircraft Noise* ***A****nnoyance*. The project lasted from June 2009 to March 2013 and involved 21 partners from industry and research from nine countries. COSMA pursued the following objectives: In a basic step, the project aimed at achieving a better understanding of the psychological effects of aircraft noise on residents in the vicinity of an airport. On the basis of this knowledge, new mathematical models for the contribution of aircraft noise to annoyance around airports were developed. A so-called *Virtual Resident* tool was created that allows a prediction of the aircraft noise-induced annoyance for present as well as future airport scenarios on the basis of diverse acoustical and non-acoustical variables. Further development and refactoring of the *Virtual Resident* tool is still continued after the project. The ultimate goal of COSMA that likewise goes on beyond the time frame of the project was to provide recommendations for guidelines concerning aircraft design, operating practices and airport scenarios. To shed more light on the key factors influencing annoyance and disturbance due to aircraft noise and to ascertain data input for the *Virtual Resident* tool, a multi-platform gathering technique was employed at important European airports including a telephone survey, an in-depth study in the field, and two laboratory studies (Müller, 2011). The telephone survey and the field study were carried out with an identical methodology at three airports: London Heathrow (United Kingdom) which is one of the busiest hubs in the world, Stockholm Arlanda (Sweden) which is an important Scandinavian airport surrounded by predominantly rural areas with a very low population density, and Cologne/Bonn (Germany) which is a major German hub with a twenty-four-hour operation and heavy night-time traffic. The present work focuses on the data obtained in the vicinity of Cologne/Bonn Airport.

In the following chapters, the theoretical background of sound, noise and annoyance will be described first. Prior work on the link between aircraft noise exposure and annoyance as well as the impact of possible influence factors of this relation will be summarized. The current knowledge about the relation between short-term and long-term reactions to noise will be outlined as well. Since the construct *fairness* has been investigated mainly in the organizational and legal context, in an excursus, the history of the research on fairness and the relevance for the context of aircraft noise and annoyance are shortly presented. Next, the research questions of the telephone and the field studies are defined in detail. Afterwards, the methodology and results are described and discussed separately for the telephone survey (part A) and the in-depth field study (part B). At the end, the implications of the results of both studies and remaining research gaps are summarized in an overall conclusion and a subsequent outlook section. An attempt is made to integrate the results of the two studies into a prominent model (Guski, 1999) of long-term noise effects.

2 Theoretical background

2.1 Sound and noise

Sound is a physical phenomenon that occurs in gas, liquids, and solids due to pressure variations and that can be detected by the human hearing system (Hoffmann, von Lüpke, & Maue, 1999). Audible sound is almost always airborne sound (Schmidt & Schaible, 2000) which can be described as minimal pressure variations in air caused by the oscillation of aerial molecules. Sound is measured by the sound pressure level, L, in the unit decibel (dB). For a more detailed introduction into the propagation of sound as well as the link between the sound pressure, the sound intensity and the sound pressure level, see Crocker (2007) or Hoffmann, von Lübke, and Maue (1999).

The human hearing system is varyingly susceptible for certain frequencies. To adjust the measured values of a sound level meter to these human peculiarities, weighting curves have been established. For many years, the *A*-weighted sound pressure level has been the internationally most common measure (Pearsons, 1973) and has also been obligatory for the assessment of aircraft noise in Germany (Normenausschuß Akustik und Schwingungstechnik (FANAK) im DIN Deutsches Institut für Normung e.V., 1984). Consequently, the values of the sound pressure level are indicated in dB(A). The use of the alternative *B*- or *C*-weighting is very rare (Guski, 1987; Hoffmann et al., 1999).

Besides an adjustment for frequencies, a time adjustment is applied depending on the velocity of the sound pressure level rise and fall. Since the sound pressure level of civil aircraft noise events rises and falls relatively slowly, compared with, for instance, the sound pressure level of railway noise events, *slow* is the internationally common time adjustment for sound level meters (Isermann & Schmid, 1999). Only for fly-overs in extreme low altitudes as well as for military jets, the time adjustment *fast* is preferred (Spreng & Költzsch, 2004).

Whereas *sound* is a physical phenomenon, *noise* is considered as a rather psychological and not as a mere physical construct (Guski, 1987). The definition most often given refers to noise as *unwanted sound* (Guski, 1987; Moudon, 2009). Whether a sound is perceived as unwanted, and hence, as unpleasant, disturbing or annoying, results from the interaction between the features of the sound and the characteristics of the person exposed to this sound. On the one hand, an individual’s perception of a sound depends on the sound pressure level, duration, prevalence, timing, and frequency composition of the sound (Interdisziplinärer Arbeitskreis für Lärmwirkungsfragen beim Umweltbundesamt, 1990). On the other hand, current states of the individual but also rather time-invariantt personality traits, attitudes, and cognitions play an important role for the interpretation of a sound as noise (Guski, 1999). Supplementary to the definition of noise as unwanted sound, noise is defined as the acoustical energy that is able to impair the health of an individual or his/her physical, mental, social, or economic wellbeing (Guski, 1987; Klein, 2001).

2.2 Sources and descriptors of aircraft noise

2.2.1 Sources of aircraft noise

Aircraft noise occurs whenever air passes over the structure of the aircraft or through its propulsion system and causes fluctuating pressure disturbances (Smith, 1989). For the observer on the ground, noise emission becomes an issue mainly during the take-off and landing approach. With exception for military aircraft flying with supersonic speed, noise emitted on cruising altitude is hardly perceived on the ground. The two main sources of aircraft noise are the propulsion system and the airframe. During departures and on flight altitude, the noise produced by the propulsion system dominates (Kloepfer et al., 2006). In contrast, during the landing approach, airframe noise is the dominant noise component in modern aircraft with low-noise power-plants (Dobrzynski, 2010). A detailed overview over the sources of aircraft noise is given by Smith (1989).

2.2.2 Common descriptors of aircraft noise

Hereinafter, common aircraft noise descriptors are shortly presented. For this purpose, the categorization postulated by Jones and Cadoux (2009) is used distinguishing between single event metrics, exposure metrics and supplementary metrics.

Single event metrics

For single noise event, the metric that mostly describes the disturbance and annoyance potential of an aircraft sound is the maximum sound pressure level, L_{max} (Isermann & Schmid, 1999). Maximum levels of noise events are especially relevant for the interference with communication and sleep (e.g., Elmenhorst et al., 2012; Hall, Taylor, & Birnie, 1985). An additional metric that is recommended whenever activity disturbance is an issue of research is the *Sound Exposure Level*, *SEL* (FICON, 1992). The *SEL* accounts for the intensity and the duration of a sound and can be described as “the dB(A) value that would be measured if the entire event energy were uniformly compressed into a reference time of one second” (Jones &

Cadoux, 2009, p.2). The disadvantage of this type of measures, however, is the lack of an accepted methodology for the aggregation of those single event metrics into a kind of cumulative noise metric (FICON, 1992). For the description of a single noise event, also the *slope of rise* can be considered that describes how steep the sound pressure level rises. Individuals react stronger to aircraft noise events with a steep rise resulting from high speed and low flight altitudes (Brink, Lercher, Eisenmann, & Schierz, 2007).

Exposure metrics

Research on the effects of transportation noise mainly focuses on noise exposure and (constantly) recurring noise events spread over a certain period of time, e.g., one hour, one day, or one year and less on single noise events. Hence, a noise metric is needed that averages the continuously changing sound pressure level over a given period of time. Three common descriptors of long-term aircraft noise exposure are outlined in the following. For a more comprehensive list, see Isermann and Schmid (1999) or Jones and Cadoux (2009).

- The energy equivalent continuous sound pressure level, L_{eq}

The energy equivalent continuous sound pressure level, L_{eq} is a direct measure of the average sound energy at a given point of immission without any adjustments for the time of day (Isermann & Schmid, 1999). Therefore, the L_{eq} is also referred to as *energy equivalent sound pressure level*. The L_{eq} is defined by Equation 1 (Crocker, 2007, p. 37)

$$L_{eq} = 10\,log\,\frac{1}{T}\int_{0}^{T} 10^{L(t)/10}\,dt \qquad (1)$$

with

log = decadic logarithm

T = averaging time, e.g., 1 hour or 24 hours

$L(t)$ = Sound pressure level changing over time

The L_{eq} is the basis for the new German Aircraft Noise Act that became effective in 2007 (Gesetz zum Schutz gegen Fluglärm, Bundesministerium der Justiz, 2007)[1]. For the establishment of noise abatement zones around airports, the values of the L_{eq} for the periods 06:00 to 22:00 (daytime) and 22:00 to 06:00 (night-time) are considered. The *A*-weighted energy-equivalent continuous sound pressure level is referred to as L_{Aeq}.

[1] In Germany, the energy equivalent sound pressure level is abbreviated with $L_{eq\,(3)}$. This is necessary because the former German Aircraft Noise Act was based on a not energy-equivalent halving parameter of 4 in which halving sound intensity corresponded to a reduction of 4 dB instead of energy-equivalent 3 dB. Since the term $L_{eq\,(3)}$ is used only in Germany, in the following, the internationally common term L_{eq} is used in this work.

- The day night average sound level, L_{dn}

The day night average sound level, L_{dn}, is a 24 hour-L_{eq} measure with a 10 dB(A)-penalty for the night-time period between 22:00 and 07:00. The L_{dn} is currently used, for instance, in the United States of America (Jones & Cadoux, 2009). For the formula of the L_{dn}, see Crocker (2007, p. 37).

- The day evening night average sound level, L_{den}

The day evening night average sound level, L_{den}, is a 24 hour-L_{eq} measure with a 10 dB(A)-penalty for the night-time period (cf. above) and an additional 5 dB(A)-penalty for the evening defined as the time between 19:00 and 23:00. The L_{den} is used for environmental noise maps established in accordance with the Directive 2002/49/EC (2002) for the assessment and management of environmental noise in the European Union. The default values (in local time) are 07:00 to 19:00 for the day, 19:00 to 23:00 for the evening and 23:00 to 07:00 for the night, but the start of the day and accordingly the start of the evening and night can be set by the Member States. For the formula of the L_{den}, see Annex 1 of the Directive 2002/49/EC (2002).

Supplementary metrics

An important supplementary metric is the statistical indicator L_X which refers to the *A*-weighted sound level that is exceeded for x % of the measurement time, e.g., 10 % or 90 % (Crocker, 2007). Whereas the first is a metric for intrusive noise, for instance, due to aircraft fly-overs, the latter is often used to characterize the background noise (Jones & Cadoux, 2009).

A metric that similarly refers to certain level boundaries is the *number above a certain threshold* (*NAT*). The *NAT* is defined by the number of sound events within a time period exceeding a certain threshold, e.g., 60 dB(A) or 75 dB(A). This noise indicator combines information about the sound level of single noise events and the number of noise events (Jones & Cadoux, 2009).

Besides the metrics listed above, a diversity of additional noise indicators exists for the assessment of long-term noise exposure which has been applied or which is still in use in different countries of the world. For a detailed description of these noise indicators, see Jones and Cadoux (2009) or Pearsons (1973). In recent times, new noise indices were introduced in the German-speaking area, amongst others, with the purpose to make the noise exposure more understandable for the community. Such examples are the Frankfurt Aircraft Noise Index, *FFI*, and the Frankfurt Night Index, *FNI,* as well as the Zurich Aircraft Noise Index, *ZFI*, (Brink, Schreckenberg, Thomann, & Basner, 2010; Schreckenberg, Basner, & Thomann, 2009). However, in the international context, those metrics are of minor importance.

2.3 Effects of aircraft noise on man

According to the World Health Organization, WHO, (1999) environmental noise in general might not only affect the hearing system (= auditory effects) but is likewise capable to cause adverse physiological as well as psycho-social effects (= non-auditory effects). In the following, the current state of knowledge on auditory and non-auditory effects of noise is shortly summarized.

2.3.1 Auditory effects

There is broad evidence for a persistent hearing impairment as a consequence of long-term exposure to continuous sound pressure levels above 85 dB(A) (Stansfeld & Matheson, 2003). The exposure to an equivalent sound pressure level of 70 dB(A) or below across 24 hours, in contrast, is not expected to cause hearing in the vast majority (95%) of the population, even after a lifetime exposure (Passchier-Vermeer & Passchier, 2000; Ortscheid & Wende, 2000). Owing to the establishment of noise abatement zones around airports (cf. the latest version of the German aircraft noise act, Bundesministerium der Justiz, 2007), at least in Germany, residents of communities around civil airports are not exposed to equivalent sound pressure levels that are potentially causing hearing damages (Ising, Scheuch, & Spreng, 2004).

For few single aircraft fly-overs, no acute hearing impairment is assumed for individual maximum levels up to 115 dB(A) and a slope of rise below 60 dB(A) per second. For a high density of fly-overs with a high slope of rise, no acute hearing impairment is assumed for maximum levels at 105 dB(A) and below (Ortscheid & Wende, 2000). Due to the elevation of minimum altitude of low-altitude flights on 300 m in 1990, permanent hearing impairment caused by single aircraft noise events can be ruled out largely nowadays (Ising et al., 2004). Hence, with regard to transportation noise, the non-auditory effects are more in the focus of research than auditory effects.

2.3.2 Non-auditory effects

Non-auditory effects are broad and diverse and include performance effects, physiological responses, health outcomes, annoyance, and sleep disturbance (Smith, 1991). In the following section, non-auditory effects are categorized into the three types a) primary reactions, b) secondary reactions, and c) tertiary reactions as recommended by Griefahn (2000).

Primary reactions

Primary reactions can occur as acute reactions immediately after the stimulus onset or as global reaction over several acute reactions within a certain period of time (Griefahn, 2000). A major primary reaction of noise refers to physiological processes: Noise is considered as non-specific stressor causing changes in the reticular activating system (RAS). The subsequent stress response is characterized by an activation of higher cerebral centers, the sympathetic nervous system, the adrenal medulla and cortex, and the limbic system (Smith, 1991; Griefahn, 2000). The consequence of this activation can be changes in the blood pressure, heart and respiration rate, and peripheral blood flow as well as the release of stress hormones (Ortscheid & Wende, 2000; Babisch, Fromme, Beyer, & Ising, 2001). Such physiological reactions are reported to start already at a maximum sound level of 60 to 65 dB(A) (Interdisziplinärer Arbeitskreis für Lärmwirkungsfragen beim Umweltbundesamt, 1990).

A likewise good evidence exists for the adverse effects of noise on sleep: Sleep disturbance, in terms of higher rates of changes in the sleep stages and the number of awakenings, increases proportionally with the noise exposure (Stansfeld & Matheson, 2003). The prevalence of those effects rises together with the number of noise events, the maximum level, and with the slope of rise (Basner et al., 2008; Elmenhorst et al., 2012). Noise prolongs the time that is needed to fall asleep both initially and after once awake, increases the probability of occurrence of body movements during the night, and reduces the total sleep time (Jansen & Ising, 2004; Smith, 1991). An objective sleep impairment is particularly likely to occur at an exposure to more than 50 noise events per night with a maximum indoor level of 50 dB(A) or more (Stansfeld & Matheson, 2003).

Besides sleep also daytime activities as reading, listening, or conversation are likely to be disturbed or interfered with by noisy events (Hall et al., 1985; Öhrström & Skanberg, 1996; Kurra, Morimoto, & Maekawa, 1999b). Amongst all activities, communication is reported to be the most frequently disturbed daytime activity (Guski, 1991; Öhrström & Skanberg, 1996). Communication is prone to be disturbed because the sound of the interfering noise event can mask the sound that contents the intended information (Guski & Bosshardt, 1992; Höger & Schreckenberg, 2003). Generally, speech comprehensibility is decreased when a) speech and the interfering noise have a similar frequency spectrum, b) the frequencies and the sound level of the interfering noise are highly fluctuating, and c) with enlarged distance between speaker and recipient (Lazarus, 1988; Kloepfer et al., 2006).

Moreover, there is evidence from laboratory experiments that exposure to noise, especially to uncontrollable noise, diminishes cognitive performance directly via, e.g., inducing learned helplessness, increasing arousal, altering the task solution strategy, and decreasing the attention to the task (Passchier-Vermeer & Passchier, 2000). Amongst others, effects of transportation noise were found on the recall and recognition performance and the accuracy in search tasks (Bomann, Enmarker, & Hygge, 2005).

Secondary reactions

Secondary reactions occur immediately or after a certain time after the (recurrent) appearance of the stimulus (Griefahn, 2000). For example, an impaired cognitive performance with regard to the reaction time, vigilance, and short-term memory in a performance test, can result from sleep disturbance during the preceding night (Elmenhorst et al., 2010; Griefahn et al., 2006; Öhrström, 1995). Moreover, particularly in children, a decreased cognitive performance was found in terms of an impaired long-term recall and recognition performance as well as a diminished reading comprehension (Haines, Stansfeld, Job, Berglund, & Head, 2001; Hygge et al., 2002; Hygge, 2003). These effects cannot be attributed only to a disturbed night's sleep but rather to the masking of speech by the intrusive noise as well as to a lower persistence and motivation during the task performance and an impairment of information encoding, storage, and retrieval under noise exposure (Evans, Hygge, & Bullinger, 1995; Höger & Schreckenberg, 2003; Hygge, 2003). Some of these effects occurred already at an equivalent sound pressure level of 55 dB(A) (Hygge, 2003).

Another major secondary reaction to long-term exposure of, above all, transportation noise is the feeling of annoyance which was found both in adults and children (e.g., Evans et al., 1995; Finke et al., 1975; Guski, 1987; Haines et al., 2001; Passchier-Vermeer & Passchier, 2000; World Health Organization, 1999). The construct of annoyance and the relation between the aircraft noise exposure and annoyance are described in more detail in Section 2.4.

Tertiary reactions

Tertiary reactions are clinically relevant health damages or persistent changes of behavior. They are assumed to be the consequence of long-term exposition to noise or recurrent appearance of primary and secondary reactions over a longer period (Griefahn, 2000). As described above, single noise events can cause changes in the reticular activating system and the release of stress hormones leading to temporary changes, such as an increased blood pressure, increased heart rate and vasoconstriction. On the long run, this is regarded as a health risk. Diseases that are not reversible can be expected (Griefahn & Muzet, 1978; World Health Organization, 1999). For instance, there are some indications for an association between long-term noise exposure and the risk for cardiovascular disease as, for instance, ischemic heart diseases and hypertension (Babisch, Ising, Kruppa, & Wiens, 1994; Black et al., 2007; Jarup et al., 2008; Rosenlund, Berglind, Pershagen, Järup, & Bluhm, 2001). However, the size of effect is rather small and some findings did not show any relation at all (Fyhri & Aasvang, 2010; Goto & Kaneko, 2002).

2.4 Annoyance

Of all effects of noise, *annoyance* is considered as the main effect and as the one with the highest statistical evidence (Guski et al., 1999; Passchier-Vermeer & Passchier, 2000; Stansfeld & Matheson, 2003). Annoyance due to environmental stimuli is generally defined as "a feeling of displeasure associated with an agent or condition known or believed by an individual or a group to be adversely affecting them" (Lindvall & Radford, 1973, p. 3). According to the norm ISO/TS 15666 (ISO, 2003, p. 2), annoyance due to noise is "one person's individual adverse reaction to noise. The reaction may be referred to in various ways including, for example, dissatisfaction, bother, annoyance, and disturbance due to noise." This rather broad and non-specific definition is symptomatic for the fact that there is no consensus about the precise understanding of noise annoyance in the literature. Therefore, a short introduction into the diverse theoretical concepts is given based on the categorization suggested by Guski, Felscher-Suhr, and Schuemer (1999).

2.4.1 Noise annoyance as a result of disturbance

A number of models and findings are stating the impact of activity disturbance or interference for the development of noise annoyance, especially the interference with communication and sleep or recreation (Taylor, 1984; Hall et al., 1985; Ahrlin, 1988; Guski, 1991; Porter, Kershaw, & Ollerhead, 2000; Preis, Hafke-Dys, Kaczmarek, Gjestland, & Kleka, 2013). Two models postulated by Hall, Taylor, and Birnie (1985) and Guski (1991) are shortly outlined. The model established by Hall et al. (1985) assumes a mediating effect of activity interference for annoyance. Here, annoyance is considered as a secondary reaction, produced by the individual experience of activity disturbance or interference (e.g., disturbance of communication or sleep) caused by noisy events. The relation between noisy events, activity interference, and annoyance is depicted in Figure 1. Further laboratory studies found an effect of the interference or disruption of verbal activities on annoyance (Zimmer, Ghani, & Ellermeier, 2008; Preis et al., 2013). Moreover, it was shown that the potential for disturbance and annoyance changes with the source of sound and the acoustical properties of the sound (Zimmer et al., 2008).

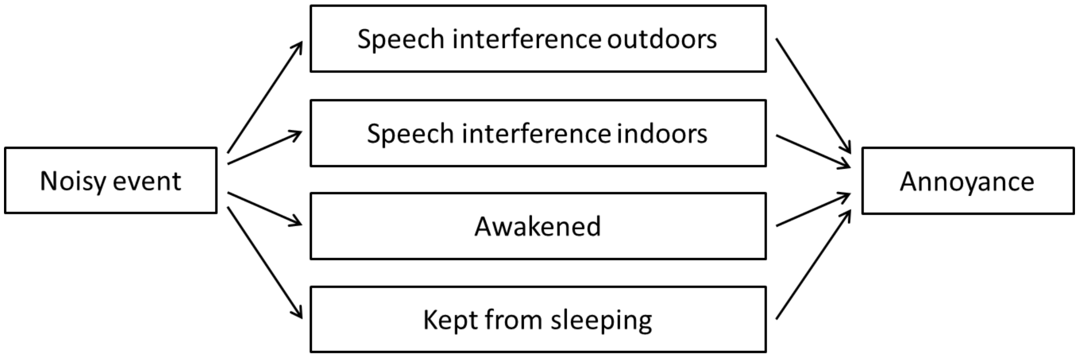

Figure 1. Conceptual model of the relation between noisy events, activity interference and annoyance (modified according to Hall et al., 1985, p. 239).

With regard to annoyance as a consequence of communication disturbance, a supplementary approach was introduced by Guski (1991). The author assumes that there is an internal reaction and activation induced by every stimulus no matter whether this stimulus is intended to be perceived and processed or not. Annoyance is considered as outcome of a conflict between the affordance for the intended activity (here the perception and interpretation of aural information) and the affordance for unintended actions against the intrusion of the interfering stimulus (Guski, 1991; Guski et al., 1999).

Notwithstanding the above, the understanding of the contribution of activity disturbance to annoyance is not consistent at all. Whereas some researchers define annoyance as a (at least very probable) product of the interference and disturbance of activities (e.g., Ahrlin & Rylander, 1979; Hall et al., 1985; Guski, 1991; Porter et al., 2000), other researchers also refer to the term *annoyance* when no activity has been intended or carried out during the assessment of noise events (Aasvang & Engdahl, 1999; Vogt, 2005).

2.4.2 Noise annoyance as emotion

As already stressed in the definition of annoyance given above, the mere belief that an environmental stimulus has adverse effects can be related to the feeling of annoyance and displeasure (Lindvall & Radford, 1973). Therefore, annoyance is considered as an "elementary affecting process related to the source of stimulation" (Guski et al., 1999, p. 514). In a path model, Leonhard and Borsky (1973) found a causal link between the reported fear for aircraft crashes and annoyance. According to the authors, a high aircraft noise level is a cue for a low altitude of the aircraft flying over and residents might perceive a great danger for an aircraft crash nearby. Since then, several findings have shown a strong relation between noise annoyance and reported fear related to the noise source (cf. Miedema & Vos, 1999).

Some authors state that the ability to experience annoyance and to emotionally respond to noise is an evolutionary outcome (Kalveram, 1996). In this view, sounds indicating rapidly approaching large objects/subjects or the presence of potential competitors would cause fear (or aggression) and provoke a fight or flight reaction. Accordingly, annoyance can be seen as a kind of cultivated fight or flight reaction. Notwithstanding, the existence of *causality* between fear and annoyance is queried (Guski et al., 1999).

2.4.3 Noise annoyance as attitude

A general assumption is that individuals most often have a relatively consistent attitude about a topic even if they do not have a profound personal knowledge of it. This attitude might result from socio-cultural traditions or mere associations with the name of the topic (Guski et al., 1999). For instance, Jonsson and Sörensen (1970) demonstrated in a laboratory experiment that creating a positive and a negative attitude towards the source of annoyance results in a reduced and increased, respectively, incidence of annoyance compared to a control group. The findings of a more recent laboratory study likewise supported the assumption that annoyance is related to attitudes to the noise source (Djokvucic, Hatfield, & Job, 2004): Participants indicated more negative noise reactions when they believed that they are hearing traffic noise during the experiment than when they believed that they are hearing ocean sounds.

2.4.4 Noise annoyance as knowledge

Annoyance is influenced by the conceptual knowledge of sounds and their effects in a certain situation, e.g., the general effects of aircraft sounds on sleep. Even if one asks a person to judge his/her actual annoyance at this very moment, one will get a judgment which is influenced by the general knowledge about sound effects (Bosshardt, 1988). The assumption of annoyance as a kind of knowledge is undergird by the finding that annoyance ratings correlate with knowledge that was gained from mass media coverage (Finke et al., 1975).

2.4.5 Noise annoyance as a result of rational decisions

In Fidell's theoretical approach (1987), the verbal report of annoyance ("That sound is annoying", p. 39) is considered as the product of a more or less rational decision-making process. Residents are regarded as deciding whether and how much they are annoyed by a given exposure and how they react on the annoyance. Fidell (1987) assumes that annoyance decisions involve not only the immediate exposure but also information about historical distribution of exposure levels, the sensitivity to noise while concentrating on a certain activity, the affective state of the respondent when the noise occurs as well as costs and payoffs of an annoyance decision.

2.4.6 Noise-induced annoyance – an integrative approach

All approaches described above suffer from the fact that they define annoyance only from a single perspective. Therefore, attempts have been made to integrate at least a part of the listed aspects of annoyance by developing more complex models on contributors of noise annoyance (e.g., Guski, 1999; Stallen, 1999; Porter et al., 2000). An often cited model postulated by Guski (1999) is depicted in Figure 2 and will be described hereinafter.

According to this conceptual model, annoyance is a secondary reaction to long-term noise exposure. The model integrates the approaches described above in this section as it assumes that annoyance is determined not only by the (recurrent) interference of intended activities. It likewise emphasizes the influence of personal and social factors comprising knowledge, attitudes as well as emotional components on reported annoyance. At the same time, Guski's model seizes on the idea of a temporal perspective as it defines actual interference as short-term effects and reported disturbance and annoyance as long-term effects. To a large part, this model provides the theoretical basis for the present thesis.

However, the conceptual model keeps the question unanswered which time period the terms *short-term* and *long-term* refer to. Does *short-term* mean a certain moment, several minutes or several hours? Or do several hours already reflect a *long-term* period? A review of the literature on noise effects did not discover a uniform understanding. Instead, it reveals that annoyance can occur already after short periods and that the reference period for annoyance reactions varies tremendously. Whereas some researchers operationalize *annoyance* as the feeling of annoyance (and disturbance) with regard to the past 12 months (e.g., Fields et al., 2001; Kroesen et al., 2008; Wirth et al., 2004), some set the reference periods to one or half an hour (e.g., Kurra, Morimoto, & Maekawa, 1999a; Öhrström et al., 1980; Schreckenberg & Meis, 2007a; Vogt, 2005). Other researchers already refer to the term *annoyance* when single noise events are assessed (Aasvang & Engdahl, 1999; Stearns et al., 1983). For a better understanding, in this work, an *acute* annoyance response at a certain moment is distinguished from a *short-term* annoyance response across one or few hours in the style of a model suggested by Porter, Kershaw, and Ollerhead (2000). Short-term annoyance in turn is distinguished from the feeling of *long-term*[2] annoyance which has been pent up over one year or more (cf. Porter et al., 2000).

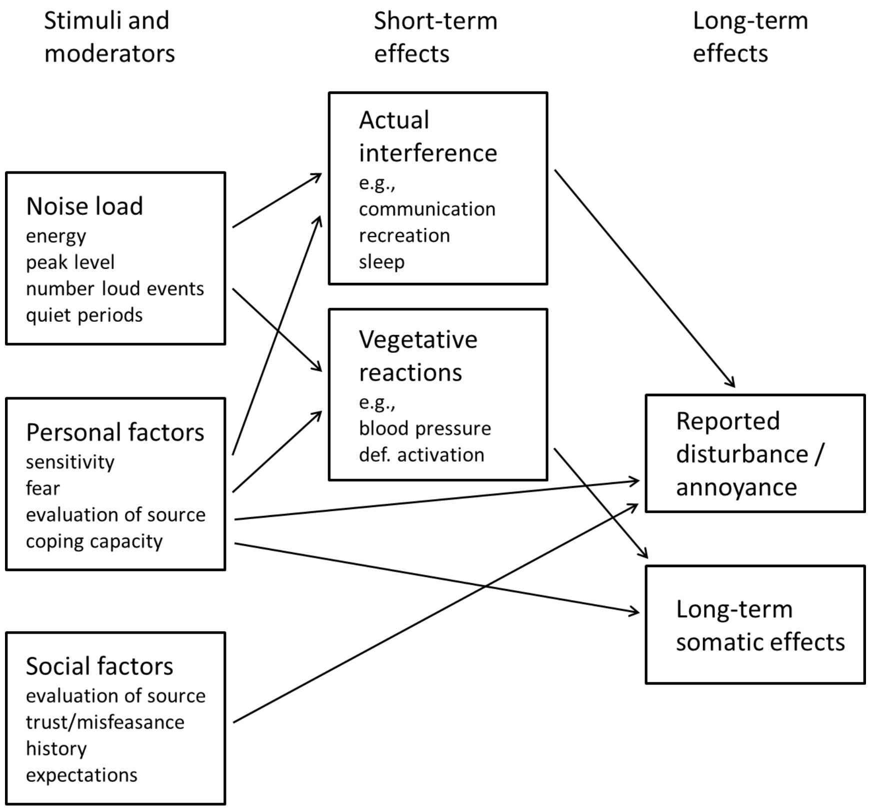

Figure 2. A conceptual model of short-term and long-term reactions to noise (modified according to Guski, 1999, p. 47).

2.5 Assessing annoyance

2.5.1 Annoyance scales

According to Miller (1974), measurement instruments for noise annoyance can be categorized into direct and indirect measures. Direct measures mean asking a respondent to rate his or her degree on annoyance such as “Rate your annoyance from one to seven where one is ‘no annoyance’ and seven is ‘extremely annoyed’” (ibid., p. 754). This procedure is considered as the only way to directly measure annoyance reactions (Levine, 1981). Indirect measures mean asking a respondent about the type of activity disturbed by the noise and the degree of disturbance of this activity. The degree of total annoyance is then a combination of the number of activities disturbed and the degree of disturbance. Generally, direct measures are more common (Miller, 1974).

[2] The authors also refer to *chronic* annoyance.

In the past, there has been a high diversity of annoyance scales with differing wording and with a varying number of response options leading to the problem of a reduced comparability of the results of international studies (Felscher-Suhr, 2000; Levine, 1981). A person's reported response to noise depends on the used answer scale (Schultz, 1978). Hence, the type of the answer scale accounts for a significant amount of heterogeneity in annoyance ratings between different surveys (Janssen et al., 2011). Also the position of the question for the annoyance judgment varies considerably from survey to survey (Felscher-Suhr, 2000; Levine, 1981). As a consequence, Team 6: *Community Response to Noise* of the International Commission on the Biological Effects of Noise (ICBEN) developed an internationally comparable semantic answer scale (Fields et al., 2001). This scale is composed as a kind of Thurstone-scale (Thurstone, 1931) with equidistant intervals between the answer options which allows parametric statistical analyses (Felscher-Suhr, 2000). The question for the assessment of noise-induced annoyance recommended by the ICBEN is "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?" The semantic five-point scale comprises the options "extremely", "very", "moderately", "slightly", and "not at all" (Fields et al., 2001, p. 669). This question and the corresponding answer scale are available in nine languages.

Supplementary to the semantic scale, a numerical scale was introduced which is "Next is a zero to ten option scale for how much (… source…) noise bothers, disturbs, or annoys you when you are here at home. If you are not at all annoyed, choose zero, if you are extremely annoyed choose then, if you are somewhere in between choose a number between zero and ten. Thinking about the last (… 12 months or so…), what number from zero to ten best shows how much you are bothered, disturbed, or annoyed by (… source…) noise" (Fields et al., 2001, p. 669). The two questions and scales found entrance into the international norm ISO/TS 15666:2003(E) on the assessment of noise annoyance in social surveys (ISO, 2003).

Although these two standardized questions and scales are a substantial progress, one major drawback remains just like for all global and direct annoyance questions: Asking residents about their general annoyance requires an abstraction across a multitude of situations (Felscher-Suhr et al., 1996). As demonstrated by Hallmann, Guski, and Schuemer (2001), respondents think of very different aspects when judging their global annoyance due to noise. Moreover it is queried whether this general annoyance question including also disturbance and bother is capable to capture the major part of the negative feelings and emotions due to aircraft noise (Kroesen & Schreckenberg, 2011).

2.5.2 Study designs for the assessment of annoyance

Depending on the dimension of annoyance (acute vs. short-term vs. long-term) which is subject to the assessment, diverse methods are qualified for the investigation of the relation between the noise exposure and annoyance.

Studies for the examination of noise-induced annoyance and disturbance in a community with respect to a longer period, often defined for the past 12 months (cf. Fields et al., 2001), are usually designed as social surveys. These surveys can be conducted as face-to-face interviews (e.g., Schreckenberg & Guski, 2005; Schreckenberg & Meis, 2007a), telephone interviews (e.g., Michaud, Keith, & McMurchy, 2005), postal questionnaire (e.g., Öhrström & Skanberg, 1996; Wirth et al., 2004), or online surveys (e.g., Kroesen et al., 2008). The methods listed vary significantly with respect to the controllability of the data collection from a high controllability in face-to-face interview to a very low controllability in postal questionnaires or online surveys (for a summary see Möhring & Schlütz, 2010). However, a systematical investigation of the comparability of the results obtained in these different study designs has been lacking so far to the author's knowledge. In particular, the discussion still goes on whether online surveys are capable to produce results in equal quality as traditional methods (Roster, Rogers, Albaum, & Klein, 2004; Fricker, Galesic, Tourangeau, & Yan, 2005; Braunsberger, Wybenga, & Gates, 2007). Nevertheless, at least for the rather traditional survey methods face-to-face interview, telephone survey, and postal questionnaires, the effect of the type of contact on annoyance ratings was shown to be small (Janssen et al., 2011; van Kempen & van Kamp, 2005).

Another approach for the examination of community annoyance is the analysis of complaint data (Hume, Terranova, & Callum, 2002). However, this method is considered as rather poor since the complaining behavior results from the interaction of many personal and environmental factors (Lindvall & Radford, 1973; Maziul, Job, & Vogt, 2005). Moreover, there is some evidence that the complaining behavior of an airport community does not correlate with the results of an annoyance survey (Avery, 1982).

Although to the author's knowledge no consistent definition for the construct *short-term annoyance* exists in the literature, it has been examined implicitly in several studies. Most often, annoyance during shorter periods, such as one or half an hour, was investigated in laboratory settings using standardized noise scenarios (e.g., Kurra et al., 1999a; Öhrström et al., 1980; Sandrock et al., 2008; Vogt, 2005). Even though laboratory studies provide the advantage of a high controllability and standardization of the experimental procedure (Öhrstrom, Björkman, & Rylander, 1988), they suffer from a high specificity of the situation

(Felscher-Suhr et al., 1996). It is difficult to examine noise reactions of individuals in connection with a high number of different daily activities including, for instance, recreation, sleep, concentrating, and watching TV, in the laboratory (Öhrstrom et al., 1988). Moreover, the laboratory atmosphere is assumed to create a context that is not comparable to situations of the everyday life (Felscher-Suhr et al., 1996).

To overcome the shortcomings of laboratory studies, few attempts have been made to measure short-term annoyance and disturbance in a realistic but still relatively controlled setting in the field. For instance, Felscher-Suhr et al. (1996) phoned their participants several times a day to ascertain the activity currently carried out as well as the experienced disturbance of this activity due to transportation noise. Noise levels were recorded in the interval of three minutes. More recently, one-hour annoyance due to road traffic, railway and aircraft noise has been examined across six days (Schreckenberg & Guski, 2005; Schreckenberg & Meis, 2007a) using a kind of the computerized experience sampling method (Feldman-Barrett & Barrett, 2001). Schreckenberg et al. (2005; 2007a) recurrently asked their participants via a Personal Digital Assistant (PDA) about their annoyance and activity disturbance during the past hour. Sound pressure levels of the transportation noise were calculated for each hour of the day.

Further field studies that addressed annoyance during very short periods were run by Aasvang and Engdahl (1999), Kastka (1998), and Stearns, Brown, and Neiswander (1983). Although with slightly different objectives, all three studies had in common the continuous recording of the sound pressure level simultaneously to the assessment of current aircraft fly-overs. Since the authors instructed their participants to rate their annoyance and/or the perceived acceptability of *single* aircraft noise events instead of a sequence of noise events, in the understanding of Porter, Kershaw and Ollerhead (2000), rather acute annoyance and not short-term annoyance was investigated in these studies.

2.6 The relation between aircraft noise exposure, short-term, and long-term annoyance

2.6.1 The relation between aircraft noise exposure and annoyance

Although often very surprising to laymen, it is a fact that community ratings of *long-term* noise annoyance are determined only to a little extent by acoustical parameters of the noise. The relation between noise exposure and an individual's subjective response to the noise is generally rather poor (Schultz, 1978). Following a heuristic, not more than one third of the variance in long-term noise annoyance judgments can be explained by acoustical features (Guski, 1999). The equivalent sound pressure level as sole predictor explains an even lower proportion of variance. In his review, Job (1988) reports for aircraft noise a mean correlation between the sound pressure level and noise reactions of .46. This finding corresponds to a variance explanation of approx. 21%. The results of more recent studies undergird Job's findings and partly show even smaller proportions of variance accounted for by the equivalent sound pressure level (Babisch et al., 2013; Kroesen et al., 2008; Schreckenberg & Meis, 2007a; Wirth et al., 2004). Notwithstanding, the acoustical features of the noise exposure must not be limited to the sound pressure level. Furthermore, adverse noise effects including annoyance and disturbance may be influenced by peak levels, the number of noise events, repose times, and aspects of the sound quality as well (Guski, 1999; Interdisziplinärer Arbeitskreis für Lärmwirkungsfragen beim Umweltbundesamt, 1990; Ising & Kruppa, 2002; Schreckenberg, 2014). Hereinafter, research findings on the contribution of the number of (loud) events and maximum levels to *long-term* annoyance are shortly summarized.

In the literature on noise effects, the impact of the number of noise events on noise annoyance varies considerable from no clear influence to a definite effect (Fields, 1984). Rylander and Björkman (1988; 1997) concluded that rated annoyance increases with a growing number of loud aircraft noise events which are defined as the number of events with a maximum level equal or higher than 70 dB(A), the NAT_{70}. This relation, however, is valid only up to a breakpoint of approximately 70 fly-overs during a period of 24 hours. Above this threshold, annoyance does not increase further with a rise in the number of fly-overs. For *small* and *medium* airports, i.e., airports operating less than 70 aircraft during 24 hours, Rylander & Björkman (1997) demonstrated that the impact of the number of aircraft above 70 dB(A) predicts aircraft noise annoyance better than the equivalent sound pressure level. In a recent study on aircraft noise annoyance around a *major* airport, Schreckenberg and Meis (2007a) found correlations between reported annoyance and the NAT_{70} for different periods of the day (lying between $r = .29$ and $r = .34$) that were consistently lower than the correlations to the equivalent sound pressure levels L_{Aeq} and L_{den} (varying between $r = .35$ and $r = .45$).

The contribution of the maximum aircraft noise level to long-term annoyance likewise depends on the air traffic density. Rylander and Björkman (1988) stated that the maximum level that was defined as the highest level occurring at least three times during a period of 24 hours, can predict noise annoyance ratings better than the equivalent sound pressure level, irrespective of the number of noise events. However, in a later study conducted by Rylander and Björkman (1997), no influence of the maximum noise level on noise annoyance was found. The authors finally concluded that the impact of the maximum noise level depends on the number of aircraft operated at an airport: Maximum noise levels are less important when the number of events is low, but they become decisive when the number of noise events exceeds the breakpoint of 70 per 24 hours. Notwithstanding, it is not clear whether this rule is still valid for current airport scenarios, since the air traffic and likewise the sound pressure levels of single aircraft have changed significantly during the past decades (Dobrzynski, 2010; Neise & Enghardt, 2003; Quehl & Basner, 2006)

For *short-term annoyance*, no thumb rule exists for the impact of acoustical parameters. Nevertheless, it seems plausible that the relation between annoyance during short periods and the exposure level is higher than the relation between long-term annoyance and the long-term noise exposure (R. Guski, personal communication, 17th February 2012). Respondents are expected to be capable to reflect the noise exposure of a prior short period, such as one to few hours, more easily than past year's noise load. Only a very small number of studies on short-term or acute noise annoyance and disturbance have been conducted in the field, so far (cf. Felscher-Suhr et al., 1996; Schreckenberg & Meis, 2006; Stearns et al., 1983). For the annoyance due to aircraft noise in the past hour, a correlation of r = .40 was found to the equivalent outdoor sound pressure level (L_{Aeq}) for aircraft noise (Schreckenberg & Meis, 2006). The correlations between one-hour annoyance ratings and the NAT_{55} and the NAT_{70} were r = .39 and r = .27, respectively (Schreckenberg & Meis, 2006). For the morning hours between 07:00 and 08:00 as well in the evening between 21:00 and 22:00, the NAT_{55} even was a better predictor than the L_{Aeq} of aircraft noise. The relation of the maximum outdoor aircraft noise level, L_{Amax} and the general outdoor level exceeded in 1% of the time, the L_1, to one-hour annoyance was identical, r = .29 (ibid.). Values for indoor levels were not available. The authors concluded that the number of noise events and, as a consequence, the reduction of quiet periods between fly-overs is more important than the maximum levels of single fly-overs. Nevertheless, in a prior full-factorial laboratory study, the single maximum noise levels of aircraft noise events had an effect on overall annoyance while the number of events did not (Vogt, 2005). Moreover, when the L_{Aeq} was held constant subjects tended to tolerate a higher number of aircraft at least below 27 aircraft noise events in half an hour which practically is without repose time (ibid.). In sum, the evidence on the relative size of the effect of the number of (loud) noise events, the maximum level, and the equivalent level on short-term annoyance is inconsistent.

In addition, a prior diary study by Stearns, Brown, and Neiswander (1983) found a higher relation of the average annoyance evaluation across several *single* aircraft noise events to the outdoor maximum aircraft noise level than to the indoor level in the examined room(s)[3]. The explanation given for this result suggests that due to the participant's movement in the house, outdoor measures are more consistent indicators of the aircraft noise exposure perceived by the individual. The non-aircraft noise specific indoor sound level metrics L_0 (i.e., the total maximum level) and L_{10} (i.e., the total sound pressure level exceeded in 10 % of the time) were no reliable predictors of average aircraft noise annoyance due to the high indoor background level. In contrast, in a laboratory setting with noise from several sources including aircraft, L_{Aeq}, showed a very high relation to mean annoyance (r = .92) across a period of approximately half an hour. The same value resulted from the correlation between L_1 and mean annoyance (Öhrström et al., 1980).

As a conclusion, the contribution of the acoustical parameters on annoyance varies considerably with a) the level of annoyance assessed (long-term vs. short-term), b) the indicator used to predict annoyance, c) with the setting of the annoyance examination (field vs. laboratory), and d) with the operationalization of the noise exposure as indoor or outdoor level.

2.6.2 Exposure-response curves

To provide a tool for the estimation of aircraft noise annoyance due to current and future exposure scenarios, so-called exposure-response curves were introduced. Schultz' (1978) synthesis on eleven studies on aircraft, railway, and road traffic noise established the first exposure-response curve and introduced the concept of the *percentage of highly annoyed* (% HA). The author stated that within a neighborhood, the actual outdoor and indoor sound levels vary considerably depending on characteristics of the dwelling, i.e., for instance noise insulation, shielding of the house by other buildings or the terrain. Hence, Schultz (1978) assumed that only a part of the residents actually hear the noise exposure measured in a survey. With the *highly annoyed* residents he hoped to focus on a group of residents that in fact heard the noise and "exhibit a definite and conscious response to it" (ibid. p. 379). The author defined *highly annoyed* by the top 27 to 29 % of the responses of an annoyance scale. As noise metric, the day night level, L_{dn} was used. The resulting exposure-response curve shows the percentage of people describing themselves as *highly annoyed* as a function of the L_{dn}. Although criticized (e.g., Kryter, 1982), the concept of *percentage highly annoyed* is nowadays internationally common (Giering, 2009).

[3] An effect size was not indicated. The relation was discussed using figures.

The database already analyzed by Schultz (1978) and later by Fidell, Barber, and Schultz (1991) was reanalyzed and supplemented with newer studies by Miedema and Vos (1998). On the basis of 34 datasets obtained between 1965 and 1992, Miedema and Vos (1998) established exposure-response curves for aircraft, railway, and road traffic noise, each. The authors likewise used % HA as measure for annoyance with % HA defined as the percentage of annoyance ratings exceeding the cut-off of 72 on an annoyance scale from 0 (no annoyance at all) to 100 (very high annoyance). Finally, Miedema and Oudshoorn (2001) refined the exposure-response curves established by Miedema and Vos (1998). According to the Annex III of the Directive 2002/49/EC for the assessment and management of environmental noise in the European Union (European Commission, 2002), every member state should assess the community noise effects on the basis of the curves postulated by Miedema and Oudshoorn (2001). These curves are therefore often referred to as *Miedema-curves* or *European standard curves*. The use of these curves, in particular for the estimation of the community response to aircraft noise, is not undisputed (cf. Giering, 2009). The main criticism arises from the fact that the majority of the studies considered was carried out before 1980 with no study after 1992. Many studies on community response to aircraft noise which have been conducted since then showed large deviations from the European standard curve (e.g., Brink, Wirth, Schierz, Thomann, & Bauer, 2008; Janssen et al., 2011; Schreckenberg & Meis, 2007a). Recently, Janssen, Vos, van Kempen, Breugelmanns, and Miedema (2011) demonstrated that the consideration of more recent studies results in a significant higher percentage of highly annoyed individuals at a given exposure level.

2.6.3 The relation between short-term and long-term effects of noise

Guski's model (cf. Figure 1 in Section 2.4 of this thesis) implies that short-term effects of noise, such as the disturbance of intended activities, cause long-term annoyance and disturbance. Up to now, almost nothing is known about the relation between psychological short-term effects of noise across, for instance, one hour or one day and reported noise effects that refer to longer periods such as one year. The model by Guski (1999) stresses *that* there is a relation between the two levels of noise reactions. But it makes no assumption about *how* short-term and long-term noise effects are related. Recently, Schreckenberg and Schuemer (2010) reported a moderately high relation between short-term annoyance and long-term annoyance (r = .53) that was measured by the semantic five-point scale recommended by the ICBEN (Fields et al., 2001). Nevertheless, it is not clear whether long-term annoyance resembles a kind of a subjective average of annoyance during shorter periods or whether long-term ratings rather refer to extreme situations.

The only model addressing this aspect to some extent is the one established by Porter, Kershaw, and Ollerhead (2000) which was originally developed for the context of nocturnal annoyance due to sleep disturbance. The model defines higher levels of annoyance, i.e., long-term annoyance, as accumulations of lower levels of annoyance comprising acute and short-term annoyance due to awakenings in the night and perceived sleep disturbance as well as sleepiness the day after.

In contrast, Hallmann, Guski, and Schuemer (2001) demonstrated that the global (road traffic) noise annoyance rating seems to reflect rather an individual's annoyance during extreme situations. Asking respondents to spontaneously mention aspects that where crucial for their global annoyance rating revealed that respondents most often refer to a) certain sound characteristics or single loud events, b) times during the night, in the evening and at the weekend which are times with an enhanced expectation for rest and quietness (Porter et al., 2000), and c) communicative activities and sleep that are activities which are very likely to be disturbed or interfered with by noise (Ahrlin, 1988; Finke et al., 1975; Hall et al., 1985; Taylor, 1984).

2.7 Influence variables of noise-induced annoyance

As described in the preceding sections, acoustical parameters of the noise exposure only account for at best one third of the variance in annoyance ratings. Besides the actual noise exposure, also variables such as characteristics of the person exposed to the noise as well as characteristics of the situation when the noise occurs matter (Fields, 1993; Finke et al., 1975; Guski, 1999; Kroesen et al., 2008; Miedema & Vos, 1999; Schultz, 1978). Taking up the heuristic of noise research (Guski, 1999) again, another third of the variance in noise annoyance ratings can be explained by non-acoustical variables, whilst the last third of variance remains unexplainable. There have been a huge number of studies and already two meta-analyses (Fields, 1993; Miedema & Vos, 1999) emphasizing the immense contribution of non-acoustical variables to noise responses. The impact of non-acoustics is not only obvious when looking at the judgments given in one airport community at a certain time but also when the results of studies are compared which were conducted at different airports: For the same equivalent sound pressure level, the % HA varies considerably around different airports (van Kempen & van Kamp, 2005). Figure 3 depicts the exposure-response relation for eleven studies conducted between 1990 and 2002 in comparison to the European standard curve.

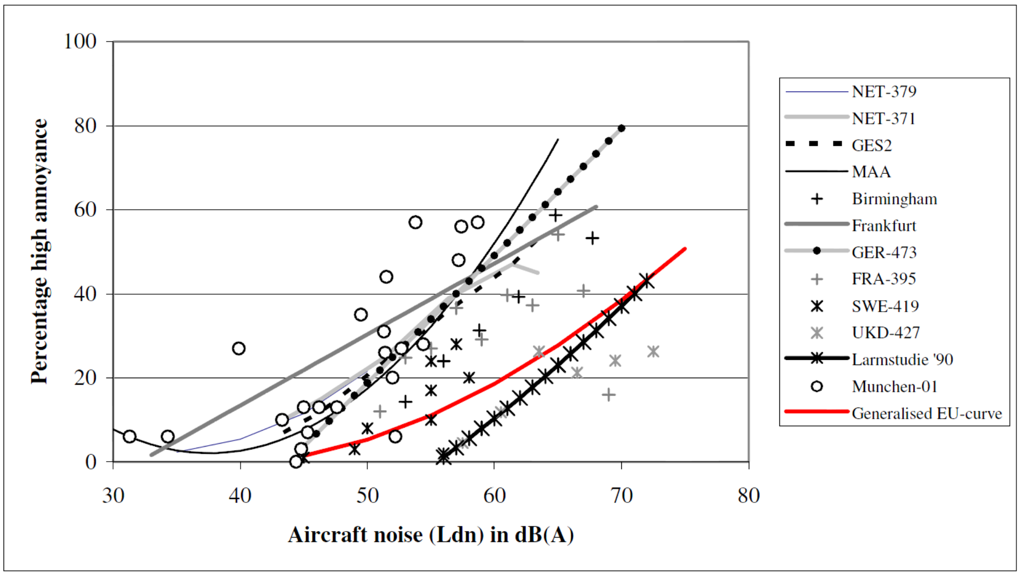

Figure 3. Summary of exposure-response data from 11 surveys, using a cut-off point of 70-75 (on a scale 0 -100) for being highly annoyed, without adjustment for potential confounders (modified according to van Kempen & van Kamp, 2005, p. 25).

Non-acoustical influence variables are manifold and can be subsumed under different categories. Although, there is no gold standard for the allocation of variables or constructs to those categories, it seems plausible to discriminate between factors referring to attitudes and traits of the individuals exposed to noise (= *personal* and *social factors*) from factors referring to features of the situation when the noise occurs (= *situational factors*) (cf. Ising et al., 2001). In addition, there are several variables that are lying on the intersection between acoustics and non-acoustics (= *parameters related to the noise source*).

In the following section, variables examined in the past decades as well as their impact on noise annoyance are presented shortly. All results described below refer to community annoyance with regard to long terms or to the general feeling of annoyance indicated without referring to any reference period[4]. Findings concerning short-term annoyance are mentioned explicitly.

2.7.1 Parameters related to the noise source

Under this category variables are subsumed that are not noise indicators in the nearer sense but that are linked to the air traffic and, hence, to the aircraft noise exposure. For example, a significant effect of the *location of the individual's home relative to the flight path* on annoy-

[4] An example for such a question is: "How would you describe your general feelings about the aircraft noise in this neighborhood? Would you say you are: (1) not at all annoyed, (2) slightly annoyed, (3) moderately annoyed, (4) considerably annoyed, or (5) highly annoyed" (Miedema & Vos, 1999, p. 3338).

ance due to aircraft noise was found (Taylor, 1984). The assumption is that aircraft flying directly over an individual's home might be perceived as particularly threatening. Moreover, the mere fact that the noise source is visible to an individual was found to increase reported annoyance (Bangjun, Lili, & Guoqing, 2003).

For the *operation type* over a residential area, a significant effect was revealed on both short-term and long-term annoyance (Schreckenberg & Meis, 2006; Schreckenberg & Schuemer, 2010): At the same L_{Aeq}, annoyance was higher for approaches than for take-offs.

Concerning the *distribution of the aircraft noise*, the conclusion is that guaranteeing foreseeable times without any aircraft operation over a given area as it is established by a runway alternation system at London Heathrow Airport has benefits for the airport community (Flindell & Witter, 1999). However, the estimated effect is rather small (Brooker, 2010).

2.7.2 Situational factors

Situational or contextual factors refer to characteristics of the context when a noise event occurs (Ising et al., 2001; Lercher, 1996b) or, following a broader definition, to all potential determinants of annoyance that are not person-related (Fields, 1993). Subsequently, an additional distinction criterion is introduced with respect to the aspect of temporal stability. Factors which are relatively consistent over many noise situations are distinguished from factors changing over time.

Noise insulation

An example for a rather persistent factor is a person's insulation from noise. According to Field's review (1993), sufficient evidence exists for the effect of noise insulation on noise-induced annoyance: Individuals who are well insulated from noise while at home reported less annoyance. Moreover, aircraft noise-induced annoyance was found to decrease with an increasing satisfaction with the sound attenuation of residents' insulation windows (Kastka, 1999). However, the mere fact that noise insulation have been fitted at home did not affect annoyance in a more recent survey (Wirth, 2004). The conclusion is that not the fact whether noise insulation has been fitted is decisive for annoyance but the degree of satisfaction with the noise insulation measures.

As it influences the individual aircraft noise exposure, a further contribution on annoyance is expected from the window position and the whereabouts of the individual, i.e., indoors or outdoors (Miller, 1974).

Degree of urbanization and background noise exposure

Although not systematically investigated to the author's knowledge, the *type of the neighborhood* and the *degree of urbanization* seem to be additional time-invariant influence factors of noise-induced community annoyance. Annoyance is assumed to be highest in rural areas, followed by suburban, urban, residential, commercial, and industrial areas in decreasing order (Miller, 1974). Evidence exists at least for the difference between reported annoyance in very rural areas versus annoyance in suburban and urban areas (Lercher, de Greve, Botteldooren, & Rüdisser, 2008). Moreover, it was assumed that annoyance due to a certain intruding noise is lower in presence of a high background noise than when the background noise is lower (Miller, 1974). However, regarding this hypothesis, evidence is contradictory (Fields, 1993).

Intended activities

While the quality of noise insulation and the characteristics of the neighborhood are rather consistent across several noise situations, there are situational factors changing from one hour to the next as, for instance, the type of activity that is carried out. Communication – may it be active, such as interactional conversations, or passive, such as listening to the radio or watching TV − is expected to be particularly disturbed because of its acoustical nature (cf. Guski & Bosshardt, 1992; Lazarus, 1988). Evidence exists for the link between the disturbance of communicative activities and long-term annoyance (Ahrlin, 1988; e.g., Finke et al., 1975; Taylor, 1984). Furthermore, the relation of the disturbance of sleep and recreation to long-term annoyance ratings is well proved (Ahrlin, 1988; e.g., Finke et al., 1975; Hall et al., 1985; Taylor, 1984). However, at least for aircraft noise, a systematical examination of the contribution of activity disturbance to annoyance in due consideration of a broad range of everyday activities has not been achieved yet. With respect to short-term annoyance during one hour, some evidence exists for the contribution of the type of activity that was carried out when the aircraft noise occurred: Schreckenberg and Meis (2006) showed that aircraft noise-induced annoyance across one hour was highest for activities requiring a high amount of concentration as well as for recreation and sleep. Aircraft noise that occurred during listening to the radio or watching TV was rated as least annoying.

Time of day

Another influence factor of annoyance and disturbance due to noise is the *time of day* when the noise occurs. According to Hoeger (2004), a generally higher susceptibility to noise exists in the evening (≈ 18:00-22:00), at night (≈ 22:00-06:00), and in the early morning (≈ 06:00-08:00). As a result of a busy and noisy (working) environment, a demand for quiet and restful periods, in particular, during the evening and night has been established in wide sections of the population (Hoeger, 2004; Porter et al., 2000). In addition, certain times of day are associated with specific activities. The results of a study on the timing of noise-sensitive activities (Fields, 1985) revealed a higher frequency of aural communication including conversation, socialization, listening to the radio, and watching TV beginning in the afternoon around 16:00. During the night, human need for recreation and sleep prevails (Fields, 1985). As mentioned in Section 2.3.2, both communication and sleep are particularly susceptible to a disturbance by noise including aircraft noise (Basner et al., 2008; Elmenhorst et al., 2012; Griefahn, 2000; Hall et al., 1985; Kurra et al., 1999b; Öhrström & Skanberg, 1996). With regard to the early morning, an individual psycho-physiological adaption process to the rhythm of the day is assumed which is likewise expected to be very susceptible to noise (Hoeger, 2004). Higher ratings for the hours in the evening, night, and early morning were found for both long-term annoyance (e.g. Hoeger, Schreckenberg, Felscher-Suhr, & Griefahn, 2002; Schreckenberg & Meis, 2006; Wirth, 2004) and short-term annoyance (Stearns et al., 1983). However, the time of day when annoyance starts to rise varies considerably between the studies.

Day of the week

For the day of the week, some evidence for an effect on aircraft noise-induced annoyance exists as well (Schreckenberg & Meis, 2006). Both short-term and long-term ratings were higher for the weekend than for weekdays. A possible explanation might likewise lie in the type of activities carried out predominantly and the time spent with these activities. According to Fields (1985), sleep patterns are different at the weekend meaning that people are staying in bed longer. Moreover, individuals are engaged in aural communication activities more often at the weekend than on weekdays. As described earlier, especially sleep, recreation and communication are highly susceptible to an interference or interruption by noise (Basner et al., 2008; Elmenhorst et al., 2012; Griefahn, 2000; Hall et al., 1985; Kurra et al., 1999b; Öhrström & Skanberg, 1996).

2.7.3 Personal and social factors

Personal factors comprise “variables which are linked tightly to an individual, show a considerable stability over time and situations, and vary between individuals considerably” (Guski, 1999, p. 47). In contrast to personal factors, *social* factors rather refer to evaluations and opinions shared by a group of individuals (Guski, 1999). However, the transitions are smooth and the two categories are often overlapping. This becomes obvious for the variable *attitudes* (described in detail in the section below). Although attitudes are relatively stable and individual (Allport, 1935), they might be influenced by the society as well (Guski et al., 1999). Therefore, personal and social factors are subsumed under one category in this chapter.

Attitudes, concerns, and expectations

According to the meta-analyses by Fields (1993) and Miedema and Vos (1999), attitudes, concerns, and expectations are deemed to be most powerful influence variables of noise annoyance. Positive evaluations of the noise source, such as the belief that the noise source is important for the economy in the region, reduce noise annoyance. In contrast, negative attitudes and concerns about the negative effects of the noise and the noise source including adverse effects on health and the environment increase reported noise annoyance (Fields, 1993; Kroesen et al., 2008). A prominent example for those concerns is *fear related to the noise source*. People who report fear for an air crash rate their noise annoyance significantly higher than people who do not express this fear (Miedema & Vos, 1999). In a more recent study (Schreckenberg & Meis, 2007b), aviation related fears and negative attitudes contributed considerably more to aircraft noise annoyance during the past 12 months than the L_{den}. The *expectation or belief that the noise situation will worsen in the future* was found to enhance aircraft noise annoyance as well (Kroesen et al., 2008; Schreckenberg & Schuemer, 2010; Wirth et al., 2004). Moreover, a significant decrease in annoyance was found in residents expecting to receive noise insulation measures in the near future (Wirth, 2004).

Another attitude potentially influencing annoyance is the *prioritization of environmental and silence aspects* to economic issues when it comes to airport-related decisions (Wirth et al., 2004) and the less specific variable *environmental conscience* (Guski, Wichmann, Rohrmann, & Finke, 1978). Reported annoyance and disturbance due to aircraft noise were higher when the individual emphasized the importance of the consideration of environmental aspects.

Noise sensitivity and personality traits

Noise sensitivity that is roughly described as “a stable personality trait covering attitudes and reactions towards a wide range of environmental sounds” (Zimmer & Ellermeier, 1999, p. 295) is considered as one of the most influential variables of noise annoyance (e.g., Job, 1988; Lercher, 1996b; Miedema & Vos, 1999; Stansfeld, 1992). Recently, the general sensitivity to environmental stressors (noise, odor) was found to determine aircraft noise-induced annoyance even more strongly than the L_{den} (Schreckenberg & Meis, 2007b). Moreover, there seems to exist a link between *noise sensitivity* and a more general personality trait comprising a disposition for the experience of adverse emotional states, as anger, tension or anxiety which is often labelled as *trait anxiety*, *neuroticism, emotionality, or negative affectivity* (Stansfeld, 1992; Persson, Björk, Ardö, Albin, & Jakobsson, 2007). However, the evidence for the relation between this personality trait and reported annoyance is contradictory (Stansfeld, 1992; Lercher, 1996b).

Evaluation of residential area and length of residence

According to Lercher's review (1996b), sufficient evidence exists for the relation between noise annoyance and the degree of satisfaction with the residential area and the immediate living environment including the dwelling. The better the surrounding environment is evaluated the lower is reported annoyance. In contrast, more recent studies did not show a consistent effect: Schreckenberg and Meis (2007b) found a significant influence of the general residential satisfaction including acoustical and non-acoustical aspects of the dwelling and the residential area as well as the infrastructure on reported aircraft noise annoyance. Wirth, Brink, and Schierz (2004), in contrast, found an annoyance-reducing effect only for a high satisfaction with the acoustical aspects of the residential area but not for the satisfaction with non-acoustical aspects.

With regard to the effect of the length of residence, prior research obtained contradictory results (cf. Fields, 1993). Some surveys did not find any association between the length of residence and reported annoyance at all (Weinstein, 1982; Shepherd, Welch, Dirks, & Mathews, 2010). In contrast, a recent survey showed that annoyance due to railway noise increases with the years lived in the noise exposed neighborhood (Pennig et al., 2012). In total, results rather counter the hypothesis of a habituation to noise and a decrease in annoyance over time.

Demographics

A multitude of variables is subsumed under the term demographics. Those variables are, for instance, age, gender, occupational status and educational level, homeownership, dependency on the noise source, and use of the noise source. Although often examined in annoyance research, for demographical factors, only seldom and if so only small effects on annoyance were found (Fields, 1993; Miedema & Vos, 1999). Gender seems to have no influence on annoyance at all. Age has a rather curvilinear effect: Relatively young and relatively old people are less annoyed (Miedema & Vos, 1999). Slightly higher annoyance is reported for people with higher educational level and occupational status, for homeowners, and for people who neither are dependent on the noise source nor use it (Miedema & Vos, 1999). However, there is also some evidence against a contribution of these variables (Fields, 1993).

Control and coping capacity

According to a conceptual model by Stallen (1999), two decisive determinants of annoyance are the constructs *control* and *coping capacity*. Stallen's model roots in the transactional stress theory (Folkman, 1984; Lazarus, 1999) and describes noise exposure as a kind of stressor to which an individual reacts in a certain manner. How an individual reacts depends amongst others on a) the perceived threat of the stressor noise, b) how much influence the individual believes to have over the noise situation (= the concept of *control*), and c) how the individual rates his or her ability to deal with this stressor (= the concept of *coping capacity)*. Evidence for an annoyance-reducing effect of the constructs *control over noise* and *coping capacity* has been found in various surveys on annoyance induced by transportation noise (Graeven, 1975; Guski et al., 1978; Hatfield et al., 2002; Kroesen et al., 2008).

Whilst there is consensus about the understanding of the term *coping capacity*, a number of approaches to the definition of specific *coping strategies* or *measures* exists. For instance, a distinction is made between cognitive and behavioral strategies (Folkman & Lazarus, 1988). Problem-oriented strategies are distinguished from avoidance and comforting cognitions (van Kamp, 1990). A further distinction is made between short-term and long-term strategies (Felscher-Suhr, Schreckenberg, Schuemer, & Möhler, 2001; Wirth, 2004). Research on coping with environmental stressors (including noise and odor) showed that the effect of coping varies depending on the type of strategy (Cavalini, Koeter-Kemmerling, & Pulles, 1991; Felscher-Suhr et al., 2001; Steinheider & Winneke, 1993; Wirth et al., 2004)

Trust in authorities and perceived fairness

The perceived amount of control and the capacity to cope with noise is not only affected by the individual's beliefs about the own abilities and resources. It is also influenced by the degree to which the individual thinks that authorities responsible for the noise exposure (e.g., the airport management, the government, and airlines) act in a proper manner and really make an attempt to consider residents' noise situation (Stallen, 1999). This construct is referred to as *trust in authorities* or alternatively as *misfeasance* (Stallen, 1999; Guski, 1999; Lercher, 1996b). Similarly, the construct *preventability belief* describes a respondent's conviction that the noise exposure could be prevented or at least reduced by the noise authorities (Guski, 1999; Stallen, 1999). High mistrust and the belief that noise could be prevented have been shown to increase noise annoyance (Fields, 1993; Guski, 1999; Lercher, 1996b; Stallen, 1999).

A construct strongly related both to *control* and *trust in authorities* is *perceived fairness*. In recent laboratory studies (Maris et al., 2007a; Maris et al., 2007b), a fair treatment decreased reported annoyance during the period of the experiment compared to the neutral condition while an unfair treatment increased annoyance. Since the residents' perceived fairness of the distribution of aircraft noise, the airport-related decision-making and communication of noise authorities is a core topic of this thesis, an entire section is dedicated to the construct *fairness* (see Section 2.8).

2.8 Excurse on the construct fairness

2.8.1 Prior research on fairness

When do we consider something to be fair? One possibility to define fairness is to compare our own situation with the situation of a reference person. This is what the construct *distributive justice*[5] is about. For example, when we are interested in the fairness of our own payment we can compare our effort (input) relative to our reward (outcome) with other people's ratios. According to the *model of social exchange* postulated by Adams (1965), *distributive justice* or *equity* is given when the two ratios are equivalent. Vice versa, when an inequality between these ratios is perceived, the individual will experience a feeling of *injustice*.

But how can fairness be rated when there is only an outcome but no input one can weigh it against? Here, a major problem becomes obvious: In terms of Leventhal (1980), equity theory only uses a one-dimensional concept of justice meaning that "an individual judges the fairness of his own or other's rewards solely in terms of a merit principle (p. 28)." Since equity theory (Adams, 1965) focuses on the contribution of an individual related to his rewards, it ignores possible additional criteria for distributive fairness. Following Leventhal's multidimensional approach (1980), in addition to this so-called *contribution rule,* an individual's judgment of fairness may be based on a *needs rule* dictating that persons with greater need should receive higher outcomes, or an *equality rule* which states that everybody should receive similar outcomes regardless of his or her needs or contributions. These distribution rules apply to the allocation of both favorable and unfavorable outcomes including rewards and resources but also punishments. The relative importance of these distribution rules may vary with the social situation, i.e., with the social setting as well as the role of the individual in this setting (Leventhal, 1980).

[5] The terms justice and fairness will be used interchangeable in the following.

Besides using these rules for judging the fairness of a distribution (i.e., *distributive fairness*), an individual may also consider the circumstances under which a distribution was made, that is, the procedures leading to a certain outcome. This concept is known as *procedural fairness* and refers to a person's perception of the "fairness of procedural components of the social system that regulate the allocative process" (Leventhal, 1980, p. 35). Thibaut and Walker (1975) first examined this construct in the context of justice psychology in situations when a decision is made by a third person or party and when this decision has consequences for an individual. The authors postulate that a fair procedure is given when the individual has control in the decision-making process. Thibaut and Walker (1975) distinguish between *process control* and *decision control*. *Process control* means that an individual has the chance to express his or her perspectives and to bring arguments during the procedure before the decision is made. *Decision control,* in contrast, refers to the actual amount of influence the individual has on the outcome of the decision-making process. At the same time, Leventhal (1980) developed criteria for the construct procedural justice and examined these criteria in the context of organizational psychology. Leventhal (1980) stated six rules for a fair procedure.

1) *Representativeness rule*: During all phases of an allocative process, the concerns, values and outlook of all parties affected by the process are taken into account.
2) *Consistency rule*: Procedures are applied consistently over time and people. Procedures are valid for all persons in the same way. Nobody is put at an advantage or at a disadvantage. When procedures are applied over time, these procedures are kept stable.
3) *Bias suppression rule*: Procedures are free from bias and are not led by self-interests.
4) *Accuracy rule*: The allocative process is based on sufficient, correct, and appropriate information.
5) *Correctability rule*: Opportunities exist to alter or reverse an inaccurate decision at various stages of a process. Accordingly, all parties involved in this process have the chance to appeal or challenge a decision.
6) *Ethicality rule*: The allocative procedures are compatible with fundamental standards of ethics and morality accepted by the individuals affected by these procedures.

Tyler (1988) made an attempt to combine the concepts of Thibaut und Walker (1975) and Leventhal (1980). According to the author, *process control* and *decision control* reflect Leventhal's *representativeness rule*. Furthermore, Tyler (1988) postulated that *process control* can be equated with *having voice*. Roughly defined, *having voice* means "participating in allocation decision-making by expressing one's opinion about the preferred allocation"

(Folger, Rosenfield, Grove, & Corkran, 1979, p. 2253). The finding that *having voice* or *process control* increases the perceived fairness of a procedure is termed *voice effect* (Folger et al., 1979). This effect is assumed to be the phenomenon with the highest evidence in procedural justice research (Lind, Kanfer, & Earley, 1990). A *voice effect* even occurs when an individual has the chance to present his or her views only after the decision has already been made (Lind et al., 1990).

Given that the process resulting in a certain decision is perceived as fair, what are the consequences for the evaluation of the outcome of this process and an individual's behavior? Thibaut and Walker (1975) first showed, that an individual's satisfaction with a decision is built upon the judged fairness of the procedure leading to this decision. Many studies have emphasized the importance of procedural fairness for the evaluation and acceptance of a result, such as pay or performance evaluation (for a summary see Tyler, 2000; van den Bos, Lind, Vermunt, & Wilke, 1997). Moreover, fair procedures were found to be related to job satisfaction, trust in the management (e.g., Alexander & Ruderman, 1987), organizational commitment, and performance (Colquitt, Conlon, Wesson, Porter, & Ng, 2001) as well as to the attitude to judges and the court (Tyler, 1984). Furthermore, a fair treatment can reduce physiological stress (Vermunt & Steensma, 2003).

So far, only the fairness of a procedure and the result arrived by this procedure has been considered, but not the way how the result of the procedure is communicated. Bies and Moag (1986) introduced the construct *interactional justice* that focuses on the quality an individual is treated with by a decision-maker. Bies and Moag (1986) postulate four criteria that characterize a fair interaction:

1) *Truthfulness*: The interaction is candid meaning that an individual is treated in an open and forthright manner, and that the individual is not deceived.
2) *Justification*: Explanations and justifications must be adequate so that a decision can be understood and accepted.
3) *Respect*: The interaction is respectful and polite, i.e., the communication is courteous and not personally attacking.
4) *Propriety*: Prejudicial and improper comments are suppressed.

Following Bies and Moag (1986), both the model of Leventhal (1980) and Thibaut and Walker (1975) fail "to distinguish between the procedure from its enactment" (p. 45). Even when an individual considers a procedure and its result as fair, according to Bies and Moag (1986), this individual may perceive unfairness because of an improper treatment or a lack of justification of the procedure and its result by the decision-maker. Furthermore, it was shown that also in case of a negative outcome, the procedure of decision-making was perceived as fairer when an adequate justification or causal account was given during the interaction (Bies & Shapiro, 1987; Bies & Shapiro, 1988). Rated adequacy of an explanation is higher when the recipient considers the explanation to be reasonable and when the recipient is mildly instead of severely harmed by the outcome (Shapiro, Buttner, & Barry, 1994).

Within the construct *interactional justice*, a further distinction can be made between the two sub-constructs *interpersonal fairness* and *informational fairness* (Greenberg, 1993; Greenberg, 1993). *Interpersonal fairness* reflects the degree to which people are treated with politeness, dignity, and respect by the authorities who are involved in executing procedures or determining outcomes (Colquitt et al., 2001). *Informational fairness* "focuses on the explanations provided to people that convey information about why procedures were used in a certain way or why outcomes were distributed in a certain fashion" (Colquitt et al., 2001, p. 427).

The fairness standards described in the preceding section are summarized in *Figure 4*.

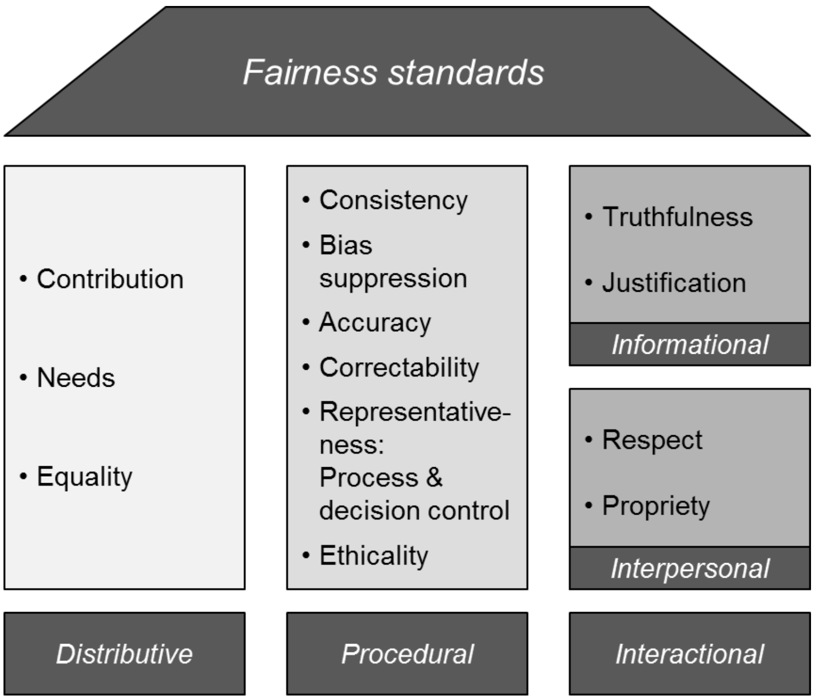

Figure 4. Standards of *distributive, procedural* and *interactional fairness – a summary based on the work of* Thibaut and Walker (1975), *Leventhal* (1980), Bies and Moag (1986), and Greenberg (1993).

For a long time, there was the discussion whether interactional fairness has to be considered as a separate construct or only the social facet of *procedural* and *distributive fairness* (cf. Bies & Moag, 1986; Greenberg, 1993; Colquitt, 2001). In a meta-analysis with 183 justice studies, Colquitt, Conlon, Wesson, Porter, and Ng (2001) showed the independence of *interactional fairness* from other constructs of fairness and emphasized the incremental variance explanation by *interactional fairness* criteria. Moreover, the results of this meta-analysis suggest a differentiation between *informational* and *interpersonal fairness.* The four justice dimensions *distributive, procedural, interpersonal* and *informational justice* were moderately to highly related, but not so highly that one underlying construct seemed plausible (Colquitt et al., 2001). The same conclusion has been derived from a study on the construct validity of an organizational justice questionnaire by Colquitt (2001): Confirmatory factor analyses showed a significantly better fit for a four-factor model than for models with two or three distinct dimensions.

There is a considerable number of fairness measures varying in accordance to their shapes and sizes (Colquitt & Shaw, 2005). The range of measures reaches from direct one-item measures to indirect multiple-item questionnaires. Indirect measures were found to correlate higher with possible outcomes than direct ones in the above mentioned meta-analysis (Colquitt et al., 2001).

2.8.2 Fairness in the context of aircraft noise exposure

So far, the dimensions of fairness most often have been examined in the organizational and legal context (cf. Tyler, 2000). However, it seems plausible that the *perceived fairness* contributes to annoyance induced by aircraft noise as well. On the one hand, exposure to aircraft noise can include characteristics of a decision-making process. This applies, for instance, to decision-making on the ban versus the prolongation of night-time traffic or the establishment of a runway alternation system. Amongst others, crucial aspects might be the amount of influence the airport residents have on the decisions and the manner they are informed about the decisions. On the other hand, aircraft noise exposure likewise meets the criteria of an allocative process, for example, when the expansion of an airport is planned and/or new departure and approach routes are determined. Here, the decisive question is the distribution of noise: Is it fairer to divide a rather moderate noise exposure over a high number of airport residents? Or is it fairer to bundle the routes and, thus, to expose only a small number of residents to high aircraft noise and, consequently, to prevent the majority of the residents from being exposed to aircraft noise? The question about fairness, moreover, does not only apply to single residents but also to an entire community: Whereas the one community is affected by both the merits of the airport (e.g., in terms of fiscal revenue) and the drawbacks, i.e., the noise exposure, the other community might suffer only by the noise.

Although not under the scope of fairness research, the effect of information policy on community aircraft noise annoyance as well as the request for authorities' communication to residents have been examined (e.g., Haugg et al., 2003; Maziul & Vogt, 2002; Vogt & Kastner, 2000). Maziul and Vogt (2002) underlined the desire of the residents to be informed comprehensively about current actions at the airport. Moreover, they found that the introduction of a free-toll telephone service which enables residents to receive aviation-related information reduced community annoyance in tendency but not statistically significant. From the perspective of noise exposure as a social allocation or decision-making process, Maris, Stallen, Vermunt, and Steensma (2007a; 2007b) introduced *procedural fairness* as one facet of the construct *fairness* into the context of noise annoyance for the first time. The authors seized the assumption that noise is man-made sound, i.e., artificially produced, (Stallen, 1999; van Gunsteren, 1999) and, thus, can be considered as social experience, too. As a consequence, the evaluation of the sound management procedures affects the evaluation of the sound itself (Maris et al., 2007a). Maris et al. (2007a; 2007b) run two laboratory experiments that focused on *voice* or *process control* as one aspect of procedural fairness: In experiment one, the participants who could voice their preference for a certain sound and who believed that this preference was taken into account (fair procedure) were less annoyed by the sound than participants who could not voice their preference (neutral procedure). In experiment two, it was shown that participants who voiced their preference and whose preference was ignored (unfair procedure) were significantly more annoyed than participants who could not voice a preference (neutral procedure). The authors concluded that not only the acoustical features of the sound can produce annoyance, but also the social process of exposing an individual to unwanted sound.

Nevertheless, several questions remain open: Can the effect of *procedural fairness* on reported aircraft noise annoyance be replicated in a field setting where the interaction does not take place between two individuals but rather between an individual and a noise exposing organization or system? How important are further criteria of fair procedures as, for instance, Leventhal's (1980) accuracy, correctability, and bias suppression rule? And which impact do the criteria of the further dimensions *distributive, interpersonal,* and *informational fairness* have on noise annoyance ratings?

3 Research questions

Part A: Telephone study

The focus of the telephone survey was on the examination of *long-term* aircraft noise annoyance, i.e., the annoyance due to aircraft noise during the past 12 months, and of the non-acoustical variables influencing annoyance in addition to the *A*-weighted long-term energy equivalent sound pressure level, L_{Aeq}, for aircraft noise. Here, the understanding of annoyance follows the rather broad definition of the ISO/TS 15666:2003(E) (ISO, 2003) which subsumes dissatisfaction, bother, annoyance, and disturbance under the term *annoyance*. Moreover, the telephone study served the preparation of the subsequent field-study, in particular with regard to the subsequent selection of examination areas for the field study, the adequacy of the survey instruments, and the identification of the most important non-acoustical and presumably rather time-invariant factors influencing annoyance ratings. Based on the literature review on aircraft noise-induced annoyance, the following research questions were derived.

Research question A 1: Status quo of long-term aircraft noise annoyance

What is the status quo of aircraft noise annoyance in the community around Cologne/Bonn Airport which is a major German airport with a 24 hour operation scheme? Related to this main question are the aspects:

- How highly is aircraft noise-induced annoyance rated in general and regarding the night-time period?
- How high is annoyance at a given noise level compared to annoyance findings of prior studies conflated in the European standard curve?

Research question A 2: Long-term annoyance during several times of day

Research on aircraft noise-induced annoyance has revealed certain times when noise is perceived as particularly annoying. These times are mainly the evening and night. Based on prior findings, the following questions arise:

- Aircraft noise annoyance in the course of the day: What are the times when aircraft noise is particularly annoying? What is the air traffic density at Cologne/Bonn Airport during these times? Is the general long-term annoyance rating related to the annoyance of certain times of day? How strongly is night-time annoyance related to general annoyance?

Research question A 3: Predictors of long-term aircraft noise annoyance

A multitude of variables have been found to influence noise annoyance ratings in prior research so far. Considering a broad range of personal as well as home and area-related variables in addition to the L_{Aeq}, the questions arise:

- What are the main predictors of general and night-time annoyance during the past 12 months? Do the predictors differ between general and night-time annoyance?

Research question A 4: Residents' perception of Cologne/Bonn Airport

Prior research stressed the contribution of evaluations related to the local airport and air traffic to community annoyance as well as the general importance of a good neighborhood between the airport and its residents. This may hold potential for approaches to reduce community annoyance. Therefore, the residents' perception of Cologne/Bonn Airport and the air traffic in this area is assessed by the questions:

- Which positive and negative aspects of the airport and air traffic are perceived? Does a link exist between perceiving certain aspects and long-term annoyance?
- According to the residents, which actions of the airport management could improve the residents' quality of life? Is there a link between mentioning certain actions and long-term annoyance?

Part B: Field study

So far, the vast majority of studies have focused on noise annoyance with regard to longer periods, for instance the past 12 months, and assessed annoyance most often only by a single retrospective judgment. Only few studies addressed short-term annoyance across few days or hours in the field. For the first time, in the present field study, a broad range of actually measured instead of calculated noise parameters as well as situational factors are related to judged short-term annoyance during the period of one hour. Here, the term *annoyance* again refers to the definition postulated by the ISO/TS 15666:2003(E) (ISO, 2003), that means that annoyance is not restricted to activity disturbance. Recording the outdoor aircraft noise levels is presumed to be methodically advantageous to calculating the levels. Thereby, information about the background noise can be gained and parameters that take into account background levels, e.g., the ratio of (maximum) aircraft noise to background noise can be derived. Moreover, noise descriptors that require an exact measurement of the aircraft noise level, such as the time per hour affected by aircraft noise and the exact slope of rise of the aircraft noise events, are ascertainable. The contribution of these potentially supplementary noise metrics to annoyance ratings has not been assessed systematically yet but will be examined in the present thesis. The following research questions arise:

Research question B 1: Predictors of short-term annoyance due to aircraft noise

- How much do the diverse acoustical parameters of the aircraft noise exposure during the preceding hour contribute to one-hour aircraft noise annoyance? Which is the best single acoustical predictor?
- Which non-acoustical parameters contribute to one-hour annoyance? Does the consideration of non-acoustical variables besides acoustical parameters improve the prediction of one-hour annoyance ratings? A comprehensive prediction model for short-term aircraft noise annoyance will be developed which considers both acoustical and non-acoustical variables.

Research question B 2: The relation between short-term and long-term annoyance due to aircraft noise

Literature on psychological effects of noise suggests *that* there is a link between short-term and long-term annoyance due to aircraft noise. Little is known about *how* short-term and long-term annoyance is related. The following questions arise:

- What is the relation between reported short-term and long-term annoyance due to aircraft noise? Does the long-term annoyance rating reflect an average of the short-term annoyance ratings during several days or does it rather refer to the highest short-term rating? Or is another linkage function more likely such as an accumulative process?
- How important is the contribution of daytime short-term annoyance due to aircraft noise to general long-term annoyance compared to the contribution of self-rated sleep quality at night?

Research question B 3: Evaluation of aircraft noise authorities

Besides the airport management, several other authorities participate in the decision-making concerning the local air traffic and, thus, in the allocation of aircraft noise in the vicinity of Cologne/Bonn Airport. To discover starting points for measures to build trust in the noise authorities and in order to minimize community annoyance, the following questions are addressed in the field study:

Research question B 3.1: Evaluation of authorities' influence on aircraft noise exposure and of their will to act in the residents' interest

- How much control do the residents of Cologne/Bonn Airport attribute to several aircraft noise authorities? In comparison to this, how is the perceived effort the authorities invest in the considerations of residents' opinions and needs regarding aircraft noise? Is there a link between this perceived effort and long-term annoyance due to aircraft noise?

Research question B 3.2: Perceived fairness of air traffic-related decision-making and the allocation of aircraft noise at Cologne/Bonn Airport

To measure fairness in the context of aircraft noise exposure, a suitable questionnaire needs to be designed, implemented, and tested. With the newly developed questionnaire, the following questions are addressed:

- How do residents rate the fairness of the allocation of aircraft noise, the air traffic-related decision-making and information at Cologne/Bonn Airport?
- Is *fairness* a multidimensional construct, i.e., can distinct factors being identified? How do the scores of the different fairness dimensions correlate with each other?
- What is the relation between the fairness dimensions *distributive, procedural,* and *informational fairness* and the presumed outcomes *satisfaction with the residential area*, *long-term aircraft noise annoyance, trust in authorities*, and *attitude towards the airport*? The relation between the fairness ratings and presumed outcomes are expected to vary depending on the fairness dimension. To find an answer to this research question, specific hypotheses have been formulated:
  - *Annoyance* and *satisfaction with the residential area* are hypothesized to correlate highest to the scores of *distributive fairness*. Aircraft noise annoyance during the past 12 months is expected to be negatively related to *distributive fairness* whereas the satisfaction with the residential area is expected to be related positively to *distributive fairness*.
  - *Procedural* and *informational fairness* are expected to be positively related to the construct *trust in authorities* as well as to the *attitude towards the airport*.
  - Scores of indirect measures of fairness are hypothesized to be related more strongly to the possible outcomes than the score of a direct and global measure.

Part A: Telephone study

4 Methods of the telephone study

The following chapter describes the methodology of the telephone study that was run in the vicinity of Cologne/Bonn Airport with 1,262 respondents from six different examination areas. After a short introduction of the airport, the examination areas are characterized with regard to their aircraft noise exposure as well as to their distance to the airport and their degree of urbanization. Afterwards, the study sample and the interview questionnaire are outlined. The chapter closes with the presentation of the statistical approach to the examination of the research questions of the telephone study.

4.1 Examination areas

4.1.1 Cologne/Bonn Airport

Cologne/Bonn Airport is located in the German State of North Rhine-Westphalia approximately 14 km southeast of the inner-city of Cologne and approximately 16 km north of the inner-city of Bonn. The airport is an important cargo hub operating 24 hours a day with busy periods between 00:00 and 05:00. According to information provided by the airport, in 2009, approximately 562,000 tons of cargo and 9.7 million passengers were carried (Köln Bonn Airport, 2014). Behind Frankfurt and Leipzig, Cologne/Bonn Airport takes the third rank in a comparison of cargo statistics among German airports. With regard to passenger statistics, Cologne/Bonn Airport ranks seventh in Germany. Between 1990 and 2007, both cargo and passenger statistics increased more than threefold. From 2007 on, the numbers have been stagnant. The airport Cologne/Bonn Airport was founded in 1950 and has held three runways since then: an intercontinental runway (14 L/32 R) with a parallel take-off and landing runway (14 R/32 L) as well as a crosswind runway (06/24) (Köln Bonn Airport, 2014). Approximately 400,000 individuals are exposed to an equivalent aircraft noise exposure above 45 dB(A).

For the telephone study, six examination areas that varied considering their distance to the airport (between approximately 1 km and 20 km) and with regard to their equivalent aircraft noise exposure (40 – 55 dB(A)) were selected. Figure 5 depicts the six examination areas.

4.1.2 Criteria for the area selection

The selection of the examination areas was mainly based on the values of the exposure to aircraft noise in a given area. Aircraft noise exposure was operationalized by the *A*-weighted equivalent continuous sound pressure level, L_{Aeq}. The L_{Aeq}-values were extracted in 5-dB steps from a noise contour map provided by the airport. Compliant with the German Aircraft Noise Act (Gesetz zum Schutz gegen Fluglärm, Bundesministerium der Justiz, 2007), the L_{Aeq} had been calculated in accordance with the Technical Instructions on Aircraft Noise Calculations, AzB, (Umweltbundesamt Arbeitsgruppe Novellierung der AzB, 2007) for the six months of the year with the highest air traffic volume. Exposure data were available for the daytime between 06:00 and 22:00 (= $L_{Aeq,6\text{-}22}$) and night-time between 22:00 and 06:00 (= $L_{Aeq,22\text{-}6}$).

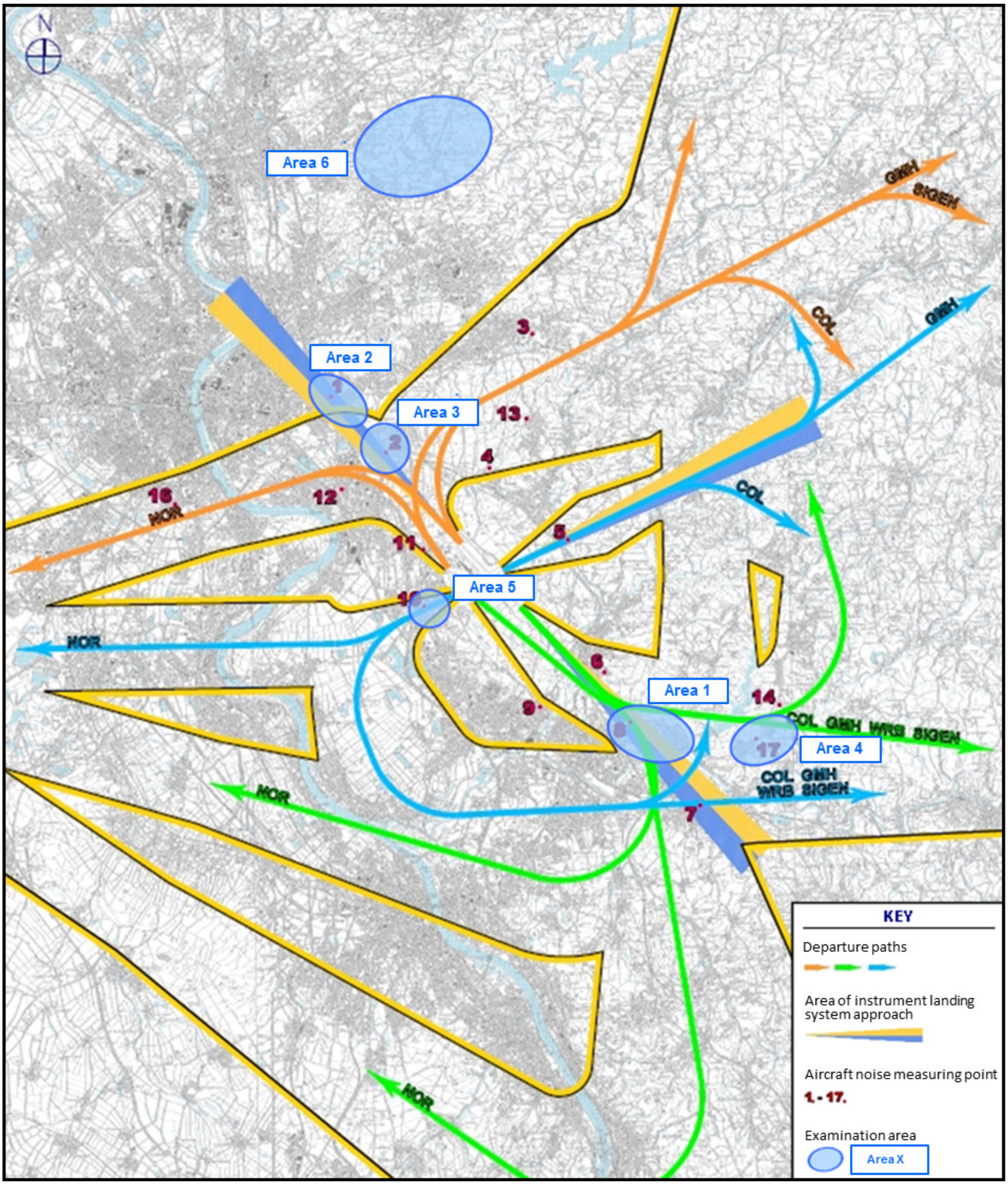

Figure 5. The six examination areas at Cologne/Bonn Airport

Furthermore, the six examination areas differed with regard to the minimum flight altitude of aircraft, whether noise insulation is granted by the airport, the dominant type of operation over the area (departure vs. arrival), and the degree of urbanization (rural, suburban, urban). For this purpose, rural areas were defined by a density of population of less than 500 inhabitants per km^2, the presence of agriculture areas and predominantly detached houses. Suburban areas had 500 to 2,500 inhabitants per km^2 with predominantly (semi-) detached houses and multi-family houses. Urban areas were characterized by a population density higher than 2,500 inhabitants per km^2 and the presence of predominantly multi-family houses and apartment blocks. The six examination areas were subdivided into even smaller subareas with a size of 500 m x 500 m in maximum. Within those subareas, the criteria described above (i.e., the minimum altitude of aircraft, the dominant type of operation, etc.) were identical. The dominant type of operation was ascertained using public information given online by the airport (Köln Bonn Airport, 2014) and the noise contour map described earlier in this section. Additional information about the usual flight altitude was obtained by means of the online air traffic control tool "STANLY Track" by the German air navigation service provider, DFS (DFS Deutsche Flugsicherung GmbH, 2013). Moreover, for each subarea, the position to the flight path was ascertained using the noise contour map that contains also the standard routes for approaches and departures. For this purpose, areas located directly beneath the flight path were distinguished from areas located slightly, i.e., more than 250 m, beside the standard route. Data on the background noise exposure due to further sources of transportation noise was taken from a map for environmental noise that was made available by the Ministry for Climate Protection, Environment, Agriculture, Nature Conservation, and Consumer Protection of North Rhine-Westphalia (Ministerium für Klimaschutz, Umwelt, Landwirtschaft, Natur- und Verbraucherschutz des Landes Nordrhein-Westfalen, 2014) on the internet. Background exposure data was not available for all examination areas. However, with few exceptions which are mentioned explicitly, aircraft noise was assumed to be the dominant noise source. In the following, the six examination areas are described in more detail.

4.1.3 Characteristics of the examined areas

Area 1: Siegburg - Kaldauen, Siegburg - Stallberg

Examination area 1 was situated in two districts of the town Siegburg. The district Stallberg (approximately 3,800 inhabitants in total) was considered entirely for the telephone study. Of the district Kaldauen (approximately 7,500 inhabitants in total), only the western part was examined. Both districts are located 7.5 km south-east of Cologne/Bonn Airport. The phenotype of examination area 1 is suburban. Area 1 is subject to an aircraft noise exposure of $L_{Aeq,6-22}$ and $L_{Aeq,22-6}$ around 55 dB. In the whole examination area, noise insulation is granted by the airport. Over Stallberg and Kaldauen, both departures and approaches are operated. The altitude of departing aircraft is 3,000–6,000 ft at daytime and 3,000–4,000 ft at night, respectively. The flight altitude of approaching aircraft is 1,500-2,000 day and night.

Area 2: Cologne - Merheim, Cologne - Ostheim, Cologne - Neubrück

Examination area 2 was located on the right bank of the Rhine River in the border area of the three Cologne districts Merheim, Ostheim, and Neubrück, approximately 9 km north-west of Cologne/Bonn Airport. In total, the three districts hold a population of more than 28,000 inhabitants. The area is very urban with townhouses, multiple dwelling units, and detached houses. Area 2 is exposed to aircraft noise with $L_{Aeq,6-22}$ and $L_{Aeq,22-6}$ around 55 dB. Over this area, approaches are operated exclusively. The flight altitude of approaching aircraft is 2,000–2,500 ft at daytime and 1,500–2,000 ft at night. Noise insulation is granted in this area. Whilst aircraft noise exposure is nearly identical everywhere in this area, the exposure to further transportation noise varies. Three of 11 subareas are located directly beneath the motorway. Nevertheless, the maximum levels of approaching aircraft are usually salient.

Area 3: Cologne - Rath/Heumar

Examination area 3 contained the western part of the Cologne district Rath/Heumar on the right bank of the Rhine River, approximately 6 km north-west of Cologne/Bonn Airport. In total, around 11,000 inhabitants live in Rath/Heumar. Examination area 3 has a suburban phenotype and is subject to an aircraft noise exposure of $L_{Aeq,6-22}$ and $L_{Aeq,22-6}$ around 55 dB. The area is affected mainly by the noise from approaching aircraft. Usually, departing aircraft do not cross this area directly since they veer earlier. The flight altitude of approaching aircraft is approximately 1,500 ft (day and night). Noise insulation is granted. One of 11 subareas is located directly next to railways. Two further subareas are situated along the main road and the motorway, respectively. Single fly-over sounds can be masked by the background noise.

Area 4: Hennef (Sieg) - Heisterschoß; Hennef (Sieg) - Happerschoß

Examination area 4 was situated in two districts of the town Hennef (Sieg). The district Heisterschoß (approximately 1,200 inhabitants) was considered entirely for the telephone study. Of the district Happerschoß (approximately 1,400 inhabitants in total), only residents living in the northern part were interviewed. Examination area 4 is located around 12 km south-east of Cologne/Bonn Airport. The area is rural and exposed to an equivalent aircraft noise of $L_{Aeq,6\text{-}22}$ and $L_{Aeq,22\text{-}6}$ around 50 dB. Noise insulation is granted only in Heisterschoß. Over both districts, departures are operated exclusively. The flight altitude of departing aircraft is 4,000–7,000 ft during the day and 4,500–6,000 ft at night.

Area 5: Cologne - Wahnheide

Examination area 5 contained the district Wahnheide which is an outlying borough of Cologne on the right bank of the Rhine River with approximately 7,700 inhabitants. The area is located only few hundred meters next to the terrain of the airport. Wahnheide has a rather suburban phenotype with (semi-)detached houses prevailing. The area is overflown exclusively by aircraft operated via the crosswind runway. This operation direction applies to approximately 10 to 15 % of the yearly air traffic. The aircraft noise exposure during daytime is characterized by $L_{Aeq,6\text{-}22}$ around 50 dB. No night traffic is operated over this area. However, depending on the wind direction, the sub-areas lying immediately next to the airport can be subject to nocturnal aircraft noise mainly due to aircraft departing from the two other runways or already during the actuation of the engines. The night-time exposure is around $L_{Aeq,22\text{-}6}$ of 40 dB. Noise insulation is not granted in this area. Over examination area 5, departures are operated predominantly and approaches are very rare. The flight altitude of departing aircraft is 1,500–2,000 ft.

Area 6: Odenthal, Bergisch Gladbach - Schildgen

Examination area 6 was located in two adjacent towns: Schildgen (approximately 6,200 inhabitants) and Odenthal (approximately 16,000 inhabitants). Schildgen is a district of Bergisch Gladbach. Odenthal is a small municipality including several villages. Area 6 is located approximately 16 km north-west of Cologne/Bonn Airport and has a rural phenotype. The area is subject to low aircraft noise exposure, $L_{Aeq,6\text{-}22}$ and $L_{Aeq,22\text{-}6}$ vary around 40 dB. Noise insulation is not granted. Only approaches are operated over this area. The altitude of approaching aircraft is 3,500–5,000 ft during the day and 4,500–6,000 ft at night. One of the 18 subareas is located along the main road. The resulting noise exposure is capable to mask single fly-over sounds.

4.2 Sample

4.2.1 Selection of telephone numbers

After the conduction of a pre-test (cf. Section 4.4.1), the response rate for the telephone survey was estimated to be 10 to 30 %. Therefore, a sample containing around 2,000 telephone numbers for every area was aimed at. For every street located within the chosen examination areas, all land line telephone numbers which were registered in the public telephone directory were copied into a telephone number database. The phone numbers were immediately anonymized and received a participant ID and an area code. Only land line numbers of private citizens were selected. Numbers of companies and institutions were discarded for three reasons: a) People answering a number of a company or institution do not necessarily live in the selected area. b) An interference or interruption of the interview was expected to be probable. c) The interview was assumed to possibly interfere with the work task. Mobile phone numbers were not considered either to avoid reaching individuals in an unfavorable situation, such as working or driving.

From the database described above, telephone numbers were selected randomly by interview software. The interviewee only needed to dial the number manually. This interview software is a stand-alone application created with Matlab 2007a by the German Aerospace Center (DLR) in Cologne to provide a computer-based accomplishment of the telephone interview. The software led the interviewer through the questionnaire and guaranteed an efficient and error-reducing interview process by asking only questions relevant for a certain interviewee. Results of the interview were saved automatically. The pool of telephone numbers was updated after every interview in order that the numbers of participants who have already been reached were marked accordingly.

4.2.2 Participants

Participants of the telephone interview were residents who lived in one of the selected examination areas. Every person with a minimum age of 18 years who had answered the phone was asked whether he or she feels comfortable to answer some questions about aircraft noise. People who agreed to do so became participants of the telephone study. Participation was not rewarded in any way.

4.3 Conduction of the survey

The telephone survey was completed from mid of July till mid of October 2010 by six employees of the Leibniz Research Centre for Working Environment and Human Factors (IfADo)[6] in Dortmund. Phone times were predominantly from Monday to Friday in the after-noon and early evening hours and partly on Saturday morning to noon. Interviewers were trained using a comprehensive written instruction.

4.4 Questionnaire

4.4.1 Pre-testing the interview questionnaire

A preliminary version of the interview questionnaire was tested in April 2010. The pilot tests aimed at the following goals: a) an estimation of the proportion of reachable individuals and of a realistic response rate, b) the testing of the questions and answer scales regarding comprehensiveness and usability, c) an estimation of the interview duration, and d) the testing of the interview software. The pre-test interviews were run in six areas with a different aircraft noise exposure in the vicinity of Cologne/Bonn Airport. The pre-test areas were comparable to the examination areas of the subsequent survey but not identical. Out of the more than 1,000 persons called, 221 could be reached meaning that they answered the phone. Of the individuals reached, 48 completed the interview. This corresponds to a response rate of 17.8 %. The interviewers of the pilot study were instructed to write down all comments of the interviewees with regard to the comprehensiveness of the questions as well as all exceptional occurrences during the interview procedure. On the basis of the experiences of the pre-tests, the preliminary questions and answer scales were revised towards the final version of the interview questionnaire which is described in the next section.

4.4.2 Final version of the questionnaire: Content and answer scale formats

General long-term aircraft noise annoyance was measured by a closed standardized question with a semantic five-point answer scale recommended by the International Commission on Biological Effects of Noise (ICBEN): “Thinking about the last 12 months, when you are at home, how much does aircraft noise bother, disturb or annoy you?”(Fields et al., 2001; ISO, 2003). The semantic answer scale contained the options “extremely”, “very”, “moderately”, “slightly”, and “not at all”. Night-time annoyance was assessed using the same question but with the addition “…at night between 10 p.m. and 06 a.m.?” Supplementary, an open format

[6] The IfADo was one of the partners in the COSMA consortium.

question was applied to gain information about the times of day when aircraft noise is particularly annoying. As recommended by Fields et al. (2001), in order to obtain preferably unbiased judgments, questions about aircraft noise-induced annoyance were posed very early in the survey only preceded by two neutral opening questions that were not directly related to the topic aircraft noise.

For a possibly high explanation of the variations in noise reactions, the ascertainment of a broad range of influence variables in a standardized interview is recommended (Guski et al., 1978). The selection of potential predictors of aircraft noise annoyance for the interview was based on previous studies (Guski et al., 1978; Kroesen et al., 2008; Maziul & Vogt, 2002; Schreckenberg & Meis, 2007a; Taylor, 1984; Wirth et al., 2004), reviews (Flindell & Stallen, 1999; Guski, 1999; Job, 1988; Lercher, 1996b), and meta-analyses (Fields, 1993; Miedema & Vos, 1999) as well as to a minor extent on intuitive reflections on further plausible predictors. During several months prior to the telephone survey, two studies which postulated a link between nocturnal aircraft noise exposure and hypertonia and cardiovascular diseases as well as between nocturnal aircraft noise and cancer (Greiser, Greiser, & Janhsen, 2007; Greiser, 2009) were discussed in regional newspapers. To account for a potential influence of aircraft noise-induced annoyance by aviation-related media coverage (cf. Finke et al., 1975), also questions on recently perceived news related to Cologne/Bonn Airport or aviation in general were included.

With one exception, all variables were surveyed either by open questions with answer options not read out and visible only to the interviewer or by closed questions using the semantic five-point scale recommended by the ICBEN (Fields et al., 2001; ISO, 2003). Only the question about the general attitude towards the airport used a semantic five-point answer scale ranging from “very negative” to “very positive”. Designing interview questions in an equal format was assumed to make the answering easier to the participants and to minimize biases due to unfamiliarity with the answer scale format. In order to avoid effects resulting from the sequence of the answer categories, the answer scales were inverted between the participants. Half of the participants always got read out answer scales starting with the highest answer category (e.g. “extremely”) and the other half always used answer scales starting with the lowest category (e.g. “not at all”). The interview software automatically allocated one of the two interview versions to the interviewees by random.

In order to save the interviewee from irrelevant questions, every open question was preceded by a filtering question asking a question that could be answered with “yes” or “no”. An example is the question “Do you see concrete negative aspects of the airport and air traffic in your opinion?" If the interviewee answered with "yes", then he or she was asked what these aspects are. At the maximum, the questionnaire for the telephone interview comprised 43 questions spread over six sections as shown in Table 1. The exact number of the questions varied depending on the interviewee's answers to the filtering questions. Table 1 shortly summarizes the content of this questionnaire. The entire questionnaire can be found in Appendix A in an English version which has been successfully used for the annoyance examinations at London Heathrow Airport (United Kingdom) as well.

Table 1

Sections and content of the telephone interview

Section	Content (Number of questions per topic)
Introduction	Short summary of the COSMA-project and its objectives
Residential area	Questions about the length of residence (1) and the satisfaction with the residential area (1)
Noise annoyance	Questions about aircraft noise annoyance during the past 12 months in general (1), at night (1) and at several times of day (2)
	Questions about noise annoyance due to other sources of noise (3)
Coping measures	Questions about measures to cope with the aircraft noise (2)
Attitudes	Questions about the general attitude towards the local airport (1) as well as about concrete positive (2) and negative aspects (2) of the airport and air traffic.
	Questions about actions the airport could take for its residents (2)
	Question about prioritization of economic or environmental aspects in airport-related decision-making (1)
	Questions about recent media coverage on topics related to air traffic or the local airport (3)
Personal information	Global question about noise sensitivity (1)
	Questions about demographic characteristics, e.g., age, gender, educational and occupational level (10)
	Questions about the use of the airport (1) and economic dependence on the airport (1)
	Questions about home ownership (1) and noise insulation (3)
	Questions about times not at home (2)
End of the interview	Question about further comments on aircraft noise (1)
	Question about interest in participation in upcoming field study (1)
	Farewell

4.5 Statistical analysis

For the descriptive and inferential analysis, the software package SPSS 20 (IBM) was used. In case a certain effect size must be calculated manually as no corresponding SPSS-command existed, the reference for the equation used is given in the following. The dependent variable *aircraft noise-induced annoyance* was considered as metric variable with equidistant intervals between the response categories (cf. Felscher-Suhr, 2000; Fields et al., 2001). Parametric tests were performed whenever the requirements check did not reveal significant deviations from assumptions which were mainly an interval scale of measurement, the homogeneity of variance, and a normal distribution. When the data set did not meet these premises adequate non-parametric tests were applied.

4.5.1 Research questions A 1 and A 2: Status quo of long-term aircraft noise annoyance and long-term annoyance during several times of day

For the description of the status quo of general and night-term aircraft noise annoyance during the past 12 months, arithmetic means and standard deviations were calculated. To discover differences in the mean ratings between the six examination areas or between the exposure classes, a standard analysis of variance (ANOVA) was used. A Welch-test[7] was applied in case the variance in the examination areas or exposure classes were not homogeneous. For the comparison between the annoyance results obtained at Cologne/Bonn Airport and the values predicted by the European standard curve, mainly descriptive analyses were performed. The same applies to the description of aircraft noise annoyance during several times of the day.

4.5.2 Research question A 3: Predictors of long-term aircraft noise annoyance

A prediction model for aircraft noise annoyance during the past 12 months in general and with regard to the night-time was developed using the linear regression approach. The development of the model was achieved in two steps. To avoid over-parameterization, firstly, the contribution to long-term annoyance was investigated separately for each variable that was available from the interview questionnaire or the noise contour map. A separate pre-selection of the predictors in a prior step seemed reasonable, because testing *all* variables simultaneously in a multiple regression analysis could have led to false conclusions. Due to potential correlations between the variables, an exclusion of single variables on the basis of

[7] Welch-test: a modification of the standard ANOVA that does not require homogeneity in the variances (Sedlmeier & Renkewitz, 2008).

the *p*-value can result in an elimination of relevant variables, too (Fahrmeir, Kneib, & Lang, 2007).

For the constructs *presence and evaluation of domestic noise insulation, presence of other sources of transportation noise*, and *perception of aviation-related news*, new categorical variables were generated by combining the two original questions, i.e., the filtering question and the subsequent question on an appropriate response category. The resulting variable *presence and evaluation of domestic noise insulation* comprised the response options "no insulation", "not highly satisfied with noise insulation", and "highly satisfied with noise insulation". The new categories of the variable *presence of other sources of transportation noise* contained "no transportation noise", "motorway", "road traffic", "tram", "railway", and "combined sources of transportation noise". The variable *perception of aviation-related news* comprised the levels "no news", "irrelevant news", "negative news", and "positive news".

Pre-selection of predictors

Within the pre-selection process, for all metric variables a scatter plot was drawn and a curve that was fitted using the LOWESS procedure was inserted to assess the linearity of the relation to the aircraft noise annoyance ratings. In case this curve did not follow at least a quasi-linear trend, the potential predictor variable was transformed to meet the requirement of linearity. To assess the contribution of the single variables to annoyance, Pearson's *r* was used for metric variables. The relation between dichotomous variables and aircraft noise annoyance ratings was tested by means of a point-biserial correlation analysis. For categorical variables, the standard ANOVA or the Welch-test was applied and the effect size η^2 was calculated[8]. For the variables *position of participant's home to the flight path*, *minimum aircraft altitude over the area, dominant operation type over the area*, and *presence and evaluation of domestic noise insulation*, the effect of the L_{Aeq} was controlled for in a partial correlation test (for metric variables) or in an analysis of co-variance (for categorical variables) since these variables were logically associated with the aircraft noise exposure level. A further ANCOVA-analysis was calculated for the variable *degree of urbanization of the area* since the areas with a suburban or urban phenotype are more exposed to aircraft noise only due to chance.

Prediction model for general and night-time aircraft noise annoyance

Two separate prediction models were developed for general and night-time aircraft noise annoyance in the past 12 month. All those variables which have been shown to have at least a

[8] η^2 was calculated manually as SPSS did not output this effect size. The equation for η^2 can be found in (Sedlmeier & Renkewitz, 2008, p. 478).

small effect on aircraft noise annoyance at a 5 % significance level in the pre-selection phase were tested in a multiple regression model. The definition of a "small effect" was a (partial) $r \geq .1$ or a (partial) $\eta^2 \geq .01$ (Cohen, 1992; Sedlmeier & Renkewitz, 2008). Predictor variables with a semantic five-point scale were considered as metric variables[9]. All categorical variables having more than two answer options were transformed into dummy-variables (for the procedure, see Tutz, 2000). In a manual backwards selection process, predictors which did not have a significant standardized regression coefficient (β) on a 5 % level were removed from the multiple regression model starting with the variable with the highest *p*-value. Dummy-coded categorical variables were removed only when none of the dummy categories significantly affected the annoyance ratings.

4.5.3 Research question A 4: Residents' perception of Cologne/Bonn Airport

The residents' perception of Cologne/Bonn Airport was described by analyzing the responses given to the open format questions of the variables *perception of negative and positive aspects of the local airport and air traffic* and *belief that the airport could take actions to improve the residents' situation*. Mostly descriptive analyses were performed. The relation between giving a certain response (= coded with 1) or not (= coded with 0) and the individual's long-term annoyance was assessed using a point-biserial correlation analysis. Since all these examinations were explorative, the significance level was not adapted to multiple testing (cf. Bender, Lange, & Ziegler, 2007).

[9] The predictor variables which were ascertained by means of the same semantic five-point scale as used for the assessment of aircraft noise-induced annoyance can be considered as metric variables with equidistant intervals between the response options (Fields et al., 2001). For the variable *attitude towards the airport* that was assessed by a different five-point scale, likewise, a metric measurement level was assumed to facilitate an easy comparison with the effect sizes of the other metric predictors. The adequacy of regarding data ascertained with rating scales as metric data is discussed elsewhere (Bortz, 2005; Sedlmeier & Renkewitz, 2008).

5 Results of the telephone study

5.1 Sample statistics

To reach the number of participants aimed at, 4,034 telephone numbers had to be dialed in the six examination areas 1: Siegburg-Stallberg/Kaldauen, 2: Cologne-Ostheim/Neubrück/ Mülheim, 3: Cologne-Rath/Heumar, 4: Hennef-Heisterschoß/Happerschoß, 5: Cologne-Wahnheide, and 6: Odenthal with Bergisch Gladbach-Schildgen. 369 (9.1 %) of the phone numbers turned out to be invalid meaning that they were not connected. Out of the 3,665 individuals reached by phone, two thirds had no interest, were too young to take part (age < 18 years), or were not comfortable with answering the interview questions due to language problems. Table 2 summarizes the coverage and response rate up to 12th October 2010. The survey ran until 18th October, but for this time no information about the response rate was ascertained. Response rates in the six examination areas were comparable to the rates across the entire sample with exception for Hennef-Heisterschoß/Happerschoß. Here, the percentage of completed interviews was considerably higher than for the whole sample (50.8 %). The reason for this high rate was inexplicable.

Table 2

Coverage and response rate of the telephone survey in the vicinity of Cologne/Bonn Airport (until 12th October 2010)

	n	%
Completed interviews	1,239	33.8
Drop out due to language or age problems	131	3.6
Drop out due to no interest	2,284	62.3
Drop out due to early termination of the interview	11	0.3
Individuals reached	3,665	100.0

Up to 18th October 2010, a total of 1,265 individuals from six areas completed the interview. Results of three participants were excluded from further analyses. According to the interviewer's statements, two participants (both female, 74 and 80 years old, respectively) had difficulties to understand the meaning of the questions and forgot several questions before they could answer. Another participant's answers (female, 72 years old) were excluded from the analysis, because of consulting every answer with her husband first. The remaining sample of 1,262 interviews was spread over the examination areas as displayed in Table 3.

Table 3

Number of interviews per examination area included in the analyses

Area	*n*	%
1: Siegburg - Stallberg /Kaldauen	217	17.2
2: Cologne - Ostheim/Neubrück/Mülheim	217	17.2
3: Cologne - Rath/Heumar	216	17.1
4: Hennef - Heisterschoß/Happerschoß	201	15.9
5: Cologne -Wahnheide	200	15.8
6: Odenthal, Bergisch Gladbach - Schildgen	211	16.7
Total	1,262	100.0

780 participants (61.8 %) were women, 482 (38.2 %) were men. Mean age was 58.6 (*SD* = 15.5) years covering a range from 18 to 95 years. 15 participants refused to indicate their age. Table 4 shows the age distribution for the sample in comparison with the actual age statistics across all examined areas which were provided by the local registration offices. Statistics of age and gender in the different examination areas varied slightly. They are reported in Appendix B.

Table 4

Age statistics of the telephone interview sample in comparison to the actual age statistics in the examined areas

Age category	% in the sample	% in the six areas[a]
18 - 24	2.9	9.7
25 - 34	4.3	13.0
35 - 44	10.5	18.8
45 - 54	21.0	19.1
55 - 64	19.9	14.2
65 - 74	26.7	14.9
≥ 75	14.8	10.2
Total	100.0	100.0

Note. [a] Values are weighted mean proportions across the six examination areas with a reference group of residents ≥ 18 years.

Residents aged between 18 and 44 years were underrepresented whereas elderly residents in the age of 65 years or older were overrepresented in the survey sample. This imbalance found expression in the employment statistics. 730 interviewees (57.8 %) were not employed at the time of the interview. 509 interviewees (40.3 %) indicated to be employed and 23 interviewees (1.8 %) did not make any statement about their employment. Table 5 shows statistics of unemployment and employment in more detail.

Table 5

Statistics of unemployment and employment in the telephone study sample

Characteristic	*n*	%
Unemployed		
Pensioner	604	82.7
Homemaker	80	11.0
Temporarily unemployed, e.g., due to maternal leave	31	4.2
Still in training/never been employed so far	15	2.1
Total	730	100.0
Employed		
White-collar worker	287	56.4
Blue-collar worker	36	7.1
Civil servant	59	11.6
Self-employed	81	15.9
Executive	35	6.9
No information available/no answer	11	2.1
Total	509	100.0

The length of residence of the interviewees covered a range of 0.3 to 95 years with a mean period of 27.6 years (*SD* = 16.8). 897 respondents (71.1 %) were homeowners, 358 (28.4 %) were tenants, and 7 individuals (0.6 %) gave no answer to this question. Socio-demographic statistics varied slightly between the six examined areas. Appendix B provides information about the employment rates, the length of residence, and rates of homeownership for each examination area separately.

5.2 Research question A 1: Status quo of aircraft noise-induced annoyance

The following section describes the current status of aircraft noise annoyance in the vicinity of Cologne/Bonn Airport. General aircraft noise annoyance over the past 12 months and aircraft noise annoyance at night were examined separately. Firstly, the results are reported for the six examination areas and afterwards according to the aircraft noise exposure level. Since the age statistics of the present sample showed an imbalance, the effect of age on aircraft noise annoyance was investigated. Thus, the question whether the assessment of the status quo of aircraft noise annoyance has been biased is examined. Afterwards, the results of the present survey are compared to the European standard exposure-response curve.

5.2.1 Status quo of annoyance depending on the examination area

As Figure 6 shows, general aircraft noise annoyance ranged in the six examination areas from 3.42 (area 1) to 1.84 (area 6). The mean annoyance over all six examination areas was 2.92 (SD = 1.29). A Levene-test showed that the variance in the six areas is not homogeneous ($p < .001$). Thus, a Welch-test was calculated to compare the mean ratings between the areas. The mean general annoyance ratings differed significantly between each of the examination areas, $F(5, 548.85) = 69.25$ ($p < .001$). A Tamhane-T2[10] post-hoc test revealed significant differences in the means between the areas 1 to 4 compared to the areas 5 and 6 ($p < .001$). Moreover, the mean annoyance differed significantly between the areas 5 and 6 ($p < .001$).

Across all examination areas, night-time annoyance (M = 2.70, SD = 1.52) was on average slightly lower than general annoyance. A paired t-test showed a significant mean difference ($t(1, 1262) = 8.96$, $p < .001$, two-tailed testing). In each examination area except for area 2 and area 4, the mean night-time annoyance ratings were likewise slightly lower than the mean general annoyance ratings and the mean differences were statistically significant at a 5 % significance level.

The mean ratings for night-time aircraft noise annoyance varied between 3.25 (area 3) and 1.51 (area 6). The variance in the examination areas was not homogeneous as shown by a Levene-test ($p < .001$). A Welch-test produced significant mean differences between the six examination areas ($F(5, 581.71) = 91.30$, $p < .001$) and a Tamhane-T2 post-hoc test revealed significant mean differences between each of the areas 1 to 4 compared to the areas 5 and 6 ($p < .001$). Mean night-time annoyance also differed significantly between the areas 5 and 6 ($p < .001$).

[10] Tamhane-T2: a post-hoc test that does not require the assumption about variance homogeneity (Brosius, 2011).

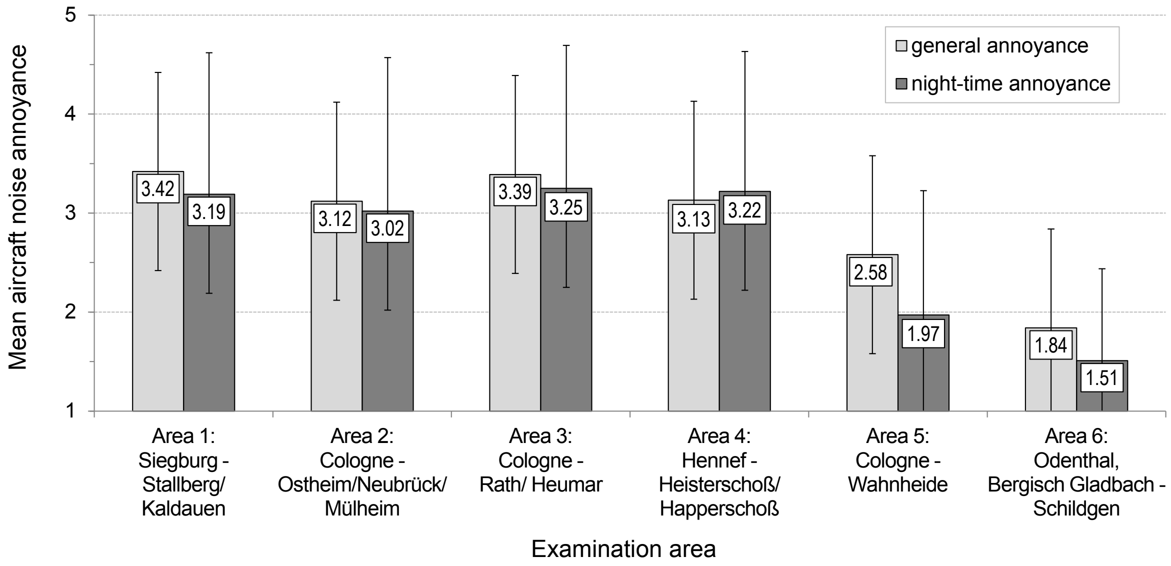

Figure 6. Mean aircraft noise annoyance ratings and standard deviations for the six examination areas. General annoyance was assessed by the question "Thinking about the last 12 months, when you are at home, how much does noise from aircraft bother, disturb or annoy you?" Night-time annoyance was assessed using the same question but with the addition "…at night between 10 p.m. and 06 a.m.?" The ratings scale ranged from 1 = "not at all" to 5 = "extremely".

5.2.2 Status quo of annoyance depending on the exposure level

From the $L_{Aeq,6\text{-}22}$ and the $L_{Aeq,22\text{-}6}$ that were available from the noise contour map, the *A*-weighted energy equivalent sound pressure level for 24 hours, the $L_{Aeq,24\,h}$, was calculated[11]. The correlation between these three measures and the ratings given for general and night-time aircraft noise annoyance was assessed using Pearson's *r*. The results are depicted in Table 6.

Table 6

Association between measures of exposure (L_{Aeq}) and measures of response, N =1,262

	$L_{Aeq,24\,h}$	$L_{Aeq,6\text{-}22}$	$L_{Aeq,22\text{-}6}$
General annoyance	.41***	.41***	.39***
Annoyance at night	.40***	.39***	.42***

Note. *** p < *.001.*

[11] Analogous to equation 7 of DIN 45641(Normenausschuß Akustik und Schwingungstechnik (FANAK) im DIN Deutsches Institut für Normung e.V., 1990) the $L_{Aeq,24\,h}$ was calculated by means of the equation

$L_{Aeq,24\,h} = 10log\left[\frac{1}{24}\left(16 \cdot 10^{0.1(L_{Aeq,6-22})/dB} + 8 \cdot 10^{0.1(L_{Aeq,22-6})/dB}\right)\right]$ with *log* = the decadic logarithm.

General annoyance ratings correlated highest with the $L_{Aeq,24\,h}$ ($r(1260) = .414$, $p < .001$) but the correlation to the $L_{Aeq,6\text{-}22}$ was virtually equal since the exact coefficients differed only in the second and third decimal place ($r(1260) = .407$, $p < .001$). Ratings for annoyance at night were related highest to the $L_{Aeq,22\text{-}6}$ ($r(1262) = .42$, $p < .001$). Figure 7a and 7b show the relation between the $L_{Aeq,24\,h}$/$L_{Aeq,6\text{-}22}$ and the mean aircraft noise annoyance ratings in general and at night, respectively, as bar graphs.

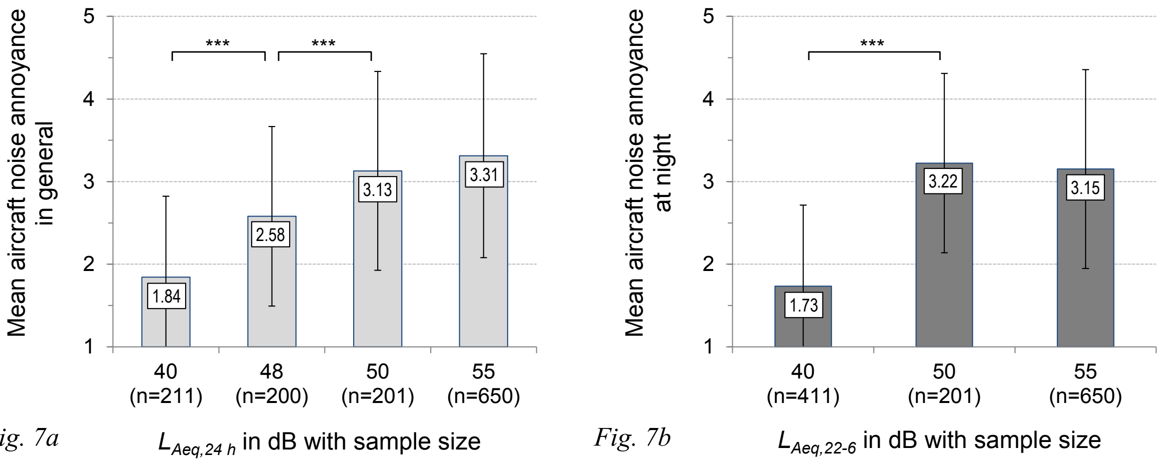

Fig. 7a *Fig. 7b*

Figure 7a + 7b. Mean ratings and standard deviations for general (7a) and night-time (7b) aircraft noise annoyance. General annoyance was assessed by the question “Thinking about the last 12 months, when you are at home, how much does noise from aircraft bother, disturb or annoy you?” Night-time annoyance was assessed using the same question but with the addition “…at night between 10 p.m. and 06 a.m.?” The rating scale ranged from 1 = “not at all” to 5 = “extremely”. *** significant mean difference ($p < .001$) according to a Tamhane-T2 post-hoc test. The category “48 dB” exists only for the $L_{Aeq,24\,h}$ as the corresponding examination area (Cologne-Wahnheide) is exposed to an $L_{Aeq,22\text{-}6}$ of 40 dB at night (cf. Section 4.1.3).

The variance in the annoyance ratings for the different aircraft noise exposure levels was not homogeneous in a Levene-test. This applies both for general and night-time ratings ($p <.001$). A Welch-test showed significant mean differences in annoyance ratings across the different exposure levels both with regard to annoyance in general ($F(3, 483.32) = 111.87$, $p < .001$) and regarding night-time ($F(2, 535.49) = 185.02$, $p < .001$). A monotone increase of the mean general aircraft noise annoyance was found with every step in the exposure level (see Figure 7a) although the mean difference between the exposure levels $L_{Aeq,24\,h} = 50$ dB and $L_{Aeq,24\,h} = 55$ dB was not significant in a Tamhane-2 post-hoc test ($p = .340$).

For night-time annoyance, Figure 7b shows a significant increase only between the exposure levels $L_{Aeq,22\text{-}6} = 40$ dB and $L_{Aeq,22\text{-}6} = 50$ dB. Between $L_{Aeq,22\text{-}6} = 50$ dB and $L_{Aeq,22\text{-}6} = 55$ dB, annoyance ratings for night-time were equal ($p = .899$). The same tendencies can been seen in Figure 8a and 8b, that depict the distribution of response frequencies of the five rating categories “not at all”, “slightly”, “moderately”, “very”, and “extremely” for general aircraft noise annoyance ratings (8a) and night-time annoyance ratings (8b). Whereas in Figure 8a, the proportion of very or extremely annoyed respondents continuously increases and the proportion of slightly or not at all annoyed individuals decreases with higher sound levels, Figure 8b does not show this continuity. Here, the proportion of slightly or not at all annoyed respondents decreases only from a $L_{Aeq,22\text{-}6}$ of 40 dB to 50 dB, but not from a $L_{Aeq,22\text{-}6}$ of 50 dB to a $L_{Aeq,22\text{-}6}$ of 55 dB. Actually, the percentage of very or higher annoyed individuals slightly decreases and the percentage of slightly or less annoyed slightly increases from $L_{Aeq,22\text{-}6} = 50$ dB to $L_{Aeq,22\text{-}6} = 55$ dB.

Furthermore, Figure 8a and 8b, enable a comparison of the distribution of response categories between general and night-time annoyance ratings. The percentage of interviewees describing themselves as not at all annoyed is higher for night-time ratings than for general ratings in each of the three exposure categories 40 dB, 50 dB, and 55 dB. Concurrently, the proportion of extremely annoyed interviewees was higher for the night-time period, in particular for the exposure categories 50 dB and 55 dB.

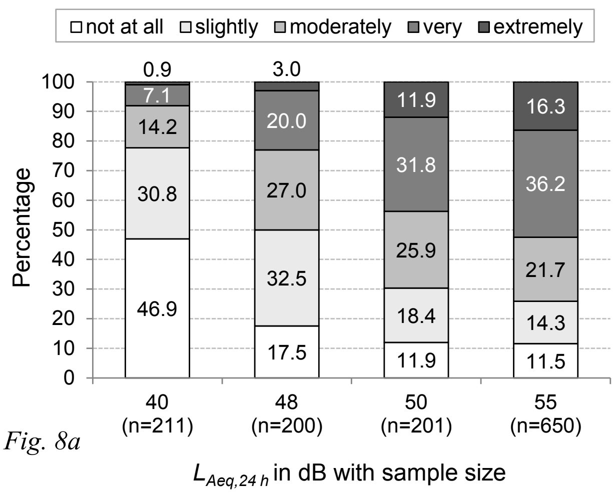

Fig. 8a

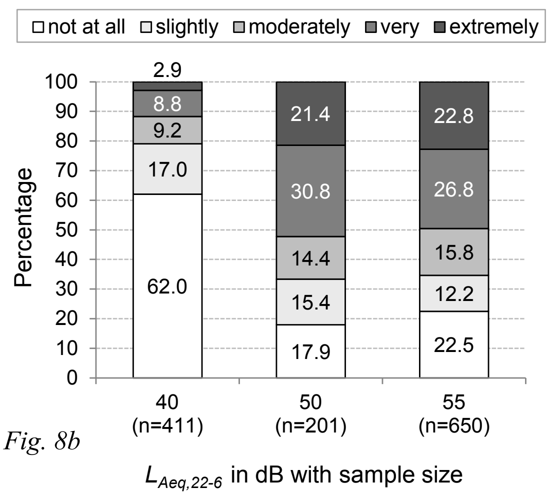

Fig. 8b

Figure 8a + 8b. Distribution of response frequencies of the five response categories “not at all”, “slightly”, “moderately”, “very”, and “extremely” annoyed for general aircraft noise annoyance (8a) and night-time aircraft noise annoyance (8b). The category “48 dB” exists only for the $L_{Aeq,24\,h}$ as the corresponding examination area (Cologne-Wahnheide) is exposed to an $L_{Aeq,22\text{-}6}$ of 40 dB at night (cf. Section 4.1.3).

The results described above are possibly connected to the presence of domestic noise insulation devices and the respondents’ degree of satisfaction with them. For each of the three areas with a night-time exposure of either 40 dB, 50 dB, or 55 dB, the proportion of residents whose homes have *not* had noise insulation fitted as well as the proportion of residents whose homes have had insulation fitted was ascertained. For the latter, two subsamples of residents were distinguished: a) respondents who are *highly* satisfied and b) respondents indicating to be *not highly* satisfied with their noise insulation devices. As Figure 9 shows, the proportion of interviewees indicating to be highly satisfied with the noise insulation of their home is considerably higher at a night-time aircraft noise level of $L_{Aeq,22\text{-}6}$ = 55 dB than at $L_{Aeq,22\text{-}6}$ = 50 dB. As will be shown in Section 4.5.2, a high satisfaction with noise insulation significantly reduces aircraft noise annoyance.

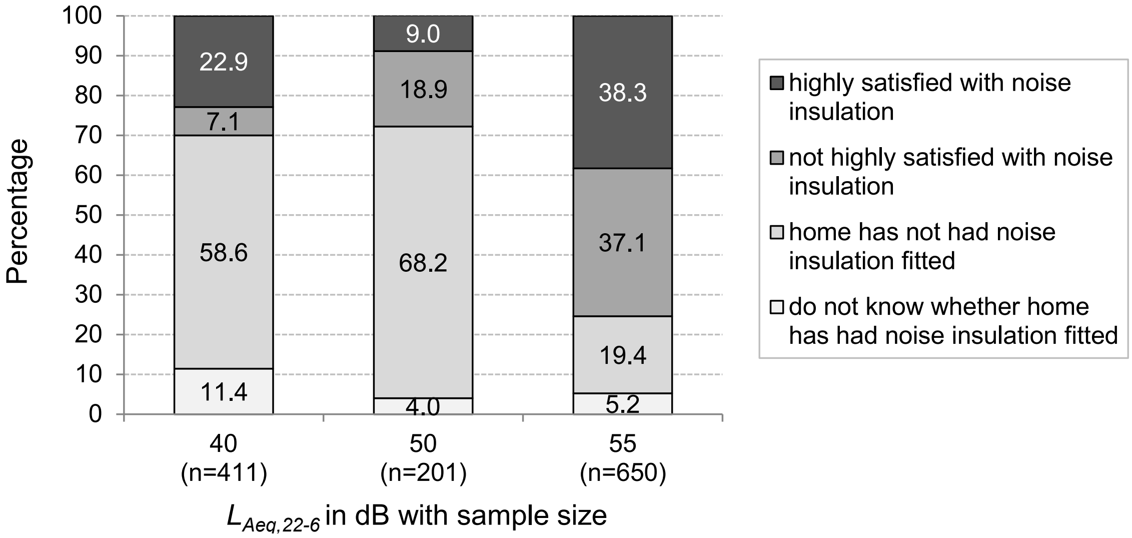

Figure 9. Percentage of respondents indicating that either no noise insulation has been fitted at home or that noise insulation has been fitted which they are highly satisfied ("very" or "extremely") or not highly satisfied ("not at all", "slightly", or "moderately") with for different exposure levels.

5.2.3 The relation between age and annoyance

In order to graphically depict the relation between age and aircraft noise annoyance, aircraft noise annoyance ratings were plotted against the seven age categories already used to describe the age distribution of the sample (cf. Section 5.1, Table 4). As shown in Figure 10, both general annoyance and night-time annoyance due to aircraft noise follows most likely a curvilinear trend. Participants of the telephone study under 35 years were less annoyed than participants in the age between 35 and 74. For individuals older than 75 years, annoyance ratings decreased again.

Due to the curvilinear trend of the relation, assessing the significance of the association between age and annoyance with Pearson's r seemed not meaningful. Instead, the seven age categories were compared using an ANOVA-approach. A Levene-test showed that the variance in the age categories was homogenous neither for general nor for night-time annoyance ratings (p = .004 and p = .012, respectively). Therefore, a Welch-test was calculated. The results indicated a significant difference of the means in the general annoyance ratings between the seven age categories $F(6, 262.25) = 3.10$, p =. 006. A post-hoc test (Tamhane-T2) revealed significantly different means between the age categories 18-24 years and 45-54 years (p = .036), 18-24 years and 55-64 years (p = .039), and between 18-24 years and 65-74 years (p = .016). The mean night-time annoyance differed significantly between the age categories in a Welch-test, too, $F(6, 262.48) = 2.70$, p = .015. A post-hoc test (Tamhane-T2) found a significant difference in the means between the age categories 18-24 years and 55-64 years (p = .026).

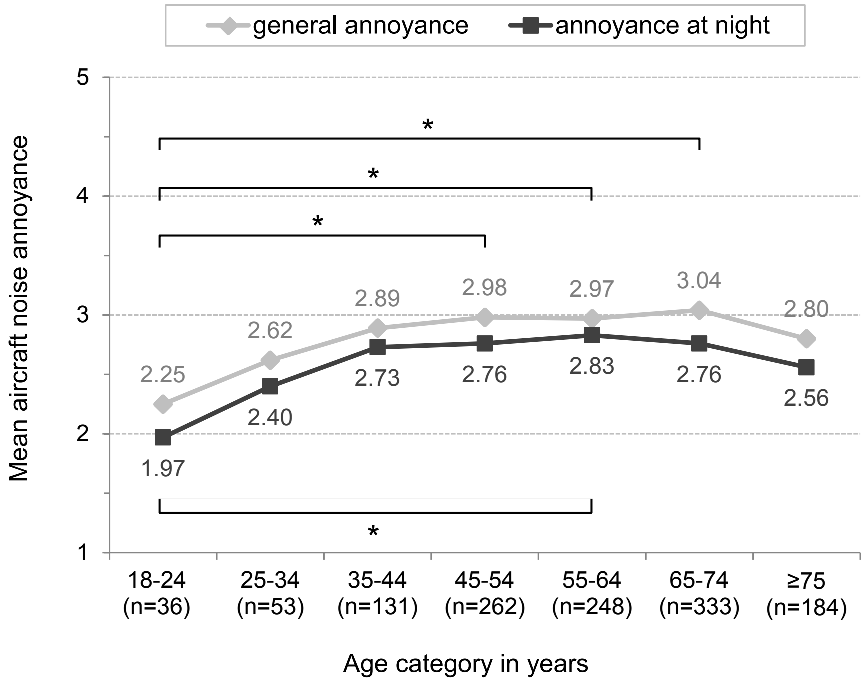

Figure 10. Mean ratings for aircraft noise annoyance in general and considering night-time in several age categories. * $p < .05$.

To quantify the effect of age on annoyance ratings, the effect size η^2 as estimator of the variance explained by the age categories was calculated. With $\eta^2 = .01$, results suggest a small effect of age on both general and night-time annoyance ratings. Therefore, the potential bias caused by the imbalance of the age distribution in the sample is likewise assumed to be small.

5.2.4 Comparison to the European standard curve

In order to compare the annoyance ratings of the telephone survey at Cologne/Bonn Airport with the results of previous studies generalized in the European standard curve (EU-curve), the L_{dn} was calculated as recommended by Miedema and Oudshoorn (2001) with Equation 2.

For the purpose of comparability, the equation was used as described in Miedema and Oudshoorn (2001) although the L_d and L_n at Cologne/Bonn Airport are based on the periods 06:00-22:00 and 22:00-06:00, respectively.

$$L_{dn} = 10\log\left[\left(\frac{15}{24}\right)\cdot 10^{\frac{L_d}{10}} + \left(\frac{9}{24}\right)\cdot 10^{\frac{(L_{n+10})}{10}}\right] \tag{2}$$

with

log = the decadic logarithm

L_d = the long-term L_{Aeq} between 07:00-22:00

L_n = the long-term L_{Aeq} between 22:00-07:00

The percentage of highly annoyed respondents (% HA) was determined using the cut-off criterion 72 on a 0-100 scale (Miedema & Oudshoorn, 2001). To meet this cut-off, the % HA by aircraft noise was calculated as the percentage of respondents who describe themselves as "extremely bothered, disturbed or annoyed" (= 5) plus the percentage of respondents describing themselves as "very bothered, disturbed or annoyed" (= 4) with a weighting of 0.4 for the answer category 4 (cf. Miedema & Vos, 1998; Schreckenberg & Meis, 2007a). Figure 11 depicts the exposure-response relation for the data of the telephone study at Cologne/Bonn Airport compared to the generalized EU-curve.

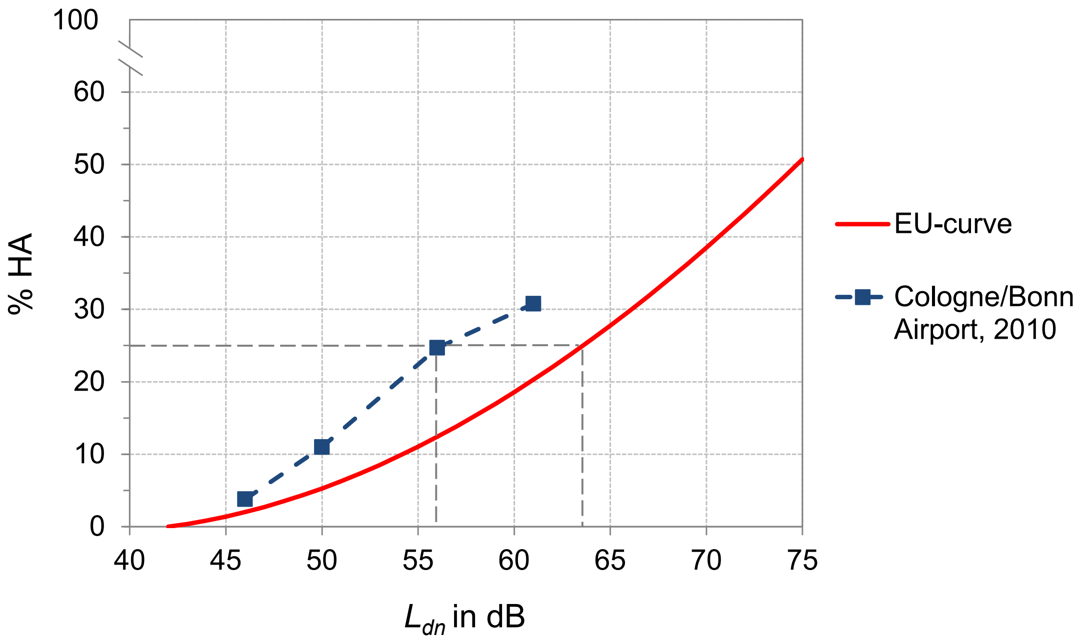

Figure 11. Comparison of the percentage of highly annoyed respondents (% HA) in the telephone survey at Cologne/Bonn Airport with the EU-curve (2001; Miedema & Oudshoorn, 2001).

For a given noise level, the percentage of highly annoyed respondents is higher in the present sample than would be predicted by the EU-curve. The estimated L_{dn} that corresponds to the critical percentage of 25 % HA (displayed as dashed grey line in Figure 11) at Cologne/Bonn Airport lies between 56 dB and 57 dB. The respective L_{dn} indicated by the EU-curve is around 64 dB.

5.3 Research question A 2: Annoyance during several times of day

This section focuses on the question how general aircraft noise annoyance and aircraft noise annoyance at night are related. Furthermore, it is examined whether there are times of day when aircraft noise is more annoying than during other times. The results are compared to the air traffic density during a given time.

5.3.1 The relation between general and night-time annoyance

As already shown in Section 4.5.1 (cf. Figure 6), mean ratings for general aircraft noise annoyance and night-time aircraft noise annoyance during the past 12 months differed only slightly. General and night-time annoyance were highly related with a Pearson's coefficient of $r(1260) = .82$ ($p < .001$). This correlation also remained very high when the $L_{Aeq,24\ h}$ and the $L_{Aeq,22\text{-}6}$ (which are highly correlated themselves, $r(1260) = .89$, $p < .001$) were considered: The partial correlation between general and night-time annoyance after controlling for the effect of the $L_{Aeq,24\ h}$ and $L_{Aeq,22\text{-}6}$ was $r_{12.34} = .78$ ($p < .001$). A two-tailed t-test for paired samples indicated that the mean night-time annoyance was significantly lower than the mean general annoyance, $t(1261) = 8.96$, $p < .001$, although the mean difference was only 0.22 on a scale ranging from 1 to 5. A significant mean difference between general and night-time annoyance still remained, when area 5, that has no night traffic, was excluded, $t(1061) = 5.76$, $p < .001$. The mean difference, however, was with 0.15 even smaller.

5.3.2 Aircraft noise annoyance in the course of the day

Respondents were asked at what times of day on weekdays and at the weekend aircraft noise is particularly annoying. Multiple times could be mentioned in an open-format question. It seems meaningful to see the annoyance in the course of the day in relation to the actual air traffic density around the airport at those times (Figure 12). For the time between mid of 2009 to mid of 2010 that was assumed to be the reference period for the annoyance ratings across 12 months, no detailed information about the air traffic was provided by the airport. According to the judgment of the reference person of aircraft noise management at

Cologne/Bonn Airport, air traffic between 2009 and 2011 can be considered as comparable. Thus, the figures of the flight plan which were used for the field study examinations (cf. Part B) as well and which covered the period from June to November 2011 are presented here.

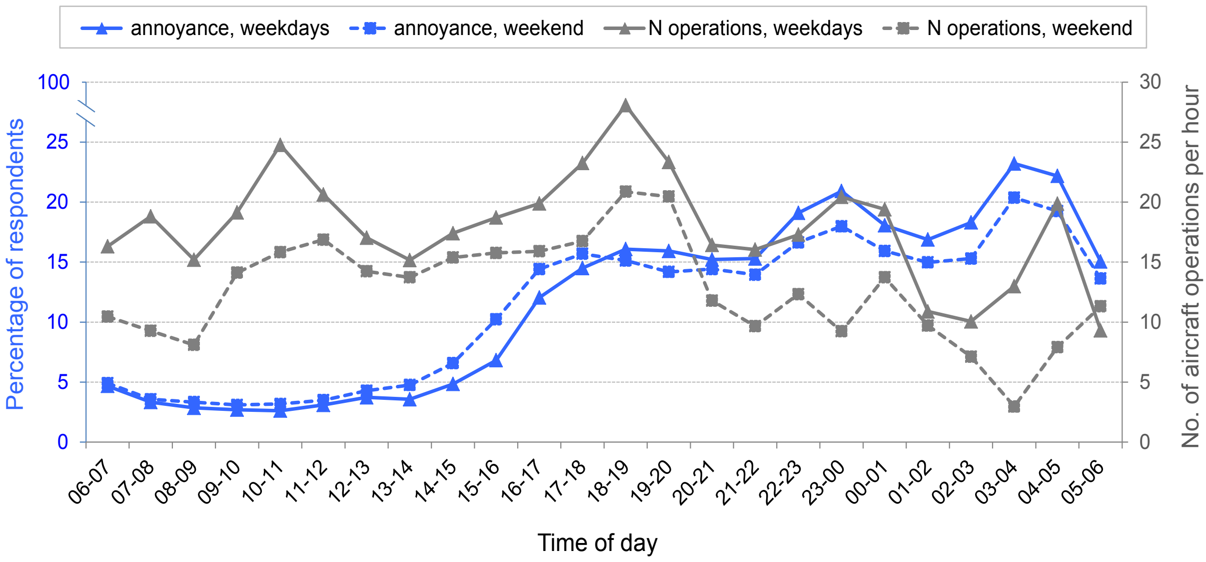

Figure 12. Times of day when aircraft noise is particularly annoying. For every period, the percentage of participants in the whole sample (N = 1,262) who perceived this time as particularly annoying is depicted. Results are based on a free enumeration. Multiple choices were allowed.

As depicted in Figure 12, on the one hand, the annoyance graphs have a very similar trend for weekdays and the weekend. Only from the beginning of the early evening until the early morning, annoyance on weekdays is consistently higher. On the other hand, Figure 12 shows that the graphs for enhanced annoyance and air traffic density do not match. Although there is a substantial amount of air traffic during the late morning until noon, especially on weekdays, only a small percentage of interviewees perceived aircraft noise as particularly annoying during this period. Between 18:00 and 19:00 when air traffic density reaches the daily maximum, 16 % or less of the respondents perceived aircraft noise as particularly annoying. The times of day when aircraft noise was most often perceived as particularly annoying (by up to 23 % of the respondents) lies between 23:00 and 24:00 as well as between 03:00 and 04:00. Compared to the early evening, during these times, the absolute number of aircraft operations per hour is lower. However, this does not automatically lead to lower noise exposure levels because during these times freight planes prevail which produce considerably higher maximum sound levels than passenger planes. Around midnight, the highest number of freight planes arrives at Cologne/Bonn Airport and around 04:00, the highest number of freight planes takes off at Cologne/Bonn Airport after cargo has been discharged and loaded up again in the preceding four hours.

Moreover, the relation between general aircraft noise annoyance and the perception of certain times as particularly annoying was investigated by means of a point-biserial correlation analysis. The perception of certain times as particularly annoying is a dichotomous variable with the levels 0 = the time period was named as particularly annoying by the interviewee and 1 = the time period was not named. The coefficients for the correlation between general annoyance ratings and a certain time of day show a clear increase beginning in the afternoon between 16:00 and 17:00. The highest correlations were found for the time between 03:00 and 04:00 (up to $r(1260) = .40$, $p < .001$). A table showing all correlations is given in Appendix C.

5.4 Research question A 3: Predictors of long-term aircraft noise annoyance

The following section investigates the variables contributing the most to aircraft noise annoyance ratings. A prediction model for general and night-time annoyance due to aircraft noise is developed.

5.4.1 Pre-selection of predictors

Developing a model for the prediction of aircraft noise annoyance during the past 12 months was achieved in two steps. First, to avoid over-parameterization, a pre-analysis was run by investigating all 33 variables available from the interview questionnaire or the noise contour map considering their effect on aircraft noise annoyance. For metric variables for which at least a quasi-linear relation to aircraft noise annoyance had been shown in a scatter plot, (partial) correlation analyses were calculated. Analyses of (co-)variance or, if necessary, Welch-tests were used for categorical variables as well as for the variable *age* that has been transformed into a categorical variable. Second, in a multiple linear regression model, only those variables were introduced that had at least a small effect ((partial) $r \geq .1$ and (partial) $\eta^2 \geq .01$) on annoyance. A summary of the pre-analysis is depicted in Table 7.

Out of the 33 variables extracted from the interview data or from the noise contour map, only 15 had a significant and at least small effect on long-term aircraft noise annoyance in general and/or with regard to the night-time period.

Table 7

Results of pre-analysis of potential predictors of aircraft noise annoyance, N = 1,262

Variable/Scale	Related to general annoyance?[a]	Related to night-time annoyance?[a]
$L_{Aeq,24h}$	x	x
$L_{Aeq,22\text{-}6}$	x	x
Position of participant's home to flight path (directly beneath flight path, beside flight path)		
Minimum aircraft altitude over area in ft	x	
Dominant operation type over area (predominantly take-off, predominantly approach, both take-off and approach)		x
Degree of urbanization of area (rural, suburban , urban)	x	x
Presence of other sources of transportation noise (no, yes)		
Length of residence in years		
Satisfaction with residential area (1 = not at all satisfied - 5 = extremely satisfied)	x	x
Presence of further (non-transportation) noise sources (no, yes)		
Carrying out of coping measures (no, yes)	x	x
Attitude towards airport (1 = very negative - 5 = very positive)	x	x
Perception of positive aspects of local air traffic (no, yes)		
Perception of negative aspects of local air traffic (no, yes)	x	x
Suggestions for airport actions to improve the residents' situation (no, yes)	x	x
Environmental conscience (Prioritization of environmental or economic issues or both)	x	x
Perception of aviation-related news (no, yes)	x	x
Age (in categories, see Section 5.2.3)	x	x

Note. [a] Only effects with an effect size of (partial) Pearon's $r \geq .1$ or (partial) $\eta^2 \geq .01$ at a level of significance of 5 % were considered.

Continuation of Table 7

Results of pre-analysis of potential predictors of aircraft noise annoyance, N = 1,262

Variable/Scale	Related to general annoyance?[a]	Related to night-time annoyance?[a]
Gender		
Self-rated noise sensitivity (1 = not at all sensitive - 5 = extremely sensitive)	x	x
Homeownership (tenant, owner)		
Suffering from hearing disorder (no, yes)		
Presence/evaluation of domestic noise insulation (no insulation, not highly satisfied, highly satisfied)	x	x
Economic dependence on airport (no, yes)		
Number of air trips during past 12 months		
Educational level (1 = still student … 5 = university degree)		
Current employment? (no, yes)		
Category of unemployment (1= still in training … 5 = never employed so far)		
Occupational level (1 = blue collar worker … 5 = executive)		
Working in shifts (no, yes)		
Category of shift work (1 = shift work without night shift … 5 = permanent night shift)		
Number of hours away from home (on weekdays and at the weekend)		
Number of persons living in the household		

Note. [a] Only effects with an effect size of (partial) Pearon's $r \geq .1$ or (partial) $\eta^2 \geq .01$ at a level of significance of 5 % were considered.

5.4.2 A prediction model for general annoyance

In a starting linear regression model, the $L_{Aeq,24\ h}$ was used as sole predictor for long-term aircraft noise annoyance in general ($\beta = .41$. $p < .001$). This model accounted for a variance of 17.0 % ($F(1, 1260) = 260.04$, $p < .001$) A more complex multiple linear regression model was tested with all relevant variables from the pre-analysis (see Table 7). In a subsequent manual backwards selection process, those predictors failed to have a significant standardized regression coefficient (β) at a 5 % significance level were removed from the model.

For general annoyance due to aircraft noise, the final model comprises ten predictors[12]. Table 8 shows the predictors and a description of their effect on annoyance. This model is based on a sample of only 1,137 respondents. The data of 125 individuals could not be used due to single missing values for non-acoustical variables. The ten predictors accounted for 54.7 % of the variance in the ratings, $F(13, 1123) = 106.55$, $p < .001$). Almost the same proportion of variance (52.2 %) was explained by a model including only the nine non-acoustical predictors ($F(12, 1124) = 104.39$, $p < .001$). The premises for a multiple regression analysis 1) linearity in the parameters, 2) homoscedasticity of errors, 3) absence of autocorrelation, 4) absence of multicollinearity, and 5) normally distributed errors were tested as postulated by Backhaus, Erichson, Plinke, and Weiber (2006). All assumptions were met.

Table 8

Predictors of general aircraft noise annoyance in a multiple linear regression model, N=1,137

Predictor	*B*	*SE*	β	*p*	Description of effect
Intercept	0.35	0.40		.385	
$L_{Aeq,24\,h}$	0.05	0.01	0.22	< .001	The higher the $L_{Aeq,24\,h}$, the higher is GA.
Suggestions for airport actions	0.65	0.06	0.25	< .001	GA is higher when suggestions for airport actions are given.
Perception of negative aspects of local air traffic	0.52	0.06	0.20	< .001	GA is higher when negative aspects of the local air traffic are seen.
Coping measures	0.40	0.06	0.15	< .001	GA is higher when coping measures are carried out.
Attitude towards airport	-0.19	0.03	-0.13	< .001	The more positive the attitude, the lower is GA.
Satisfaction with residential area	-0.17	0.07	-0.13	< .001	The more satisfied with the residential area, the lower is GA.

Note. GA stands for general aircraft noise annoyance during the past 12 months.

[12] In comparison, an automatic stepwise selection procedure was run. The same ten predictors were found with exception for the fact that single connected dummy variables of the categorical variables *degree of urbanization, prioritization of environmental or economic issues*, and *presence and evaluation of domestic noise insulation* were excluded. But in order to have a relation to the reference category and, hence, to be able to interpret the effect of a dummy-coded variable, all connected dummy variables needed to be included in the model.

Continuation of Table 8

Predictors of general aircraft noise annoyance in a multiple linear regression model, N=1,137

Predictor	*B*	*SE*	β	*p*	Description of effect
Degree of urbanization[a]					
- urban	-0.38	0.10	-0.11	< .001	Compared to rural areas, GA is lower in urban areas.
- suburban	-0.09	0.07	-0.03	.227	Compared to rural areas, GA is not lower in suburban areas.
Environmental conscience[b]					
Prioritization					
- of environmental issues	0.28	0.09	0.11	.003	Compared to a prioritization of economic issues, GA is higher when person prioritizes environmental issues.
- of both environmental and economic issues	0.09	0.09	0.04	.299	Compared to a prioritization of economic issues, GA is not significantly higher when person prioritizes both.
Presence/evaluation of noise insulation[c]					
- not highly satisfied with noise insulation	0.24	0.07	0.08	< .001	GA is higher when person is not highly satisfied with noise insulation than when person is highly satisfied with insulation.
- no insulation	0.07	0.07	0.03	.289	GA is not significantly higher when there is no insulation than when there is insulation which the person is highly satisfied with.
Noise sensitivity	0.11	0.03	0.08	< .001	The higher noise sensitivity, the higher is GA.

Note. GA stands for general aircraft noise annoyance during the past 12 months. [a] reference category is “rural areas”, [b] reference category is “prioritization of economic issues”, [c] reference category is “highly satisfied with noise insulation”.

To test the categories of the dummy-coded categorical variables *degree of urbanization*, *presence and evaluation of domestic noise insulation,* and *environmental conscience*, an additional regression analysis was calculated using changed reference categories. The results of this additional analysis showed that a) residents living in urban areas rate their annoyance significantly lower than residents from suburban areas (B = -0.29, SE = 0.08, β = -0.09,

$p < .001$), b) residents who prioritize environmental issues rate their annoyance significantly higher than residents prioritizing both environmental and economic issues ($B = 0.18$, $SE = 0.06$, $\beta = 0.07$, $p = .001$), and c) residents having no noise insulation rate their annoyance significantly lower than residents who are not highly satisfied with noise insulation of their homes ($B = -0.17$, $SE = 0.07$, $\beta = -0.07$, $p = .015$).

For the three categorical variables described above, the estimated marginal mean annoyance ratings that have been controlled for the influence of all other predictors are displayed in Figure 13a to 13c.

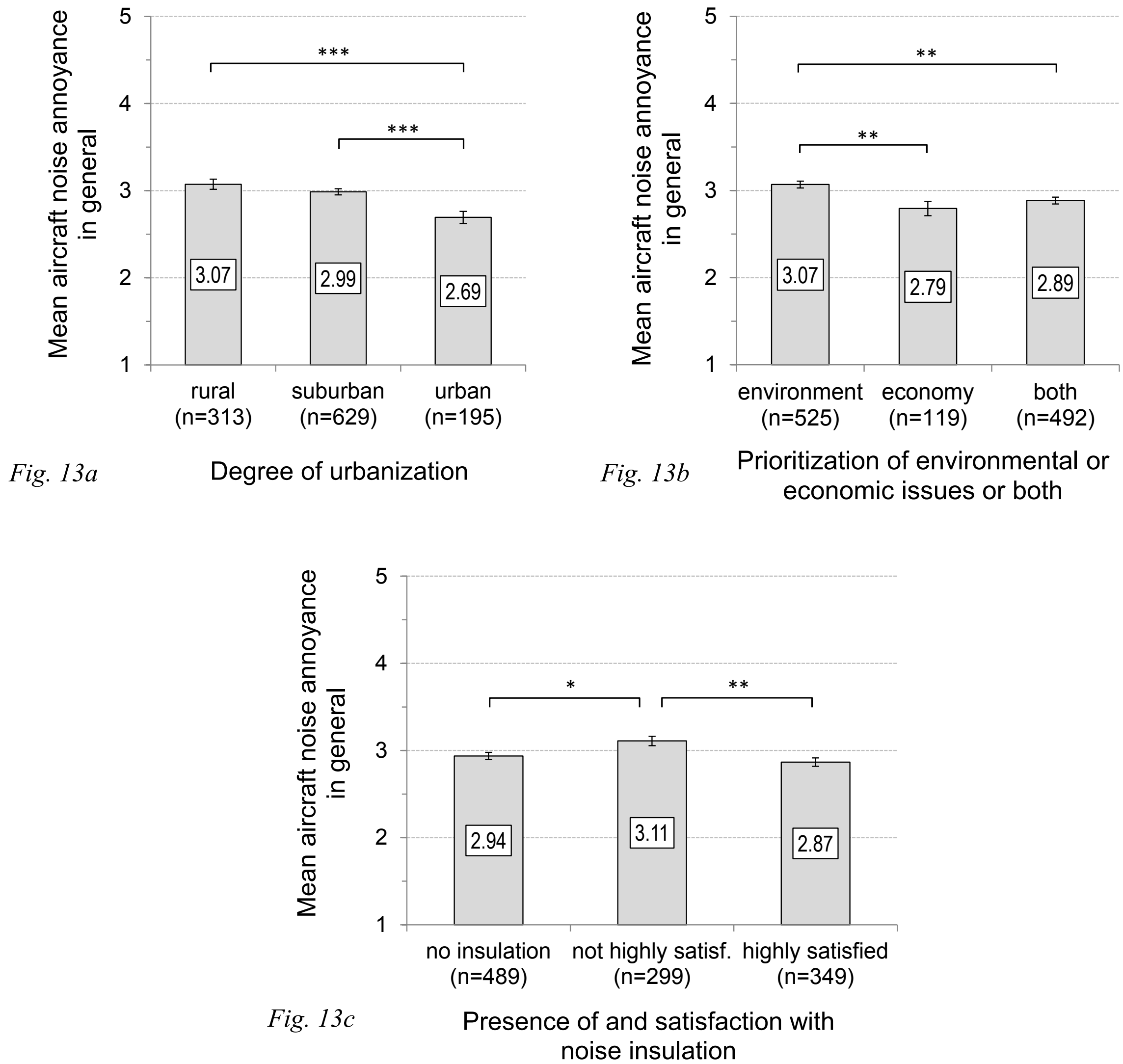

Figure 13a-c. Estimated marginal means and standard errors of general aircraft noise annoyance for the levels of the predictors *degree of urbanization* (a), *prioritization of environmental or economic issues or both* (b), and *presence and evaluation of domestic noise insulation* when the influence of additional predictors is controlled for. * $p < .05$, ** $p < .01$, *** $p < .001$.

In total, for general aircraft noise annoyance during the past 12 months, the following relations can be summarized. a) Annoyance is lower in urban areas than in suburban and rural areas. b) Annoyance is higher when the respondent stresses the importance of environmental issues than when he or she advocates for economic issues or for both environmental and economic issues. c) Annoyance is lower when the respondent is highly satisfied with the domestic noise insulation or when no insulation is present than when he or she is not highly satisfied with the insulation.

5.4.3 A prediction model for night-time annoyance

As already shown in Section 5.2.2 (see Figure 7b), the relation between the $L_{Aeq,22\text{-}6}$ and night-time annoyance ratings is only quasi-linear. Via a graphical assessment using a LOWESS-procedure, the trend seems to best follow a square root function (SQRT). A single linear regression model using the $L_{Aeq,22\text{-}6}$ as predictor accounted for 17.9% of the variance in the annoyance ratings ($F(1, 1260) = 276.01$, $p <. 001$). A model using the SQRT $L_{Aeq,22\text{-}6}$ as predictor explained marginally more variance, i.e., 18.1 % ($F(1, 1260) = 278.89$, $p < .001$). More importantly, the normality assumption of the residuals was only met after transforming the $L_{Aeq,22\text{-}6}$ into the SQRT $L_{Aeq,22\text{-}6}$. As a consequence, the SQRT $L_{Aeq,22\text{-}6}$ is used as acoustical predictor for night-time annoyance in the following.

A more complex multiple linear regression model was developed in the same way as for the prediction of general aircraft noise annoyance. The final model for night-time annoyance consists of the SQRT $L_{Aeq,22\text{-}6}$ and the same nine non-acoustical predictors[13] as the model for general aircraft noise annoyance. Hence, the sample the current model is based on likewise comprises data of only 1,137 respondents because single values for 125 individuals were missing. As depicted in Table 9, the regression coefficients differ only slightly from those found in the regression model for general annoyance. The present model accounts for 52.3 % of the variance in the night-time annoyance ratings ($F(13, 1123) = 96.75$, $p < .001$). A model containing only the nine non-acoustical predictors explains 49.1 % of the variance ($F(12, 1124) = 92.19$; $p < .001$). The assumptions for a multiple regression analysis (Backhaus, Erichson, Plinke, & Weiber, 2006) were met.

[13] In comparison, an automatic stepwise selection procedure was run. Again, the connected dummy-variables for *degree of urbanization of area* and *prioritization of environmental or economic issues* were excluded. Apart from that, the same ten predictors plus the additional predictor *number of flight trips in the past 12 months* were found. Including this additional predictor and all necessary connected dummy-variables, however, would lead to the complete exclusion of the predictor *prioritization of environmental or economic issues* and by this to a slightly reduced variance explanation. For this reason, the model was not changed.

Table 9

Predictors of aircraft noise annoyance at night in a multiple linear regression model, N=1,137

Predictor	*B*	*SE*	β	*p*	Description of effect
Intercept	-2.31	0.66		<.001	
SQRT $L_{Aeq,6\text{-}22}$	0.73	0.01	0.23	<.001	The higher the SQRT $L_{Aeq,6\text{-}22}$, the higher is NTA.
Suggestions for airport actions	0.66	0.08	0.21	<.001	NTA is higher when the respondent mentions suggestions for airport actions.
Perception of negative aspects of local air traffic	0.64	0.07	0.21	<.001	NTA is higher when negative aspects of the local air traffic are seen.
Attitude towards airport	-0.25	0.04	-0.14	<.001	The more positive the attitude, the lower is NTA.
Presence/evaluation of noise insulation[a]					
- not highly satisfied with noise insulation	0.49	0.09	0.14	<.001	NTA is higher when person is not highly satisfied with noise insulation than when person is highly satisfied with insulation.
- no insulation	0.26	0.08	0.08	.001	NTA is higher when there is no insulation than when there is insulation that the person is highly satisfied with.
Coping measures	0.41	0.07	0.13	<.001	NTA is higher when coping measures are carried out.
Satisfaction with residential area	-0.15	0.04	-0.10	<.001	The more satisfied with the residential area, the lower is NTA.
Degree of urbanization[b]					
- urban	-0.32	0.11	-0.08	.005	Compared to rural areas, NTA is lower in urban areas.
- suburban	-0.12	0.08	-0.04	.131	Compared to rural areas, NTA is not lower in suburban areas.

Note. NTA stands for night-time aircraft noise annoyance during the past 12 months. [a] reference category is "highly satisfied with noise insulation", [b] reference category is "rural areas".

Continuation of Table 9

Predictors of aircraft noise annoyance at night in a multiple linear regression model, N=1,137

Predictor	*B*	*SE*	β	*p*	Description of effect
Environmental conscience[c]					
Prioritization					
- of environmental issues	0.23	0.11	0.08	.041	Compared to a prioritization of economic issues, NTA is higher when person prioritizes environmental issues.
- of both environmental and economic issues	-0.04	0.11	-0.01	.715	Compared to a prioritization of economic issues, NTA does not differ when person prioritizes both.
Noise sensitivity	0.11	0.04	0.07	.002	The higher noise sensitivity, the higher is NTA.

Note. NTA stands for night-time aircraft noise annoyance during the past 12 months. [c] reference category is "prioritization of economic issues".

The results of an additional analysis testing the categories of the categorical variables against each other showed that: a) residents living in urban areas rate their annoyance significantly lower than residents from suburban areas (B = -0.20, SE = 0.09, β = -0.05, p = .030), b) residents who prioritize environmental issues rate their annoyance significantly higher than residents prioritizing both environmental and economic issues (B = 0.27, SE = 0.11, β = 0.09, p < .001), and c) residents having no noise insulation rate their annoyance significantly lower than residents who are not highly satisfied with noise insulation of their homes (B = -0.23, SE = 0.09, β = -0.08, p = .008).

Taken together these results with the results shown in Table 9, the following relations can be summarized for night-time aircraft noise annoyance. a) Annoyance is lower in urban areas than in suburban areas or rural areas. b) Annoyance is higher when the respondent prioritizes environmental issues than when he or she advocates for economic issues or for both environmental and economic issues. c) Annoyance is lower when the respondent is highly satisfied with the domestic noise insulation than when no noise insulation is present. Moreover, annoyance is lower in absence of noise insulation measures than when the respondent is not highly satisfied with the domestic noise insulation. For the three categorical variables listed, estimated marginal means of nocturnal annoyance due to aircraft noise that have been controlled for the influence of all other predictors are depicted in Figure 14a to 14c.

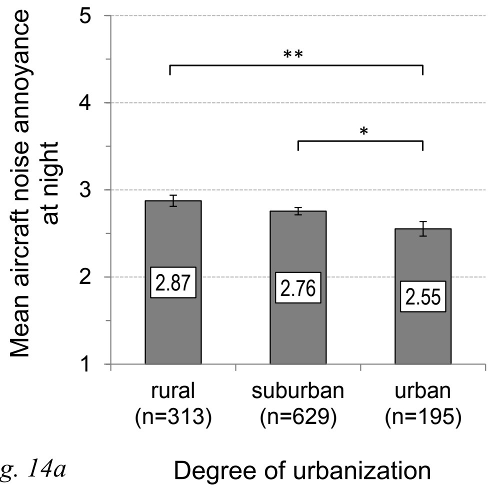

Fig. 14a

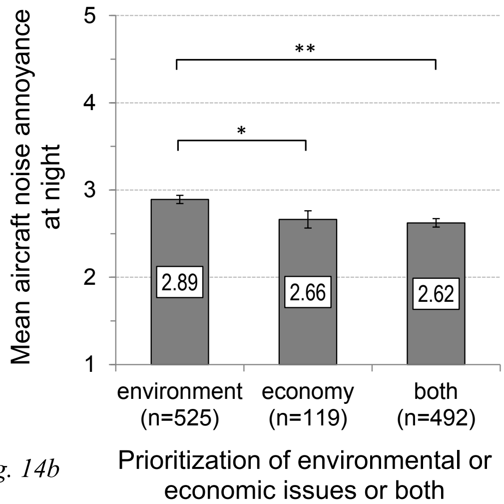

Fig. 14b

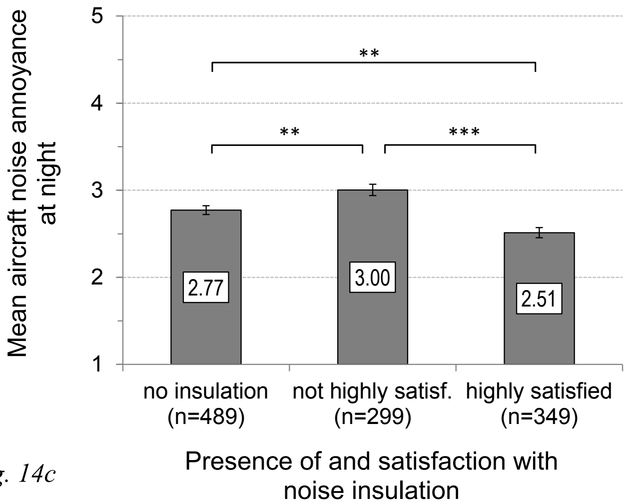

Fig. 14c

Figure 14a-c. Estimated marginal means and standard errors of aircraft noise annoyance at night for levels of the predictors *degree of urbanization* (a), *prioritization of environmental or economic issues or both* (b), and *presence and evaluation of domestic noise insulation* (c) when the influence of additional predictors is controlled for. * $p < .05$, ** $p < .01$, *** $p < .001$.

5.5 Research question A 4: Residents' perception of Cologne/Bonn Airport

Besides the questions about the status quo of aircraft noise annoyance at Cologne/Bonn Airport and predictors for this annoyance, the present telephone survey focused on the perception of the local airport and air traffic by the residents. For this purpose, open format questions regarding merits and drawbacks of the local airport and air traffic have been analyzed. In addition, to get hints for potential approaches to achieve a good neighborhood between the airport and its residents and, thus, to minimize the community annoyance, the participants were asked about actions the airport management could take to improve the residents' living situation. The three examined variables are dichotomous, i.e. either a certain aspect or airport action is mentioned (= coded with 1) or not (= coded with 0).The relation between naming a certain aspect or action and general or nocturnal annoyance due to aircraft noise is assessed via the point-biserial correlation coefficient *r*.

The interview participants were asked whether they see any concrete positive aspects of the local air traffic and airport. 966 interviewees (76.5 %) reported to do so. Table 10 lists the specific positive aspects that were mentioned, their enumeration frequency, and their relation to general and night-time annoyance ratings. At best, only very small correlations to both general and night-time annoyance ratings were found. With exceptions for the aspects “availability of jobs” and “economic development”, perceiving positive aspects of the airport and local air traffic was related in tendency negatively to long-term aircraft noise annoyance ratings.

Table 10

Positive aspects of the airport Cologne/Bonn and the local air traffic. Frequencies (%) of naming a certain aspect refer to the whole sample, N = 1,262. Multiple choices were possible.

Positive aspects	Frequency (%)	Correlation to GA	Correlation to NTA
Easy access to travel	64.0	-.04	-.03
Availability of jobs	21.9	.05	.07*
Improvement of regional infrastructure	8.4	-.06*	-.08**
Economic development	6.6	.05	.05
Good shopping facilities at airport	2.3	-.05	-.05
Availability of goods	1.3	-.02	-.00
Attractive international travel destinations	1.0	-.07*	-.08**
Cosmopolitan atmosphere	0.9	-.04	-.03
Clear construction of the airport	0.7	-.05	-.04
Airport as attractive excursion destination	0.4	-.05	-.04
Others	2.9	-	-

Note. GA stands for general annoyance. NTA stands for night-time annoyance, * $p < .05$, ** $p < .01$, *** $p < .001$.

Furthermore, interviewees were asked whether they see concrete negative aspects of the airport or the local air traffic. 655 interviewees (51.9 %) indicated to do so. Table 11 lists the specific negative aspects that were reported. Furthermore, their enumeration frequency and their relation to general and night-time annoyance ratings (point-biserial correlation) are given. The aspect "aircraft noise" was mentioned most often and was the aspect with the highest relation to aircraft noise annoyance in general and with regard to the night-time period (r = .32 and r = .30, respectively). Further rather small but statistically significant correlations were found for the negatively perceived fact of nocturnal air traffic, concerns regarding health risks for the residents, a general decrease in the quality of life, and a fall in property values as consequence of the noise exposure.

Table 11

Negative aspects of the airport Cologne/Bonn and the local air traffic. Frequencies (%) of naming a certain aspect refer to the whole sample, N = 1,262. Multiple choices were possible.

Negative aspects	Frequency (%)	Correlation to GA	Correlation to NTA
Aircraft noise (in general)	21.5	.32***	.30***
Night-time air traffic	10.5	.20***	.23***
Health risks for residents	7.8	.25***	.29***
Decreasing quality of life	7.1	.24***	.22***
Environmental risks and damage	5.8	.02	.05
Freight air traffic	2.0	.06*	.09**
Fall in value of properties	1.6	.17***	.10***
(Too) lowly flying aircraft	1.4	.05	.03
Air pollution by kerosene release	1.3	.03	.06*
Aircraft crashes	1.0	.02	.02
High density of air traffic	0.6	.01	.00
Traffic congestion	0.4	.01	.01
Others	7.1	-	-

Note. GA stands for general annoyance. NTA stands for night-time annoyance, * $p < .05$, ** $p < .01$, *** $p < .001$.

At last, interviewees had the chance to suggest actions the airport could undertake in order to improve the residents' situation, in particular, with respect to the local aircraft noise exposure. 700 interviewees of the telephone study (55.5 %) made at least one suggestion. The mentioned actions, their enumeration frequency, and their relation to general and night-time annoyance (point-biserial correlation coefficient *r*) are shown in Table 12.

Table 12

Interviewees' suggestions what Cologne/Bonn Airport could do for its residents. Frequencies (%) of naming a certain action refer to the whole sample, N = 1,262. Multiple choices were possible.

Suggested airport action	Frequency (%)	Correlation to GA	Correlation to NTA
Reduce the number of flights during the night	38.6	.35***	.35***
Partial or entire night ban for passenger and/or freight aircraft	24.6	.30***	.36***
Change aircraft fleet (towards modern quieter aircraft)	20.1	.22***	.21***
Reduce noise (not specified)	19.3	.25***	.19***
Relocate approach/departure routes; arranging flight paths over thinly populated areas	15.7	.26***	.21***
Provide/improve (domestic) noise insulation	11.6	.11***	.12***
Spread/alternate flight paths	2.7	.05	.08**
Generally higher flight altitude	2.4	.07*	.07*
Decision rights for residents	2.1	.06*	-.01
Steeper ascent after starting	1.3	.05	.09**
Freeze status quo/no expansion of airport	1.0	-.03	-.01
Monetary compensation	0.9	.02	.01
Inform comprehensively/ transparently	0.7	-.01	-.01
Others	14.1	-	-

Note. GA stands for general annoyance. NTA stands for night-time annoyance, * $p < .05$, ** $p < .01$, *** $p < .001$.

The actions which were enumerated most often by the interviewees and which were correlating with $r \geq .30$ to long-term aircraft noise annoyance refer to the nocturnal air traffic. More than one third of the whole sample requested a reduction of the number of night flights. One out of four even claimed a partial or entire curfew. Further small to medium-sized correlations were found for the suggestions to change aircraft fleet towards modern and quieter aircraft, to reduce aircraft noise (without further specification), to relocate flight paths, and to provide or to improve noise insulation (at residents' homes).

6 Discussion and conclusion of the telephone study

This section is dedicated to an extensive discussion of the methodology applied in the telephone study and the results derived from the examinations. Conclusions are drawn with regard to the answers to the posed research questions and considering practical implications for future research. Where possible, on the basis of the findings of the telephone survey, approaches are shortly discussed that may be suitable to reduce the community annoyance due to aircraft noise in the vicinity of Cologne/Bonn Airport.

6.1 Discussion of the methodology

6.1.1 Telephone interview

A telephone survey was carried out to get an overview over the current status of long-term aircraft noise-induced annoyance in the communities around Cologne/Bonn Airport and to investigate variables affecting this annoyance. Carrying out a telephone study was expected to have an advantage on face-to-face interviews with respect to its lower efforts and costs, and on postal surveys with regard to its higher response rate. However, only about one third of the residents reached by phone had interest to participate in the telephone survey. This rate is rather low, but not uncommon (Schnell, 1997). Response rates are decreasing probably because of negative experiences with cold calls that were covered as telephone surveys (Schnauber & Daschmann, 2008). Whether sending costly invitation letters as sometimes recommended for telephone surveys (Möhring & Schlütz, 2010) would have increased the response rate is a controversial question (Byrne, Harrison, Young, Selby, & Solomon, 2007; Carey et al., 2013). Unfortunately, no information about aircraft noise annoyance and personal characteristics of the non-responding population is available. With regard to the effect of high non-response rates on approximated community annoyance, two contrary consequences seem imaginable: Are non-responders (subjectively) not affected by aircraft noise and did they therefore find the interview irrelevant? In this case, community annoyance would have been overestimated as concluded earlier (Brooker, 2009; Kroesen et al., 2008). Or is the opposite true, and mean community annoyance has been underestimated, because highly annoyed people have learned to be helpless and assess any study hopeless to change their situation? A considerable number of highly annoyed residents might conceive a high mistrust in the local noise authorities and declined participation as they do not see any benefit of taking part in an annoyance study.

Another source of potential biases resulted from the limited access to a study sample that was representative for the community around Cologne/Bonn Airport with regard to age and employment. It turned out that nowadays most of the entries in the telephone directory belong to elderly people. At least in Germany, younger people obviously tend to deny a registration in the telephone directory. This imbalance was reflected by the age statistics of the sample, and as a consequence of this, also by the employment statistics. The proportion of individuals with an age of 65 years or more was about 15 % higher in the survey sample than in the population of the vicinity of Cologne/Bonn Airport. Almost half of the participants were pensioners. For the reason of an imbalanced age statistic, the effect of age on aircraft noise annoyance was analyzed in more detail. The results show that both general and night-time annoyance seems to follow a curvilinear trend: Young respondents (< 35 years) and elder respondents (≥ 75 years) are less annoyed. This curvilinear relationship between age and annoyance has already been concluded earlier with regard to both general annoyance (Miedema & Vos, 1999) and nocturnal annoyance and disturbance (Miedema & Vos, 2007). Nevertheless, when further non-acoustical factors for the prediction of long-term aircraft noise annoyance were considered, age has no influence anymore. Generally, demographical variables, such as age, gender, educational and occupational level as well as economic dependence on the airport had no or only very small effects on annoyance. These findings are consistent with prior reviews on the effect of demographical variables on noise annoyance (Fields, 1993; Miedema & Vos, 1999). Hence, for the present study the conclusion is drawn that the estimation of community annoyance at the airport Cologne/Bonn maybe be slightly biased due to an imbalanced sample but this has no significant effects on the answers to the research questions.

Notwithstanding the above, it is recommendable to use supplementary ways of contacting residents which guarantee access to a younger sample in future surveys. One example might be an online survey since the access to internet is growing continuously in Germany. In 2012, the proportion of households with internet access was 79% (Statistisches Bundesamt, 2013). However, the question whether web and telephone surveys are capable to produce results in equal quality is discussed controversially (Braunsberger et al., 2007; Fricker et al., 2005; Roster et al., 2004).

One characteristic of telephone surveys that might have had consequences for the reliability of socio-psychological construct measurement is the timely constraint of the interview. The purpose of the present telephone survey, in contrast, was to ascertain a preferably broad range of non-acoustical influence factors of annoyance. Hence, there was the need for short and concise survey instruments and the foregoing of well-established scales. Above all, the psychological constructs *coping with noise* and *noise sensitivity* were affected. Both constructs originally were designed for a measurement by means of more comprehensive scales or at least by multiple items (for noise sensitivity see, e.g.,Weinstein, 1978; for coping see, e.g., Guski et al., 1978). Zimmer and Ellermeier (1999) list several disadvantages of one-item ratings: Most relevant were the reduced precision, the decreased retest reliability, and an unwanted correlation with the respondent's noise exposure. Especially for the construct of *noise sensitivity* it cannot be ruled out that these methodological deficiencies might have led to an underestimation of the construct's contribution to long-term annoyance.

6.1.2 Noise contour maps

Few limitations of the present telephone study must be noted with regard to the measurement of the noise exposure level. Due to financial constraints, data on the aircraft noise exposure was based on L_{Aeq}-values which had not been measured at site but manually extracted by the author from a noise contour map in 5-dB steps. It is clear that this procedure leaves room for reading errors as well as for errors occurring when different areas are subsumed under certain exposure categories. To minimize this error potential, the extracted values were rechecked by an employee of the German Aerospace Center (DLR) in Cologne. Moreover, the values were compared with level recordings from the preceding 12 months at measuring points operated by the airport management in the different examination areas. The extracted aircraft noise exposure levels do not seem to be systematically biased as a post-hoc comparison with measured levels in the field study in the areas Cologne - Rath/Heumar and Siegburg - Stallberg/Kaldauen (cf. Section 8.2.2) shows. Nevertheless, the exposure level can generally vary within a neighbourhood depending on the distance to the noise source (here the overflying aircraft) as well as on the characteristics of the dwelling as, for instance, the shielding by other buildings and/or the surrounding environment, or the location of the flat within a multi-dwelling unit (Schultz, 1978). Thus, the L_{Aeq}-values extracted from noise contour maps may differ from the levels the participants were actually exposed to. The subsumption of areas under a certain exposure class may have led to a slight overestimation of the levels for some participants and to a slight underestimation for other participants. The exposure levels that were extracted for the six examination areas and that are resembling a kind of mean exposure level of an area, in contrast, are not assumed to be considerably biased to one side.

Even in case the levels extracted from the noise contour maps actually differed from the true exposure levels, with few exceptions, all research questions of this thesis could have been answered sufficiently precise. Only for the estimation of the impact of the equivalent aircraft noise level on aircraft noise-induced annoyance and the comparison of the present annoyance data with values predicted by the European standard curve might have been vague. However, as the following chapter will show both the results on the contribution of the aircraft noise level to annoyance and on the comparison of the Cologne/Bonn data with the European standard curve match with findings of the recent past. Hence, the conclusion is that the extracted exposure levels and the results derived from them are valid.

An essential drawback of operationalizing noise exposure by noise contour maps is the lacking access to information about the number of fly-overs or the maximum aircraft noise levels in an area. The same applies to the background noise level. Especially the number of aircraft and maximum levels are assumed to be important noise metrics supplementary to the L_{Aeq} (Guski, 1999; Interdisziplinärer Arbeitskreis für Lärmwirkungsfragen beim Umweltbundesamt, 1990; Ising & Kruppa, 2002). As a consequence, for future research on community annoyance, it seems reasonable to recommend a better operationalization of the aircraft noise exposure with regard to a) a more precise operational definition or direct measurement of outdoor exposure levels at the respondent's residence, b) the consideration of supplementary noise indicators besides the L_{Aeq}, and c) means for an estimation of the respondent's typical indoor noise levels by ascertaining information about the type of windows as well as the individual's window-opening behaviour.

6.2 Discussion and conclusion of the results of the research questions

6.2.1 Research question A 1: Status quo of long-term aircraft noise annoyance

With mean ratings around 2.9 and 2.7, reported aircraft noise annoyance in general and considering the night-time period was "moderate" in the words of the semantic five point scale recommended by the ICBEN and ISO 15666 (Fields et al., 2001; ISO, 2003). The examination areas 1 to 4 (Siegburg - Stallberg/Kaldauen, Cologne - Rath/Heumar, Cologne - Ostheim/Neubrück/Mülheim, and Hennef - Heisterschoß/Happerschoß) showed the highest annoyance ratings (*M*s $\geq$ 3.0). The mean long-term annoyance ratings in area 4 were not lower than in the areas 1 to 3 although the energy equivalent sound pressure levels during daytime and night-time were estimated lower by approximately 5 dB here. Significant difference in the annoyance ratings were found only for area 5 (Cologne - Wahnheide) and area 6 (Odenthal, Bergisch Gladbach - Schildgen) compared to the other four examination areas as well as between these two areas. Area 5 has the same long-term daytime exposure as area 4

($L_{Aeq,6\text{-}22}$ = 50 dB) but is overflown only in 10 to 20 % of the yearly air traffic. Aircraft altitudes are then very low and aircraft maximum levels consequently high. Moreover, air traffic over this area is operated only during the day, i.e. from 06:00 to 22:00. The results suggest that few fly-overs that are operated exclusively during daytime but that have high maximum levels are perceived as less annoying than rather frequent fly-overs with lower maximum levels operated also at night. Evidence for the effect of the number of aircraft on sleep disturbance and nocturnal annoyance has already been found elsewhere (Quehl & Basner, 2006). As area 6 has a rather continuous but very low aircraft noise exposure ($L_{Aeq,24\,h}$ ≈ 40 dB) also at night, annoyance ratings were lowest here as expected.

Annoyance ratings were not only analyzed with regard to the different examination areas but also with respect to the equivalent exposure levels. It was shown that there is a relation, although not a strong one (r ≈.4), between the aircraft noise exposure – here defined by the $L_{Aeq,24\,h}$ and $L_{Aeq,22\text{-}6}$ – and ratings for long-term aircraft noise annoyance. The association between the L_{Aeq} and mean aircraft noise annoyance ratings was analyzed separately for general and nocturnal annoyance. Whereas the mean ratings for *general annoyance* increased monotonously with the $L_{Aeq,24\,h}$ from 40 to 55 dB, the mean ratings for *night-time annoyance* rose with the $L_{Aeq,24\,h}$ from 40 dB to 50 dB, but did not change from 50 to 55 dB. This result could probably be explained by domestic noise insulation and the degree of satisfaction with it. In the examination areas with a night-time exposure around 55 dB, considerably more interviewees reported high satisfaction with the noise insulation of their homes than in the area with an exposure of 50 dB. The variable *presence and evaluation of domestic noise insulation* was proved to be a significant predictor of night-time aircraft noise annoyance in the past 12 months. Participants who reported a high satisfaction with their domestic noise insulation devices rated their night-time annoyance significantly lower than those who were not highly satisfied with their noise insulation devices or whose homes had no noise insulation fitted. The results are in line with prior findings on the relation between a good insulation from noise at home and annoyance (Fields, 1993) as well as between the satisfaction with domestic noise insulation and annoyance (Kastka, 1999).

For aircraft noise annoyance during the past 12 months, annoyance ratings for the night-time period were only slightly lower than general annoyance ratings. However, looking at the distribution of response frequencies reveals that the extreme responses “not at all” and “extremely” bothered, disturbed or annoyed are given more often when judging night-time annoyance than when judging general annoyance. It seems as if annoyance ratings for night-time tend to be located at the extremes of the response scale. This leads to the assumption that a certain proportion of the participants can cope with transportation noise at night better than others as implied already by Meyer-Baron's (2000) findings on coping with nocturnal railway noise. The results may also reflect inter-individual differences in the general ability to get a restorative night's sleep. Amongst others, the latter is determined by age as well as the presence of chronic diseases and medication (Foley et al., 1995; Langevin, Sukkar, Léger, Guez, & Robert, 1992). Since the examination of physical health symptoms was not within the scope of the present survey, no definite answer can be given on this question.

The results of the present telephone survey at Cologne/Bonn Airport were compared to results of previous studies generalized in the European standard curve (EU-curve) for aircraft noise (see Miedema & Oudshoorn, 2001). This comparison revealed that the aircraft noise exposure level (L_{dn}) corresponding to the critical proportion of 25% highly annoyed residents (van Kempen & van Kamp, 2005) is exceeded at a lower level (estimated around 56 to 57 dB) than it would be predicted by the EU-curve (63-64 dB). This finding is consistent with results of a number of studies conducted after 1990 (Babisch et al., 2009; Brink et al., 2008; Janssen et al., 2011; Schreckenberg & Meis, 2007a). Again, it must be noted that the EU-curve is based on studies carried out at least 20 years ago. But aircraft noise has changed over the years. Whereas the sound pressure level of single aircraft noise events has decreased remarkably (Dobrzynski, 2010; Neise & Enghardt, 2003), the number of the noise events has increased, and hence, the duration of silent periods has been reduced (Guski, 2004; Quehl & Basner, 2006). A large number of soft fly-over sounds can nowadays generate the same energy-equivalent sound pressure level as few very loud aircraft fly-overs in the past (Quehl & Basner, 2006). The conclusion is that the change in the composition of the aircraft noise exposure most probably has contributed to a shift of aircraft noise annoyance. New exposure-response curves must be the logical consequence of this progress. In the view of the comparably high impact of non-acoustical variables on long-term annoyance (see Section 6.2.3), those new exposure-response curves and decisions derived from them should be based not solely on the sound pressure level but also take into account non-acoustics. Different curves should preferably be established for different levels of factors that are influencing the relation between the noise exposure and the annoyance but which are independent of the exposure level. Such variables are called *moderators* in the nearer sense (Baron & Kenny, 1986; Finke et al., 1975). An example for such a moderator is the degree of urbanization of an area distinguishing between urban and rural areas. The degree of urbanization of an area is a priori unrelated to the aircraft noise exposure level, but has been shown to influence aircraft noise annoyance (Lercher et al., 2008, see also Section 6.2.3). Especially in rural areas, the

EU-curve underestimates the percentage of highly annoyed residents (Lercher et al., 2008). Hence, for a better prediction of the consequences of the founding of a new airport or the expansion of an existing airport as well as for a more precise estimation of the status quo of community annoyance, it seems meaningful to establish exposure-response curves for different types of areas and neighbourhoods.

6.2.2 Research question A 2: Long-term annoyance during several times of day

Besides the general feeling of annoyance during the past 12 months, annoyance was assessed for several times of the day including the night. Mean aircraft noise annoyance ratings in general and with regard to the night-time period were comparable except for Cologne-Wahnheide. Here, rated night-time annoyance was considerably lower than general annoyance. Since this area is overflown only during daytime, between 06:00 and 22:00, this result is not very surprising. Across all areas, the correlation between general and night-time aircraft noise annoyance during the past 12 months was very high ($r \approx .8$). This association is also reflected by the correlation coefficients between general aircraft noise annoyance ratings and naming certain times of day when aircraft noise is particularly annoying. The results indicate that respondents who perceive aircraft noise as particularly annoying during the evening and night are generally more annoyed by aircraft noise than those interviewees who do not perceive aircraft noise as particularly annoying during these times. The comparison between the air traffic density at several times and the frequency of naming a certain time of day as particularly annoying revealed that respondents generally have a higher susceptibility to noise in the evening and during the night. Annoyance is enhanced in the late evening and during the night beginning at 22:00, although these are not the hours with the highest air traffic density at Cologne/Bonn Airport. For the early evening hours around 19:00 when the air traffic density reaches its daily maximum, naming frequencies are increased but not highest. In contrast, for the hours around 11:00 when the air traffic density reaches its first maximum, the aircraft noise was not perceived as particularly annoying by the respondents.

Regarding the higher annoyance ratings during the evening and night, the results of the present telephone survey seem to emphasize previous work on the impact of the time of day on aircraft noise annoyance (Hoeger et al., 2002; Hoeger, 2004; Schreckenberg & Meis, 2006; Stearns et al., 1983). Notwithstanding the above, the conclusion that aircraft noise annoyance is generally higher during the evening and night due to a higher susceptibility to noise during these times would be debatable. On the one hand, a considerable proportion of the respondents is expected to be away from home for work during the mornings and noon and is therefore "missing" the time with the second highest air traffic density of the day. On the other hand, the vast majority of the participants stays at home during the late evening and night. Thus, the higher number of respondents indicating a particularly high annoyance for these times might be the consequence of a larger reference group. However, also at the weekend, aircraft noise is perceived as more annoying during the evening hours compared to the morning and noon. Strictly speaking, the question about the relation between times of day and aircraft noise annoyance can be clarified only in a study design that contains a repetitive assessment of aircraft noise-induced annoyance in the living environment during several times a day. Therefore, the conclusion on the contribution of the time of day to aircraft noise annoyance will be resumed when the results of the short-term annoyance assessments in the context of the field study are discussed (see Section 9.2.1).

6.2.3 Research question A 3: Predictors of long-term aircraft noise annoyance

In the present study, the aircraft noise exposure level $L_{Aeq,24\ h}$ explained only 17.0 % of the variations in the general aircraft noise annoyance ratings. For nocturnal annoyance, the proportion of variance explained by the $L_{Aeq,22\text{-}6}$ was 17.9 %. Annoyance at night and the $L_{Aeq,22\text{-}6}$ were not related by a linear but rather by a square root function meaning that reported night-time annoyance does increase more slowly at high exposure levels than at lower exposure levels. Even in consideration of this relation, the variance explanation remains small (18.1 %). These values are in line with findings of prior studies (Job, 1988; Kroesen et al., 2008; Wirth et al., 2004) which discovered that the equivalent sound pressure level accounts for an amount of variance not higher than 20 %. Including non-acoustical variables into a multiple linear regression model for annoyance enormously enhanced the predictive power compared to a model with the equivalent sound pressure level as only predictor. A model with a) the $L_{Aeq,24\ h}$ and in addition with the non-acoustical predictors b) *suggestions for airport actions*, c) *perception of negative aspects of local air traffic*, d) *attitude towards the airport*, e) *presence and evaluation of domestic noise insulation*, f) *application of coping measures*, g) *satisfaction with residential area*, h) *degree of urbanization* of the area, i) *environmental conscience*, and j) *noise sensitivity* explained 54.8 % of the variance in the general aircraft noise annoyance ratings. For night-time annoyance, the $L_{Aeq,22\text{-}6}$, and the same nine non-acoustical predictors account for 52.3 % of the variance in the ratings. In the following, the contribution of each non-acoustical predictor on reported aircraft noise annoyance is discussed.

The variable *suggestions for airport actions,* that is defined as perceiving at least one action the airport management could undertake in order to improve the living situation of the airport residents, was significantly related to general and night-time annoyance. This variable was supposed to represent one aspect of the construct *preventability belief*. When respondents are convinced that aircraft noise could be prevented or at least reduced by the different noise authorities (e.g., the airport management, airlines, and the municipal authorities), they report higher aircraft annoyance (Fields, 1993; Guski, 1999; Lercher, 1996b; Stallen, 1999). The results of the telephone survey are in line with these prior findings and hypotheses. Practical implications and consequences of this finding for the airport Cologne/Bonn and additional noise authorities are discussed at the end of this chapter.

The significant effect of the predictors *perception of negative aspects of local air traffic* and *attitude towards the airport* support former findings according to which attitudinal factors including fear for aircraft crashes and health risks as well as evaluations of the noise source are most important predictors of noise annoyance (e.g., Fields, 1993; Miedema & Vos, 1999; Wirth et al., 2004). In the present study, individuals perceiving at least one negative aspect of the local air traffic and airport rated their general and nocturnal annoyance due to aircraft noise higher than interviewees who do not perceive any disadvantage. The predictor *attitude towards the airport* was related as follows to long-term aircraft noise annoyance in general and with regard to the night-time period: The more positive the attitude, the lower is the reported annoyance.

A second major predictor, which is regarded as equally important as attitudes and evaluations, is the general *sensitivity to noise* (Miedema & Vos, 1999). Contrary to the results of a number of studies and meta-analyses (Fields, 1993; Guski et al., 1978; Job, 1988; Lercher, 1996b; Miedema & Vos, 1999; Schreckenberg & Meis, 2007b; Stansfeld, 1992), respondents' self-rated *noise sensitivity* had only a small impact on long-term aircraft noise annoyance in the present study. The standardized regression coefficient β was not higher than 0.08. The simplest explanation for this finding is supposed in the application of a single, global question instead of a scale for measuring the construct (Zimmer & Ellermeier, 1999). However, in a recent study, that used a more precise scale to measure the construct, the impact of noise sensitivity decreased to zero when additional predictors, above all, *the capacity to cope with the noise,* were considered in a prediction model (Kroesen et al., 2008).

The construct *coping with noise* was ascertained by the question "Do you do anything about the aircraft noise?" If yes: "What do you do about the aircraft noise?" This operationalization of the construct and the open question format has possibly provoked answers that were mainly indicators for reactions to noise, e.g., “I close windows” or “I speak louder in conversations”. In contrast, strategies to cope with noise are very diverse and comprises not only visible physical behavior but also cognitive “efforts to manage specific external and/or internal demands that are appraised as taxing or exceeding the resources of the person” (Folkman & Lazarus, 1988, p. 310). In the present telephone survey, carrying out coping measures is related to a higher aircraft noise annoyance. Research on the relation between coping behavior and annoyance due to environmental stressors including noise and odor came to very controversial results: Carrying out coping measures can increase (Cavalini et al., 1991; Steinheider & Winneke, 1993; Wirth et al., 2004) and likewise reduce annoyance (Cavalini et al., 1991; Steinheider & Winneke, 1993; Kroesen et al., 2008) or may have no effect on annoyance ratings at all (Meyer-Baron, 2000). Results strongly depend on how the construct is measured and which coping strategy is applied (Felscher-Suhr et al., 2001; Folkman, Lazarus, Gruen, & DeLongis, 1986).

Environmental conscience, that was operationalized by the prioritization of economic or environmental issues when aviation-related decisions need to be made by authorities, significantly affected general and night-time aircraft noise annoyance. Individuals who gave priority to environmental issues report higher aircraft noise annoyance than individuals who advocate for economic issues. Although statistically significant, this effect is small: The difference of the estimated marginal means that consider the influence of the other nine predictors is only about 0.2 for general annoyance and 0.3 for annoyance at night on a scale from 1 to 5. Effects in the present telephone survey are bigger than the effect found in a face-to-face interview from 35 years ago (Guski et al., 1978), but a little smaller than the findings of a more recent postal survey (Wirth et al., 2004). The mean annoyance ratings of individuals who regard environmental issues as being equivalent to economic issues did not differ from reported mean annoyance of respondents prioritizing economic issues.

The influence of the construct *degree of urbanization* of the examined area on community annoyance has been addressed already in the beginnings of noise research by Miller (1974), but to the author’s knowledge, it has been disregarded almost completely in the recent years. The results of the present survey showed significantly lower mean ratings for general and nocturnal annoyance in urban areas compared to rural and suburban areas. Estimated marginal means differed on a scale from 1 to 5 by about 0.4 for general annoyance ratings and by about 0.3 for night-time annoyance. The finding of higher annoyance in rural areas is in line with Miller’s assumptions (1974) as well as with more recent findings on the annoyance due to road traffic noise in the alpine region (Lercher, 1996a). Lercher (1996a) concluded that rural communities differ from urban communities with regard to attitudes, the background noise level as well as behavioral settings. In rural areas, a higher orientation towards outdoor activities and recreation has been established. In addition, the author of this thesis assumes that individuals living in or moving to rural areas probably expect lower transportation noise levels and a generally quieter living environment than individuals moving to or already living in urban areas. Lercher et al. (Lercher, 1996a; Lercher et al., 2008) further conclude that the interference of transportation noise with the special conditions of rural communities cause higher annoyance and deviations from the European standard curve for exposure-response relations. Whereas the findings by Lercher et al. (2008) as well as the results of another recent survey on community aircraft noise annoyance (Lim, Kim, Hong, & Lee, 2008) underline the contribution of the background noise level, Fields (1993) found contradictory evidence for an effect of the ambient noise level on aircraft noise annoyance in his meta-analysis. Keeping in mind the significant reduction of the level of single fly-over sounds, the question arises whether Fields' (1993) findings are still valid nowadays. Or is the background noise, in particular, in urban areas suitable to completely mask single aircraft noise events? Is it possible that the reduced salience of the single aircraft noise events in urban areas results in lower community annoyance compared to rural areas with a low background noise? As no detailed information on the background exposure was available, the present study cannot answer these questions. For future research on community annoyance due to aircraft, the consideration of the background level is therefore highly recommended.

The *satisfaction with the residential area* was significantly related to aircraft noise annoyance in general and at night. The more satisfied the respondents are, the lower they rate their annoyance due to aircraft noise. This result is consistent with prior findings of transportation noise research (Fields, 1993; Jonah, Bradley, & Dawson, 1981; Langdon, 1976; Schreckenberg & Meis, 2007b).

For the variable *presence and evaluation of domestic noise insulation*, it was shown that annoyance ratings are always lower in the condition "no insulation" than in the condition "not highly satisfied with insulation". For aircraft noise annoyance in general, the ratings for the condition "no insulation" did not even differ significantly from the ratings for the condition "highly satisfied with insulation". These findings are in line with the conclusion suggested by prior research (Kastka, 1999; Wirth, 2004) according to which not the mere presence of noise insulation devices is determining but the degree of satisfaction with them. Several questions arise from these findings. What are the factors making noise insulation (not) highly satisfying? Is it decisive that not only the bedroom but also the living-room and the home office or even the entire dwelling have had noise insulation fitted? Or is the quality of the insulation crucial, i.e., the actual attenuation of the outdoor noise? Since granting noise insulation measures are a very common attempt of the airport management to reduce the annoyance in the airport community, these questions should be addressed by future research.

In a recent study on the use of domestic noise insulation devices (Schreckenberg, 2011) two thirds of the residents of a highly aircraft noise exposed area at Frankfurt Airport indicated not to close their noise insulating windows at night. Among the respondents owning a ventilation system in the sleeping-room, only half stated to use this system. The reasons for the disuse of noise insulation measure mainly referred to the disturbing sound of the ventilation system and a perceived impairment of the room climate. As a consequence, keeping windows closed was related to a decreased satisfaction with the room climate in the bedroom and a significant increase in the annoyance due to aircraft. In the recent years, a new kind of sound insulating window was developed that enables residents to keep their windows partially open for a natural air supply while still attenuating the outdoor noise level by up to 30 dB(A) (cf. HafenCity Hamburg GmbH & Behörde für Stadtentwicklung und Umwelt Hamburg, 2011). It would be interesting to see whether noise annoyance due to aircraft noise could be reduced by replacing current window types with this kind of improved sound insulating windows.

The nine non-acoustical variables that have been discussed in the preceding sections and the equivalent aircraft noise level accounted for 54.8 % of the variance in the general aircraft noise annoyance ratings and for 52.3 % of the variance in the night-time ratings. A multiple linear regression model containing exclusively the non-acoustical predictors accounted for almost the same proportion of variance, namely 52.2 % and 49.1 %, respectively. These values hint at mediating processes. At least some of the predictors might be kind of *primary* reactions to noise and simultaneously influence *secondary* reactions, i.e., aircraft noise-induced annoyance (Guski, 1999). Moreover, it seems also plausible that a decreased satisfaction with the residential area, a negative attitude towards the airport, and the application of coping measures might be consequences of people’s annoyance (cf. Kroesen et al., 2010; Kroesen, Molin, & van Wee, 2013). The existence of rather reciprocal effects seems very probable. Negative attitudes as product of socialization (Guski, 1999) affect the reaction to the noise and hence the noise annoyance ratings. This reaction – anger, dissatisfaction, annoyance – in turn might reinforce the negative attitude, especially when options are assumed available which the airport management could take to improve the situation of the residents. The model developed in this study using the multiple regression approach cannot test or explain those hypothesized interrelations between several predictors, but it works as a basis for more specific hypotheses. In a next step, the predictors proved to affect aircraft noise annoyance need to be integrated into a more complex conceptual model taking into account direct, indirect, and reciprocal effects.

6.2.4 Research question A 4: Residents' perception of Cologne/Bonn Airport

In order to investigate how the airport and the local air traffic are perceived by the residents and to get some hints for measures and interventions to minimize the community annoyance, respondents of the telephone survey were asked about concrete positive and negative aspects of the local airport and air traffic. Via an additional question, the interviewees had the chance to mention actions by the airport management that could make their living situation better.

The percentage of respondents who mentioned positive aspects (76.5 %) was higher than the percentage of individuals mentioning negative aspects (51.9 %). However, perceiving positive aspects had no remarkable effect on rated aircraft noise annoyance while seeing negative aspects had. The negative aspects that were most often named and that had the highest relation to aircraft noise annoyance were the aircraft noise (in general), the nocturnal air traffic, the fear for health risks for residents, and a general decrease of the quality of life. Correlations ranged from $r \approx .2$ to .3. The results of the question about potential airport actions underline the significance of night-time air traffic as a major issue in the communities around Cologne/Bonn Airport. Almost two thirds of the respondents advocate for a complete or partly night ban for passenger and/or freight planes. Hence, a measure to reduce community annoyance in the vicinity of the airport would be the mitigation of nocturnal aircraft noise exposure. However, a curfew in the near future is rather unrealistic. The airport profits to a major extent from the fright traffic which is predominantly operated at night between 23:00 and 01:00 as well as around 04:00. Since not only the airport operator but also the state and the federal government are profiteers of Cologne/Bonn Airport, a legal regulation for a reduction or ban of night-time flights seems very unlikely. In 2008, the authorization for unrestricted night-time operations at Cologne/Bonn Airport was prolonged until the year 2030.

Whatever is planned to reduce noise annoyance, unwanted side-effects must be considered. A curfew probably would increase the flight density at the shoulder times of the night, i.e., in the late evening and early morning. Prior works have emphasized a high susceptibility to noise and the need for rest and quietness during these times besides the core night (Hoeger, 2004; Porter et al., 2000). At Frankfurt Airport where currently a curfew exists between 23:00 and 05:00 but air traffic density during the shoulder times is enhanced, community sleep quality and annoyance are currently investigated in the NORAH-project (Schreckenberg et al., 2011). Results have not been published yet. Nevertheless, with respect to Cologne/Bonn Airport, the recommendation is to focus on supplementary noise and annoyance abatement strategies besides a curfew as well, such as improved departure and approach procedures, a curfew for loud and heavy aircraft types, and an expansion of the grants for improved passive noise insulation (cf. the section on the effect of noise insulation on annoyance reduction).

Further airport actions that were suggested *by the residents* mainly referred to either long-term measures (e.g. changing the aircraft fleet) or to measures that require the involvement of further noise authorities besides the airport management, such as legislatures, local authorities, and also the air navigation service. An example for actions of the latter category was the relocation of flight paths and approach/departure routes. In contrast, measures that could be realized in the medium term, such as providing domestic noise insulation and a transparent information about proceedings and decisions at the airport were requested more seldom (11.6 and 0.7 %, respectively). The low rate of the wish for an open and comprehensive information flow counters the findings by Haugg, Kastner, and Vogt (2003) and Maziul and Vogt (2002) who applied a similar question. The authors asked airport residents what the airport could do to achieve and maintain a good neighborhood. Comprehensive information was the measure mentioned most often. The airports examined in those surveys were small and expanding. This circumstance accounts for the residents' higher need for information, above all about future developments. In contrast, Cologne/Bonn Airport is a steady-state airport where no expansion is currently planned. Hence, residents give priority to physical noise abatement procedures.

Nevertheless, with regard to the achievement of a good relationship between the airport and its residents, current proceedings, future airport scenarios, current and planned noise mitigation measures as well as their consequences for the community should be communicated comprehensively. In terms of an "integrated noise abatement strategy" (Bosshardt, 1988, p. 186), it is crucial that each noise abatement intervention is accompanied by explanations of the interventions as well as a realistic estimation of their effects and possible drawbacks. Moreover, it seems meaningful to resolve possibly too high expectations, for example, regarding a relocation of approach and departure routes or a mitigation of the noise exposure due to new departure or approach procedures. For instance, a local noise reduction at one place due to an improved departure procedure is always connected with a noise increase at another location (Isermann, 2013). In this context, the use of noise indicators which are transparent and understandable by the public is emphasized (Hooper, Maughan, Flindell, & Hume, 2009). A candid communication culture must be established by means of truthful and comprehensive explanations. Especially for the latter, due to possible mistrust in the airport and further noise authorities, it might be necessary to appoint an entity that is perceived as neutral and independent by the residents as well as the airport and the aviation industry. An example for such an entity is the so called *Umwelt- und Nachbarschaftshaus* (http://informationszentrum-umwelthaus.org) which is an information and communication center that was initiated by the Hessian state government as a consequence of the mediation process at Frankfurt Airport (cf. Hänsch, Niethammer, & Oeser, 1999). In consideration of the continuing debate on nocturnal air traffic, possible consequences for health (Greiser, 2009; Greiser et al., 2007) and the resulting fears for health consequences of the aircraft noise exposure of the residents, the conclusion for the airport Cologne/Bonn likewise is the initiation of a mediating instance. In this context, the findings of this work could contribute as groundwork for the dialog between residents affected by the aircraft noise exposure and the profiteers of the local airport and air traffic.

Part B: Field study

7 Methods of the field study

In the following chapter, the procedure of a field study is described that was conducted in two areas exposed to a high aircraft noise exposure with a day and night L_{Aeq} above 50 dB in the vicinity of Cologne/Bonn Airport. This in-depth study mainly focused on the investigation of short-term annoyance due to aircraft noise at daytime. Self-rated sleep quality at night was assessed as well but was of less importance for the present thesis. However, the investigation of sleep quality entailed consequences for the methodology, above all, for the participant selection and partly for the acoustical measurements. The second major topic of the field study was the examination of the perceived fairness of the allocation of aircraft noise as well as the decision-making and communication of noise authorities at Cologne/Bonn Airport.

7.1 Examination areas

The districts Cologne - Rath/Heumar and Siegburg - Kaldauen with Siegburg - Stallberg which were already considered in the telephone study (see Part A, Section 4.1) were selected as field study areas. In contrast to the telephone survey, for the field study, a larger part of the districts was considered so that the long-term aircraft noise exposure in the examination areas varied between $L_{Aeq,6\text{-}22}$ and $L_{Aeq,22\text{-}6}$, respectively, of 50 to 55 dB. The measurement points had to meet the following requirements: a) The measurement site was not primarily exposed to any other dominant noise source. b) The installation of an outdoor microphone in a preferably free-field position was feasible. c) The installation of the outdoor microphone did not pose any threat for any individual living in the surrounding neighborhood. Before the participant recruitment started, single streets within the designated examination areas were assessed to the effect whether they are suitable with regard to their background noise exposure. This was achieved by local inspections and short acoustical test measurements scattered across the areas.

7.2 Sample

7.2.1 Participants

Participants were male and female healthy individuals with a normal hearing ability corresponding to age and a permanent residence in one of the selected areas. The minimum age for participation was 18 years. A person was not eligible when one or more of the following exclusion criteria were met.

a) Hearing disorder and hearing loss: The individual indicated to suffer from tinnitus or any other hearing disorder. The individual rated his or her hearing ability as not normal or the hearing threshold measured in an audiometric screening exceeded an age-dependent limit. According to Böhme and Welzl-Müller (1998), these limits of hearing loss are
   - 10 % on at least one ear for individuals aged between 18 - 33 years
   - 15 % on at least one ear for individuals aged between 34 - 49 years
   - 20 % for individuals aged between 50 - 65 years
b) Diseases and health complaints: The individual indicated to suffer “extremely” from dominant physical or chronic sleeping disorder caused by illness
c) Regular night work
d) Infants up to an age of eight years were living in the household

Only individuals who do not suffer from any hearing disorder were selected to ensure participants’ undistorted hearing of the aircraft noise. Individuals who rated themselves as extremely suffering from any physical or sleeping disorder were not eligible as the study protocol was assumed to interfere with these individuals’ presumably higher needs for recreation. Furthermore, biased ratings of aircraft noise-induced annoyance seemed plausible. It is not completely clear whether the annoyance rating really reflects the annoyance due to the aircraft noise exposure or rather a general feeling of malaise mainly caused by the disease and influenced only to a minor extent by aircraft noise exposure. Households with small children were not selected as caring for small children, especially babies, has an enormous influence on the daily routine and sleep pattern. These particularities were expected to interfere with the study protocol. Individuals regularly working at night were not considered because a great effect of working in night shifts on the general sleep pattern and, thereby, possibly biased ratings of subjective sleep quality were assumed.

Per household up to three eligible individuals were allowed to participate. Participants signed a written informed consent form. After completing the entire field study, participants received an allowance of 250 €.

7.2.2 Participant recruitment and selection

Participants were recruited and selected in a multi-stage process. Applicants were firstly contacted during the telephone interview (see Part A, Section 4.4.2), via a postal flyer, or an online announcement on the homepage of the DLR - Institute of Aerospace Medicine. To minimize the number of applicants living in streets with a high background noise, an attempt was made to send flyers only to those streets and areas which were known to be exposed primarily to aircraft noise. Information from prior acoustical measurements and local inspection (cf. Section 7.1) was used. However, flyers were delivered by the German post office ("Deutsche Post AG") in accordance with fixed mail distributing districts. Therefore, single noisy street could not be left out completely beforehand.

Applicants received detailed information about the study protocol and were requested to complete a questionnaire that was compiled on the basis of the exclusion criteria described above. Applicants who did not meet any of the exclusion criteria were visited at their residence for an acoustical one-hour test measurement in order a) to rule out the participants' exposure to noise from sources other than air traffic and b) to ensure the feasibility of the installation of an outdoor microphone in free-field position. In addition, an audiometric screening was conducted to test the applicant's hearing threshold according to age. In case of more eligible applicants than required after this selection stage, participants were selected in accordance to the age statistics of the areas and by random.

With the arriving of their application letter or e-mail, applicants received a subject code that was used during the whole selection process and the subsequent field examinations. Survey data were anonymized. The regulations of data protection were adhered to.

7.3 Examination protocol

The general examination protocol of the COSMA field study was developed to a major part on the basis of the experiences gained in the field studies by Schreckenberg and Meis (2006; 2007a) and Stearns, Brown, and Neiswander (1983). The protocol preset four not necessarily consecutive days with a continuous recording of the outdoor sound pressure level. Recording the aircraft noise levels was presumed to be methodically advantageous to calculating the levels. Thereby, it was feasible to gain information about the background noise and, thus, to derive noise indicators that take into account background levels, such as the ratio of (maximum) aircraft noise to background noise. Moreover, noise descriptors that require an exact measurement of the aircraft noise level, such as the time influenced by aircraft noise and the exact slope of rise of single aircraft noise events could be obtained.

During the four examination days, the participants were instructed to repetitively rate their annoyance due to aircraft noise during the preceding hour. Participants were requested to assess their annoyance at the top of every hour from the time they got up until they went to bed. Two examination days were performed on weekdays, the other two ones at the weekend in order to test a possible effect of the day of the week on annoyance ratings. The hourly assessment presupposed that the participant stayed at home or at least in the near neighborhood for the whole day. Everyday activities could be carried out as usual. In addition, participants filled out a so-called morning questionnaire in the morning of each of the four examination days in order to rate their subjective sleep quality during the preceding night.

Furthermore, long-term aircraft noise-induced annoyance during the past 12 months and potential non-acoustical influence factors of annoyance were ascertained. The assessment was realized via an opening plus a concluding interview on a day prior to the beginning of the hourly annoyance examinations and the day after the last hourly annoyance assessment period, respectively.

Subsequent to the four days of continuous acoustical recording and repetitive annoyance assessments, two one-hour sessions on two separate days for the investigation of the sound quality of single fly-overs were performed. These examinations, however, are not part of this thesis. In total, the participants were engaged in study activities during seven days. Table 13 summarizes the study protocol.

Table 13
Protocol of the examinations in the in-depth field study

Examination day	Action items
1	Opening questionnaire Participants' instructions
2 - 5	Morning questionnaire Hourly assessment of short-term aircraft noise annoyance from getting up till going to bed Continuous recording of sound pressure level
6	Concluding questionnaire One-hour examination for the assessment of sound quality of single fly-overs; recording of all aircraft and background sounds
7	One-hour examination for the assessment of sound quality of single fly-overs; recording of all aircraft and background sounds

The field study protocol with all materials and measurements was tested in a pilot test with three participants living in the selected field study areas in April and May 2011. Two participants were females. The mean age was 59.7 years covering a range from 46 to 69 years.

Since no major revisions were necessary, the main examinations of the field study started mid of June and lasted until mid of November 2011. The study was conducted by three researchers of the Institute of Aerospace Medicine of the DLR plus two student assistants. Experimenters and assistants were trained using written instructions and received supervision during their first interviews and acoustical measurements. The procedure of the field study was approved by the Chamber of Physicians North Rhine.

7.4 Materials and measurements

7.4.1 Questionnaires

The following section shortly outlines the questionnaires and scales used in the present field study. The entire questionnaires and scales can be found in Appendix D in an English version which was likewise applied in a field study at London Heathrow Airport (United Kingdom). All questions were implemented on netbooks (DELL, Inspiron Mini 10) using stand-alone survey software. This software was developed with the program language C++ under the operation system Linux by the Leibniz Research Centre for Working Environment and Human Factors (IfADo) in Dortmund.

Opening and concluding questionnaire

The questionnaires for the opening and concluding interview were an extension of the questionnaire used in the telephone survey (see Part A, Section 4.4.2). The opening interview contained questions about long-term annoyance and activity disturbance due to aircraft noise in the past 12 months. Long-term annoyance due to aircraft noise was assessed using the question and the semantic answer scale recommended by the ICBEN and ISO15666:2003(E) (Fields et al., 2001; ISO, 2003). Indoor and outdoor activity disturbance was examined using an adoption of the ICBEN question and scale (Fields et al., 2001). The ascertainment of non-acoustical factors which may affect annoyance ratings was part of the opening interview as well as the concluding interview. Questions referred to demographics (e.g., age, gender, education, occupation, homeownership, length of residence), the participant's general sensitivity to noise (NoiSeQ-R: Griefahn, Marks, Gjestland, & Preis, 2007), and further personal variables as the satisfaction with the residential area, personal use of and economic dependence on the airport, and expectations regarding future aircraft noise exposure. Further questions and items examined the respondents' attitudes and beliefs about the airport Cologne/Bonn and the local air traffic in general. In addition, the participants were asked

a) who, that is, which authorities, in their view, have influence on aircraft noise exposure, b) how much control these authorities exactly have over the aircraft noise as well as c) the perceived effort these authorities make to consider the residents' views and needs. Furthermore, respondents were asked about possible noise insulation of the home, measures undertaken to cope with the aircraft noise as well as suggestions for airport actions for an improvement of the residents' situation[14].

With few exceptions, all variables were obtained either by closed question format using the semantic five-point answer scale recommended by the ICBEN and ISO15666:2003(E) (Fields et al., 2001; ISO, 2003) or by open questions with answer options which were visible only to the interviewer. Open format questions were preceded by filtering questions that could be answered by either "yes" or "no". For those variables that could not be ascertained via the ICBEN scale (cf. Fields et al., 2001; ISO, 2003), likewise semantic five-point scales were used. The sequence of the response scales that have been read out by the interviewer were inverted by random. Half of the participants received answer scales starting with the highest answer category (e.g. "extremely") and the other half always received answer scales starting with the lowest category ("not at all"). Both the opening and the concluding interview were performed as computer-assisted personal interview. To simplify the interview process, answer scales were administered to the interviewee as paper versions.

Excurse: Questionnaire for perceived fairness

To the author's knowledge, no questionnaire or survey instrument for fairness examinations in the context of noise exposure exists. Therefore, within the framework of the COSMA-project, a new questionnaire was developed and tested with the participants of the present field study. This new questionnaire is an indirect fairness measure (cf. Colquitt & Shaw, 2005). Instead of directly asking how fair an allocation or decision is it assesses criteria of fairness found in seminal works in justice research. The measure orients at the justice measure composed by Colquitt (2001) and Shapiro, Buttner, and Barry (1994). Thereby it refers to the criteria postulated by Thibaut and Walker (1975), Leventhal (1980) and Bies and Moag (1986). A draft version of the questionnaire contained all criteria postulated by the authors listed above comprising items for *process control* and *decision control*, *consistency*, *accuracy*, *correctability*, *bias suppression*, *ethicality*, *truthfulness,* and *justification* as well as *respect*

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[14] Supplementary, respondents rated their general affectivity (PANAS: Watson, Clark, & Tellegen, 1988) and the amount of control they belief to have over the aircraft noise exposure. Furthermore, respondents were asked whether they have perceived any aviation-related media coverage. These variables and the ones listed above were ascertained with the purpose of the development of a prediction model of long-term aircraft noise annoyance analogous to the prediction model of the telephone study. However, the analysis and interpretation of this model is not part of the present dissertation thesis.

and *propriety*. A small-scale pilot test ($N = 5$) and the subsequent item analyses showed that subjects found it difficult or even impossible to rate items concerning the criteria *consistency over time*, *bias suppression*, and *ethicality*. The concerning items were skipped for the final questionnaire version. None of the participants of the pre-test who were airport residents ever had personal contact to any aircraft noise authority and, hence, could rate the items addressing the *interpersonal fairness* of the communication of these authorities. The final version of the fairness questionnaire was expurgated from this scale as it was assumed that the lack of personal contact to noise authorities were also true for the majority of the whole population of airport residents around Cologne/Bonn Airport. In the end, the fairness questionnaire comprised ten items covering the dimensions *distributive fairness, procedural fairness,* and *informational fairness* as well as a directly and globally formulated control item for the purpose of validation. Table 14 shows the questionnaire items with the corresponding dimensions and fairness rules.

To rate agreement with the statements, subjects used a five-point Likert response scale comprising the response options 5 = “strongly agree”, 4 = “slightly agree”, 3 = ”partly… partly…”, 2 = “slightly disagree”, and 1 = “strongly disagree”. Hence, high item or scale scores correspond to a high perceived fairness. In order to prevent participants from marking the middle category in case of uncertainty or disapproval of a question (cf. Bortz & Döring, 2006; Bühner, 2004) and to get information about possible difficulties to rate certain items, the additional answer category “do not know” was provided.

With one exception, the presumed outcomes of fairness were assessed with a semantic five-point response scale (cf. Fields et al., 2001; ISO, 2003) ranging from 1 = “not at all” to 5 = “extremely” and the following questions:

- *Aircraft noise annoyance*: “Thinking about the last 12 months, when you are at home, how much does aircraft noise bother, disturb or annoy you overall?”
- *Satisfaction with residential area*: “How satisfied are you with your local area?”
- *Trust in authorities*: “How much do you think any of these authorities (the authorities mentioned in the preceding question) take into account the individual opinions of the residents?”

The variable *attitude towards the local airport* that was expected to be an additional outcome of fairness was assessed with a differing five-point response scale ranging from 1 = ”very negative” to 5 = “very positive” and the question “What is your general attitude towards the airport?”

Table 14

Items of the fairness questionnaire

	Item	Dimension	Rule (author)
1.	Aircraft noise is distributed fairly amongst all residents.	Distributive	Equality (Leventhal, 1980)
2.	When decisions concerning aircraft noise are being made, I have opportunities to express my views to the relevant people.	Procedural	Process control (Thibaut & Walker, 1975)
3.	When decisions concerning aircraft noise are being made, I can have influence over the results of the decision process.	Procedural	Decision control (Thibaut & Walker, 1975)
4.	During these decision-making processes, the interests of some residents take precedence over the other residents' interests. (R)	Procedural	Consistency over people (Leventhal, 1980)
5.	Sufficient information is gathered before decisions concerning aircraft noise are made.	Procedural	Accuracy (Leventhal, 1980)
6.	In those decision-making processes, decisions are often made on the basis of inaccurate information. (R)	Procedural	Accuracy (Leventhal, 1980)
7.	I have the chance to appeal decisions that I consider as wrong.	Procedural	Correctability (Leventhal, 1980)
8.	Decisions concerning aircraft noise are explained and justified to me in detail.	Informational	Justification (Bies & Moag, 1986)
9.	I am often kept in suspense about a decision for a long time. (R)	Informational	Truthfulness (Bies & Moag, 1986)
10.	In general, I feel fairly treated concerning aircraft noise.	-	-

Note: (R) This item is inverted.

Questionnaire for the assessment of short-term annoyance

The reiterating, very short survey for the assessment of short-term noise annoyance consisted of two parts: Firstly, short-term annoyance in the preceding hour was ascertained by means of the question "Thinking about the past hour, how much did aircraft noise as a whole bother, disturb or annoy you?" which is an adaption of the ICBEN question (cf. Fields et al., 2001; ISO, 2003). Secondly, the situation when the aircraft noise occurred was characterized. Respondents were requested to indicate the activity they have mostly been carrying out in the past hour and to rate the disturbance of this activity due to the aircraft noise. The participants could choose between eight activity categories plus the category "others" which requested a specification of the activity then. The activity categories were defined in the style of the categories used by Felscher-Suhr et al. (1996): a) conversation including telephoning, b) watching TV/listening to the radio, c) mental work including concentrating, reading, working at the computer, d) physical activity including homework, gardening, and sports, e) leisure activities, for instance, painting, playing an instrument, and tinkering, f) relaxation, g) socializing with friends and family, and h) eating. Multiple choices were possible. Furthermore, the whereabouts (indoors vs. outdoors or away from the area) and, if necessary, the position of the windows (closed, partially open, wide open) was surveyed. Participants autonomously filled in the questionnaire, i.e., without being supervised by an experimenter. For this purpose, they used a netbook and the survey software described at the beginning of this section. Participants were reminded of the hourly rating task by a signal tone from the netbook which could be adjusted in its volume.

Morning questionnaire

The morning questionnaire was completed autonomously by the participants on the netbook after getting up at each of the four examination days. The questionnaire contained six questions about sleep quality of the past night (e.g., “Sleep depth was … 0 = very shallow – 10 = very deep”, Griefahn et al., 2006) and additional questions about the times of going to bed and getting up as well as possible problems to fall asleep or to sleep through.

7.4.2 Acoustical measurements

Measurement of the outdoor to indoor attenuation

The acoustical measurement of the field study did not only focus on outdoor metrics. The aircraft noise levels at the participant’s whereabouts were estimated as well. A continuous acoustical measurement exclusively inside the house did not seem meaningful due to the high background noise that is produced mainly by the participants themselves carrying out daily activities, such as communication or housework. Average aircraft noise levels inside the house have been shown to be often lower than noise levels of non-aircraft events (Stearns et al., 1983). Thus, background noises were expected to impede a subsequent identification of fly-overs or to mask aircraft noise completely, especially when windows are kept closed. A measurement of the outdoor to indoor attenuation in terms of a level difference was performed to facilitate a post-hoc estimation of indoor levels on the basis of outdoor recordings. This attenuation measurement was conducted for all typical window positions in the room the participant usually spends the most time in at daytime (most often the living-room or home-office) plus in the sleeping room. For this purpose, the outdoor microphone was installed ideally in a free-field outdoor position (cf. Normenausschuss Akustik, Lärmminderung und Schwingungstechnik (NALS) im DIN und VDI, 2004), i.e., four meters above the ground and in minimum five meters away from reflecting vertical surfaces. The indoor microphone in the sleeping room and the room where the participant preferably stays during the day likewise was installed as far away as possible from reflecting vertical surfaces. For the attenuation measurement in the sleeping room, the microphone was positioned near the participant's pillow. For three fly-overs at the minimum, sound pressure levels with an *A-frequency* and a *slow*-weighting (L_{As}) were recorded simultaneously using Class-1 sound level meters (NORSONIC Nor 140) in the different outdoor and indoor locations. Data were logged with a sampling frequency of one second. Figures 15a to 15c illustrate the location of the outdoor and indoor microphone during the attenuation measurement.

Fig. 15a.

Fig. 15b.

Fig. 15c

Figures 15a-c. Example positions of microphones during the measurement of outdoor to indoor attenuation. Outdoor microphone in free-field position (a), indoor microphone in the bedroom (b), indoor microphone in the main habitable room (c).

Continuous sound pressure level recordings and identification of fly-overs

The continuous recording of the sound pressure level across four days and nights was performed by a Class-1 sound level meter (Norsonic Nor 140) and an outdoor microphone installed in the same free-field position as during the measurement of outdoor to indoor attenuation. To warrant participants' sphere of privacy, only sound pressure levels but no sounds were recorded. The sound pressure level was logged with an *A-frequency* and a *slow*-weighting (L_{As}) in the interval of one second.

Aircraft fly-overs were identified and marked manually by the author of this thesis. Since no sounds were recorded, only the sound level writings could be used to identify fly-overs and to distinguish them from background sounds. For the identification and mark of aircraft fly-overs, the program NorReview 4.0 (Norsonic) was used that graphically displays the sound pressure level writings. The premises for the identification of a certain level writing sequence as fly-over were a) an exceedance of the background level during a minimum of 20 s, b) a continuous rise and fall of the level, c) a peak level that exceeded the background level by 5 dB at a minimum, and d) the match of the sequence presumed to be a fly-over with the flight schedule of Cologne/Bonn Airport.

Calculation of acoustical parameters

From the sound level recordings and the fly-over marker times, for every participant and for every hour during the day, a multitude of acoustical parameters for the outdoor exposure was calculated. By means of the information about the participant's whereabouts and, if necessary, the window position that was reported in the survey for the hourly annoyance assessment, several personalized noise indicators could be derived that take into account a possible outdoor to indoor attenuation of the aircraft noise levels. All calculations of acoustical parameters were performed by the Department of Networked Systems and Services of the Budapest University of Technology and Economics. Table 15 lists and shortly outlines the noise descriptors that were calculated.

Table 15

Noise indicators derived from the continuous sound pressure level recordings

Noise indicator		Description
Number of aircraft (N_{AC})/number above threshold (NAT_{xx})		
N_{AC}		Number of aircraft in total.
$NAT_{55/60/65/70/75/80/85}$		Number of aircraft fly-overs with a maximum level above 55/60/65/70/75/80/85 dB(A) per hour.
Time with aircraft noise		
total AC time [min]		Overall time in minutes influenced by aircraft noise.
mean AC time [s]		Mean duration of fly-over events in seconds.
Energy-equivalent sound pressure levels (L_{Aeq})		
$L_{Aeq,total}$	p	*A*-weighted energy equivalent sound pressure level (L_{Aeq}) considering both aircraft and background noise in dB.
$L_{Aeq,bkgd}$		L_{Aeq} for background (bkgd) noise of the whole hour in dB.
$L_{Aeq,AC}$	p	L_{Aeq} for aircraft (AC) noise of the whole hour in dB.
Maximum sound pressure levels (L_{Amax}) and statistical metrics (L_X)		
L_1	p	Sound pressure level in dB(A) which is exceeded in 1% of the time.
$L_{0.1}$	p	Sound pressure level in dB(A) which is exceeded in 0.1% of the time.
max $L_{Amax,AC}$	p	Maximum level for aircraft noise in dB across one hour (= maximum of the L_{Amax} of all fly-overs).
mean $L_{Amax,AC}$	p	For each individual fly-over per hour, the L_{Amax} value in dB is computed. This parameter is the mean value from them.
(Max) Aircraft to background noise ratio (*SNR* and *MNR*)		
SNR		Signal to Noise Ratio (SNR) across one hour, with $L_{Aeq,AC}$ is defined as "signal" and $L_{Aeq,bkgd}$ is defined as "noise".
max SNR		For each individual fly-over per hour, the *SNR* value (aircraft- vs. background noise) is computed. The *max SNR* parameter is the maximum value from them.
mean SNR		The same as before, but the *mean SNR* parameter is the mean value across all individual *SNR* values.

Note. For the parameters marked with "p", also personalized values are available that take into account the outdoor to indoor attenuation in case the respondent had stayed mostly indoors.

Continuation of Table 15

Noise indicators derived from the continuous sound pressure level recordings

Noise indicator	Description
max MNR	For each individual fly-over per hour the *MNR* value (maximum level of the aircraft noise vs. background noise) is computed. The *max MNR* parameter is the maximum value from them.
mean MNR	The same as before, but the *mean MNR* parameter is the mean value across all individual *MNR* values.
Slope of rise	
max Rise	Maximum of the rise time speed in dB(A)/s of all fly-overs.
mean Rise	Mean of the rise time speed dB(A)/s of all fly-overs.

Note. For the parameters marked with "p", also personalized values are available that take into account the outdoor to indoor attenuation in case the respondent had stayed mostly indoors.

7.5 Statistical analysis

Statistical analyses of the field study data were carried out using the statistical analysis software SPSS 20 (IBM). In case calculations could not be performed with SPSS 20, the source of the equation used for the manual calculation is given hereinafter.

7.5.1 Research question B 1: Predictors of short-term annoyance due to aircraft noise

The central research question of the field study was how acoustical as well as situational and personal variables contribute to short-term annoyance induced by aircraft noise. The ultimate goal was a comprehensive prediction model for short-term annoyance ratings which takes into account acoustical as well as changing and rather time-invariant non-acoustical factors. For this purpose, the influence of a multitude of acoustical parameters and the impact of the situational non-acoustical variables *time of day*, *day of the week,* and type of *activity* that was carried out mostly during the past hour were examined separately first. In the second step, those variables contributing significantly to annoyance were combined in a more complex prediction model. At last, rather time-invariant personal factors which have been found to influence annoyance in the telephone survey (cf. Section 5.4) were included as additional predictors. For every stage of the model development, a regression analytic approach was needed that considers the repeated measurements for every participant and which allows a predictor selection on the basis of an established selection criterion. Hereto, Generalized Estimating Equations (GEE) for linear models (Liang & Zeger, 1986; Zeger & Liang, 1986) were applied. Moreover, the GEE approach has the advantage that it makes no assumption about the normality of residuals. *AR(1)* was chosen as working correlation matrix. The within-subjects variables that were characterizing the repeated measurements were *study day* and *time of day*. For the quantification of the fit of a model and as criterion for the predictor selection, the *QIC* was used that is an adaption of the Akaike Information Criterion, *AIC*, for Generalized Estimating Equations (Pan, 2001).

7.5.2 Research question B 2: The relation between short-term and long-term annoyance due to aircraft noise

Before the relation between long-term and short-term reactions to noise could be assessed, the representativeness of the acoustical measurements made during the field study needed to be examined. For this purpose, the equivalent aircraft noise level for the six months with the highest air traffic density per year was compared to the equivalent aircraft noise level measured across the four field study days and nights. For those participants whose short-term and long-term exposure did not differ by more than 5 dB, the relation between short-term and long-term annoyance was assessed. Hereto, for every participant, the mean one-hour aircraft noise annoyance was calculated, first. These values were compared to the respondents' long-term aircraft noise annoyance ratings using a paired t-test. Pearson's *r* was used to assess the association between the short-term and long-term annoyance ratings. In addition, in a multiple linear regression model, the participants' general aircraft noise annoyance ratings over the past 12 months were regressed to their mean one-hour annoyance in combination with their mean subjective sleep quality during the field study nights.

7.5.3 Research question B 3: Evaluation of aircraft noise authorities

Research question B 3.1: Evaluation of authorities' influence on aircraft noise exposure and of their will to act in the residents' interest

For the analysis of the evaluation of noise authorities by the respondents, the two questions about authorities' amount of control over the aircraft noise exposure and the amount of effort they actually make to act in the residents' interest were graphically compared to each other. Furthermore, the relation between the perceived effort of the noise authorities and the respondents' reported aircraft noise annoyance over the past 12 months were assessed using Person's *r*.

Research question B 3.2: Perceived fairness of air traffic-related decision-making and the allocation of aircraft noise at Cologne/Bonn Airport

For the analysis of the fairness items and subscales, the items 4, 6, and 9 needed to be recoded first as they were inverted. For all items, descriptive statistics and item difficulty (see Bortz & Döring, 2006, p. 219) were calculated. The internal consistency of the proposed subscales *procedural* and *informational fairness* was assessed using Cronbach's coefficient α. Furthermore, the items were tested for their homogeneity, $\bar{r}_{ii'}$ (Bortz & Döring, 2006, p. 220) and their discriminatory power assessed by the corrected item-total correlation, $r_{j(t-j)}$. Items with a discriminatory power below $r_{j(t-j)}$ = .3 or negative values were excluded from the subscale (Bortz & Döring, 2006). Item 10 was not considered in the consistency analysis as it was formulated as global and direct fairness statement that was used as validation measure.

To test the validity of the construct, i.e., the dimensionality of fairness, a principle components analysis with a VARIMAX rotation was calculated. In addition, the scores of the subscales were correlated to the global direct fairness statement as well as to the presumed outcomes *general aircraft noise annoyance*, *aircraft noise annoyance at night*, *satisfaction with the residential area*, *trust in authorities,* and the *attitude towards the airport*. Hereto, Pearson's correlation coefficient *r* was applied. The scores of the subscales were defined as the mean rating of the corresponding subscale items. No score for a subscale was calculated in case more than one item per subscale was rated with "do not know".

8 Results of the field study

8.1 Sample statistics

About 500 individuals from the vicinity of Cologne/Bonn Airport applied for a participation in the field study. Among these, 383 applicants received a questionnaire as a first selection instrument (cf. Section 7.2.2). All other applicants were rejected immediately because of a dominant road traffic noise exposure which was known from prior acoustical test measurements and local inspections (cf. Section 7.1). 281 completed questionnaires returned to the DLR. Based on the answers in the questionnaire, 100 applicants from 76 households were chosen for a further selection stage containing an audiometric screening, a health checklist and an acoustical measurement at home. Out of the 100 applicants, 23 were not eligible for participation due to the fulfillment of one or more of the following exclusion criteria: reduced hearing ability (n = 13), a background noise exposure which masked aircraft fly-over sounds (n = 7), and no possibility for a safe installation of the outdoor microphone (n = 5). One eligible applicant was not interested anymore in participating after receiving comprehensive information about the study protocol. In the end, 57 individuals were selected for the field examinations. Further 19 individuals were regarded as eligible with reservations and were therefore selected as standby participants. Since all 57 selected participants took part in the study, none of the standby participants had to be tested.

After the termination of the field study, data of 2 of 57 selected individuals had to be excluded from further analyses. Data of a male individual (from Cologne - Rath/Heumar, 70 years of age) was discarded due to the diagnosis of a hearing loss after he had already started the annoyance examinations[15]. Another male participant (from Siegburg - Stallberg, 51 years of age) was not able to complete the study because of a disc prolapse and necessary therapy that followed. Out of the remaining 55 participants from 41 sites, 34 individuals were female (61.8%) and 21 were male (38.2 %). Age ranged from 18 to 70 years (M = 45.7, SD = 14.3). Table 16 shows the age distribution in the sample in comparison with the actual age statistics in the two examined areas (Cologne - Rath/Heumar and Siegburg - Stallberg with Siegburg - Kaldauen) which were provided by the local registration offices. The category reaching from 45 to 54 years was overrepresented whereas individuals in the age between 25 and 44 years were underrepresented. The latter was mostly due to the fact that residents with small children up to eight years were not considered (cf. Section 7.2.1).

[15] As the audiometer was not available, in this case, the audiometric screening could not be run earlier.

Table 16

Age statistics of the field study sample in comparison to the actual age statistics in the examined areas

Age category	Number of participants	Proportion in the sample (%)	Actual proportion of residents ≥18 years in the two examined areas
18 - 24	8	14.5	9.4
25 - 34	3	5.5	13.1
35 - 44	7	12.7	18.2
45 - 54	26	47.3	19.1
55 - 64	6	10.9	14.6
65 - 74	5	9.1	14.7
≥ 75	0	0.0	10.9
Total	55	100.0	100.0

During the empirical study, 19 participants (34.5 %) were not employed and 32 individuals (62.7 %) were employed. Four participants (7.3 %) did not make any statement about their employment. Table 17 shows the employment statistics in more detail.

The mean length of residence was 14.3 years (*SD* = 9.9) covering a range of 2 to 54 years. 45 participants (81.8 %) were homeowners. 42 participants lived in Siegburg - Stallberg or Siegburg - Kaldauen and 13 participants lived in Cologne - Rath/Heumar.

Table 17

Statistics of unemployment and employment in the field study sample

Characteristic	*n*	%
Unemployed		
Pensioner	7	36.8
Homemaker	6	31.6
Temporarily unemployed	2	10.5
Still in training/never been employed so far	4	21.1
Total	19	100.0

Continuation of Table 17

Statistics of unemployment and employment in the field study sample

Characteristic	*n*	%
Employed		
White-collar worker	19	59.4
Blue-collar worker	0	0
Civil servant	5	15.6
Self-employed	5	15.6
Executive	3	9.4
Total	32	100.0

8.2 Aircraft noise exposure during the field study

The following section focuses on the results of the continuous recordings of the sound pressure level at 41 sites within the two examination areas. At first, the number of acoustically evaluable examination periods and the reasons for discarding recordings of certain periods are described. Afterwards, the aircraft noise exposure during the field study is characterized by means of several noise descriptors. The third part of the section describes changes of the aircraft noise exposure in the course of the day.

8.2.1 Results of the continuous recording of sound pressure levels

The 55 participants rated their aircraft noise-induced annoyance within a total of 2,988 examination periods of one hour each. For 60 periods, participants indicated that they were temporarily away from the neighborhood and therefore, the acoustical recordings were excluded from further analyses. The recordings of additional 132 examination periods had to be discarded because of inaccurate acoustical measurements due to a) a defect of the microphone and b) unforeseeably high background noise and weather conditions which were masking the aircraft fly-over sounds. For 11 periods, participants were not able to state their whereabouts and window positions due to a software error. Noise metrics for these periods were not calculated, either. In total, 2,785 evaluable examination periods for an *acoustical* analysis were available.

8.2.2 Aircraft noise exposure during the field study

The number of aircraft fly-overs during each hour ranged from 0 to 21 (M = 6.83, SD = 3.76). 55 examination periods did not feature any aircraft fly-over. It did not seem meaningful to set the energy equivalent sound pressure level for aircraft noise ($L_{Aeq,AC}$) and the maximum aircraft noise level ($L_{Amax,AC}$) to zero. Hence, all noise descriptors that are based on the $L_{Aeq,AC}$ or the $L_{Amax,AC}$ were calculated only for the 2,730 examination periods with at least one fly-over. Additionally, for 41 examination periods no valid slope of rise could be determined for aircraft noise events. Consequently, the sample of examination periods for the acoustical descriptor *slope of rise* was reduced to 2,689. Table 18 summarizes measures of central tendency and dispersion for the noise descriptors measured in the field study.

Table 18

Measures of central tendency and dispersion for the one-hour noise descriptors

Noise descriptor	*N*	*Min*	*Max*	*M*	*SD*
Number of aircraft (N_{AC})/number above threshold (NAT_{xx})					
N_{AC}	2,785	0.00	21.00	6.83	3.76
NAT_{55}	2,785	0.00	20.00	6.74	3.74
NAT_{60}	2,785	0.00	20.00	6.14	3.67
NAT_{65}	2,785	0.00	19.00	4.60	3.45
NAT_{70}	2,785	0.00	18.00	1.90	2.41
NAT_{75}	2,785	0.00	13.00	0.47	1.08
NAT_{80}	2,785	0.00	3.00	0.07	0.29
NAT_{85}	2,785	0.00	1.00	0.01	0.08
Time with aircraft noise					
total AC time [min]	2,785	0.00	34.20	7.89	4.79
mean AC times [s]	2,785	0.00	141.33	67.37	16.62
Energy equivalent sound pressure levels (L_{Aeq})					
$L_{Aeq,total}$	2,785	40.06	70.92	53.69	3.67
$p\ L_{Aeq,total}$	2,785	2.60	70.15	34.55	11.17

Note. *AC* abbreviated for aircraft, *p* denotes personalized measures which consider the participant's whereabouts.

Continuation of Table 18

Measures of central tendency and dispersion for the noise descriptors

Noise descriptor	*N*	*Min*	*Max*	*M*	*SD*
$L_{Aeq,bkgd}$	2,785	33.05	68.60	47.34	4.50
$L_{Aeq,AC}$	2,730	32.75	65.83	51.40	4.59
$p\ L_{Aeq,AC}$	2,730	0.65	60.51	32.31	11.37
Maximum sound pressure levels (L_{Amax}) and statistical metrics (L_X)					
L_1	2,785	44.40	86.30	65.62	4.35
$p\ L_1$	2,785	5.95	82.60	46.49	11.40
$L_{0.1}$	2,785	46.70	94.80	70.92	4.99
$p\ L_{0.1}$	2,785	7.95	84.70	51.79	11.64
$max\ L_{Amax,AC}$	2,730	54.40	93.30	72.05	4.92
$p\ max\ L_{Amax,AC}$	2,730	23.40	86.70	52.97	11.53
$mean\ L_{Amax,AC}$	2,730	52.10	83.90	67.32	4.28
$p\ mean\ L_{Amax,AC}$	2,730	23.40	79.20	48.23	11.31
(Maximum) Aircraft noise to background noise ratio (*SNR* and *MNR*)					
SNR	2,730	-23.85	21.31	4.10	6.01
max SNR	2,730	-1.26	36.72	17.23	4.99
mean SNR	2,730	-1.26	30.70	12.73	4.64
max MNR	2,730	2.72	46.02	25.48	5.92
mean MNR	2,730	2.72	40.71	20.09	5.53
Slope of rise					
max Rise	2,689	0.22	2.34	1.03	0.23
mean Rise	2,689	0.22	1.74	0.81	0.18

Note. *AC* abbreviated for aircraft, *bkgd* abbreviated for background, *max* abbreviated for maximum, *p* denotes personalized measures which consider the participant's whereabouts.

Furthermore, it was tested whether the aircraft noise exposure during the study period differed between Cologne - Rath/Heumar and Siegburg - Stallberg/Kaldauen. For this purpose, the $L_{Aeq,AC}$ was calculated for the period between the time the participants went to bed in the first night (i.e., the night before the first examination day) until the time when the participants made their last annoyance assessment at the last examination day. The $L_{Aeq,AC}$ for the two areas was virtually identical, Cologne - Rath/Heumar: M = 53.20 dB, SD = 2.65 dB, *range* = 48.41-57.42 dB; Siegburg - Stallberg/Kaldauen: M = 53.35 dB, SD = 2.29 dB, *range* = 46.11-57.89 dB.

8.2.3 Aircraft noise exposure in the course of the day

To display the fluctuation of aircraft noise exposure during the day, the trend of the two widely used noise descriptors number of aircraft (N_{AC}) and the A-weighted energy equivalent sound pressure level for aircraft noise ($L_{Aeq,AC}$) are depicted in Figure 16. In addition, Figure 16 shows the trend of the personalized A-weighted energy equivalent sound pressure level for aircraft noise ($p\ L_{Aeq,AC}$) which considers the outdoor to indoor attenuation due to the participant's whereabouts and the window position in the preceding hour. The graph of the $L_{Aeq,AC}$ reflects quite well the number of aircraft in the past hour. In contrast, the graph of the $p\ L_{Aeq,AC}$ deviates significantly from both the $L_{Aeq,AC}$ and N_{AC} curves.

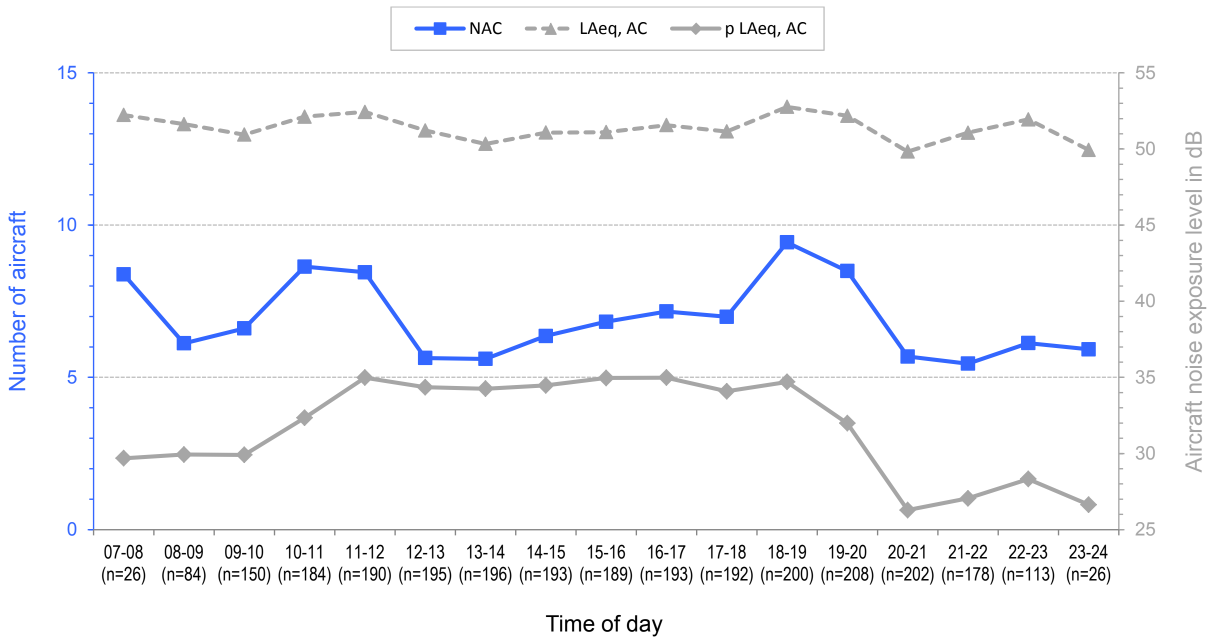

Figure 16. Aircraft noise exposure in the course of the day from 07:00 to 24:00 represented by the noise descriptors number of aircraft (N_{AC}), A-weighted, energy-equivalent sound pressure level for aircraft noise ($L_{Aeq,AC}$), and the personalized A-weighted, energy-equivalent sound pressure level for aircraft noise ($p\ L_{Aeq,AC}$) . Only time periods with a sample size of $n \geq 10$ are presented, N = 2,719.

The trend of the $p\ L_{Aeq,AC}$ obviously results from the window-closing behavior and whereabouts of the participants: The highest rates of open or partially open windows was found for the time between 07:00 and 08:00 (57.7 %) and between 09:00 to 13:00 (51.6-57.3 %). During the rest of the day, the corresponding rates varied between 26.5 %

(22:00-23:00) and 48.2 % (15:00-16:00). For the time between 11:00 and 19:00, 17.9 to 25.4 % of the participants indicate whereabouts outside the house. At other times of the day, the corresponding percentage ranged from 3.4 % (21:00-22:00) to 12.5 % (19:00-20:00).

8.3 Short-term annoyance during the field study

For the description of short-term annoyance during the field study examinations, only the examination periods during which the participant was present in the near neighborhood (N = 2,928) were considered. This number results from the total number of examination periods (N = 2,988) minus the number of periods when the participant was away from the neighborhood (n = 60). The mean number of examination periods during which the participants were at home or in the near neighborhood varied per subject between 26 and 72 (M = 53.24, SD = 7.21). Due to this high variability, it did not seem reasonable to report the mean rated short-term annoyance averaged over all the 2,928 examination periods. Instead, the averaged mean annoyance rating per participant is given here. Mean short-term annoyance was 1.76 (SD = 0.55) on a scale from 1 = “not at all” to 5 = “extremely” bothered, disturbed or annoyed. The participants’ mean short-term annoyance ratings varied between 1.00 and 2.89. To examine potential differences in the mean short-term annoyance ratings between Cologne - Rath/Heumar and Siegburg - Stallberg/Kaldauen, a t-test was calculated. The results showed no significant mean difference between Cologne - Rath/Heumar (M = 1.74, SD = 0.56) and Siegburg - Stallberg/ Kaldauen (M = 1.77, SD = 0.55), $t(53) = -.17$, $p = .865$ (two-tailed testing). Therefore, the participants from the two areas are treated as one sample for the following analyses.

Annoyance responses for *single* examination periods varied between 1 and 5. However, as Figure 17 demonstrates, among the in total 2,928 annoyance ratings, the response options 4 (“very annoyed”) and 5 (“extremely annoyed”) were chosen very seldom (n = 164 and n = 10, respectively). The single short-term annoyance ratings were not normally distributed as it was shown in a Kolmogorov-Smirnov test ($z = 16.42$, $p < .001$) as well.

The total number of completed annoyance assessments varied considerably with the time of day covering a range from 1 (between 06:00 and 07:00) and 213 periods (between 19:00 and 20:00), M = 146.40, SD = 83.60. Between 00:00 and 07:00, the total number of completed assessments was 11.

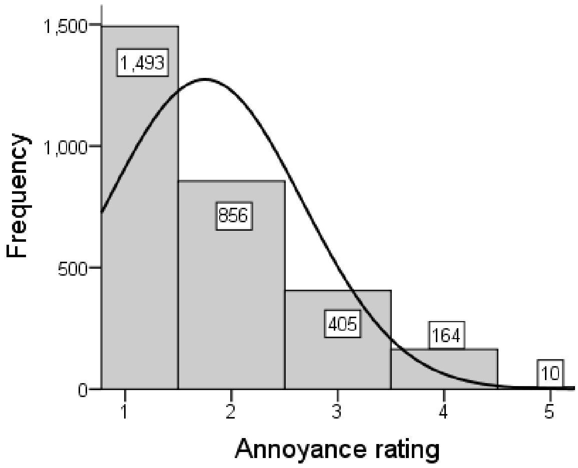

Figure 17. Distribution of one-hour aircraft noise annoyance ratings compared to the normal curve (solid line). 1 = "not at all", 2 = "slightly", 3 = "moderately", 4 = "very", and 5 = "extremely" bothered, disturbed or annoyed, $N = 2{,}928$.

8.4 Research question B 1: Predictors of short-term annoyance due to aircraft noise

In the following section, the development of a prediction model for short-term aircraft noise annoyance is described. The model development was carried out in three steps. To avoid over-parameterization, the first step was a pre-selection of potential predictors. Besides acoustical parameters, situational non-acoustical predictors that are changing in their characteristics from one hour to the next or at least between the examination days were considered separately. Afterwards, those predictors with the highest contribution to one-hour annoyance were integrated in a combined model. Finally, it was analyzed whether this model can be improved by an inclusion of time-invariant person-related predictors. The resulting model is regarded as the final prediction model for aircraft noise-induced annoyance during the past hour.

8.4.1 Pre-selection of potential predictors

For every one-hour examination period, 30 acoustical parameters (cf. Table 18) as well as the situational non-acoustical factors *time of day*, *day of the week*, and *type of activity* mostly engaged in during the preceding hour were ascertained. The effect of the noise indicators and the single non-acoustical factors on annoyance was examined separately as part of the pre-selection process. For this purpose, the influence of each potential predictor or predictor class on the criterion *aircraft noise-induced annoyance during the preceding hour* was assessed graphically as well as statistically. For the statistical analyses, several Generalized Estimating Equations, GEE, were applied. The GEE approach is an adoption of the linear regression model in the presence of repeated measurements. Additionally, GEE analyses do not require the usual normality assumption of linear regression models (Liang & Zeger, 1986; Zeger & Liang, 1986). The fit of a model is indicated by the *QIC* which is an adaptation of the Akaike Information Criterion, *AIC*, for GEEs (Pan, 2001). The lower the *QIC*-value, the better is the fit of the model. As the *QIC* is based on the *AIC,* a comparison of the model fit using the *QIC* likewise is only meaningful if the models are based on the same data set (Lewandowsky & Farrell, 2011). Therefore, in the following section, all analyses refer to the sample of those annoyance assessments which were conducted between 07:00 and 24:00 and for which aircraft noise descriptors were available. This sample contained (in maximum) 2,719 assessments. For all other times of the day, the number of completed one-hour examinations lay below 10. An analysis of these time periods did not seem meaningful.

Effect of acoustical parameters

To illustrate the effect of the aircraft noise exposure on one-hour annoyance ratings, the relation of the N_{Ac} and the $L_{Aeq,AC}$ as well as the personalized $L_{Aeq,AC}$ (= $p\ L_{Aeq,AC}$) to annoyance is depicted in Figure 18 to Figure 20. The $L_{Aeq,AC}$, and N_{AC} are very common noise metrics whereas the $p\ L_{Aeq,AC}$ has not been used in prior research yet. The three indicators were used representatively for all other acoustical parameters. The figures show a rather linear relation between the three noise descriptors and one-hour annoyance. Therefore, no transformation was necessary and a linear relationship between the acoustical parameters and the criterion annoyance could be assumed in the following regression analyses.

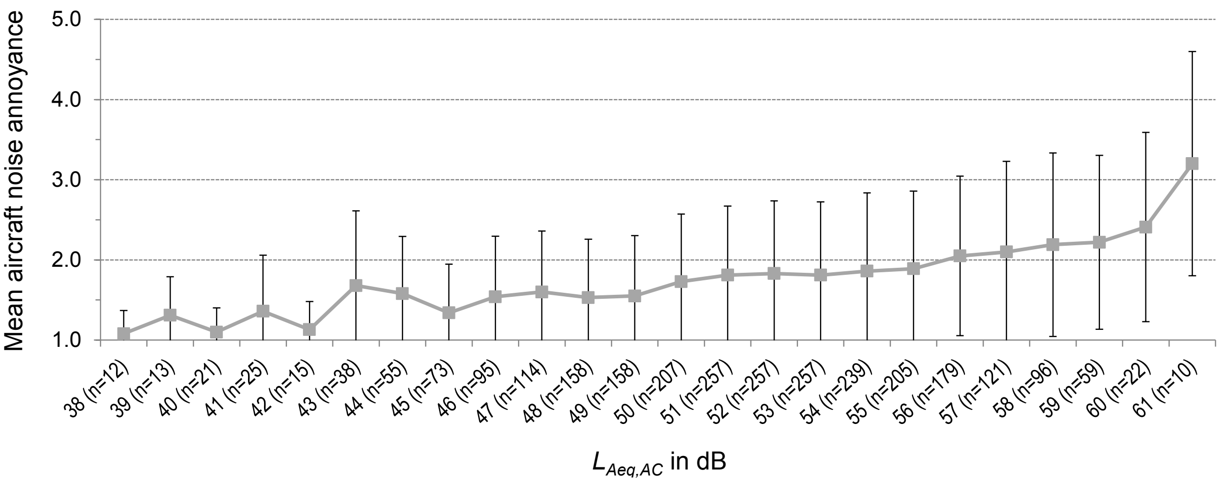

Figure 18. The relation between the $L_{Aeq,AC}$ and mean one-hour aircraft noise annoyance ratings (with standard deviations). Values for the $L_{Aeq,AC}$ are rounded off to whole numbers. Annoyance was assessed by the question "Thinking about the past hour, how much did aircraft noise as a whole bother, disturb or annoy you?" 1 = "not at all" - 5 = "extremely". Mean annoyance ratings are only given for $L_{Aeq,AC}$-values with a sample size of $n \geq 10$. $N = 2{,}686$.

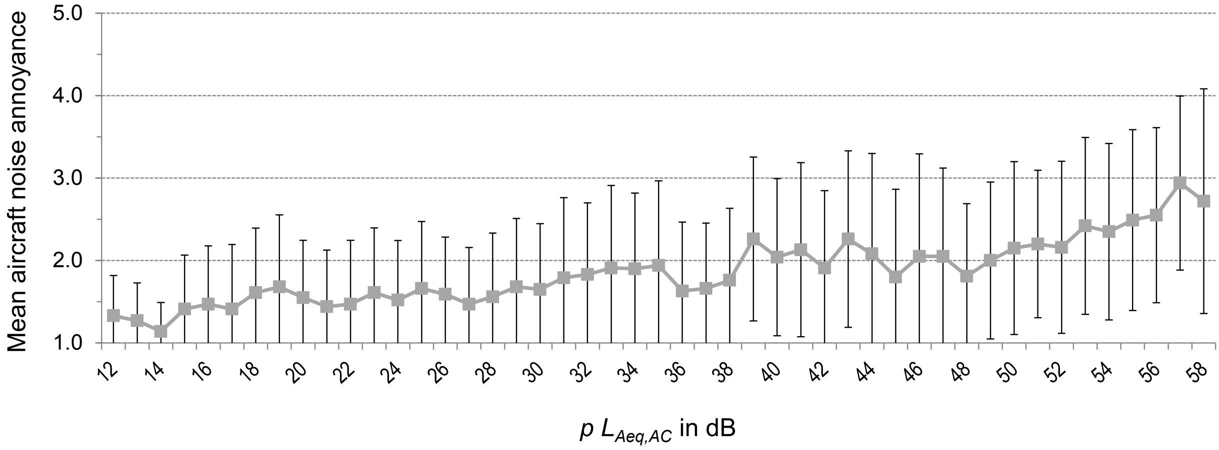

Figure 19. The relation between the $p\ L_{Aeq,AC}$ and mean one-hour aircraft noise annoyance ratings (with standard deviations).Values for the $p\ L_{Aeq,AC}$ are rounded off to whole numbers. Annoyance was assessed by the question "Thinking about the past hour, how much did aircraft noise as a whole bother, disturb or annoy you?" 1 = "not at all" - 5 = "extremely". For $L_{Aeq,AC}$-values between 12 and 21 dB and between 34 and 58 dB, sample sizes were $15 \leq n \leq 71$, each. For $L_{Aeq,AC}$-values between 22 and 33 dB, sample sizes were $81 \leq n \leq 129$, each. Mean annoyance ratings are only given for $p\ L_{Aeq,AC}$-values with a sample size of $n \geq 10$. $N = 2,676$.

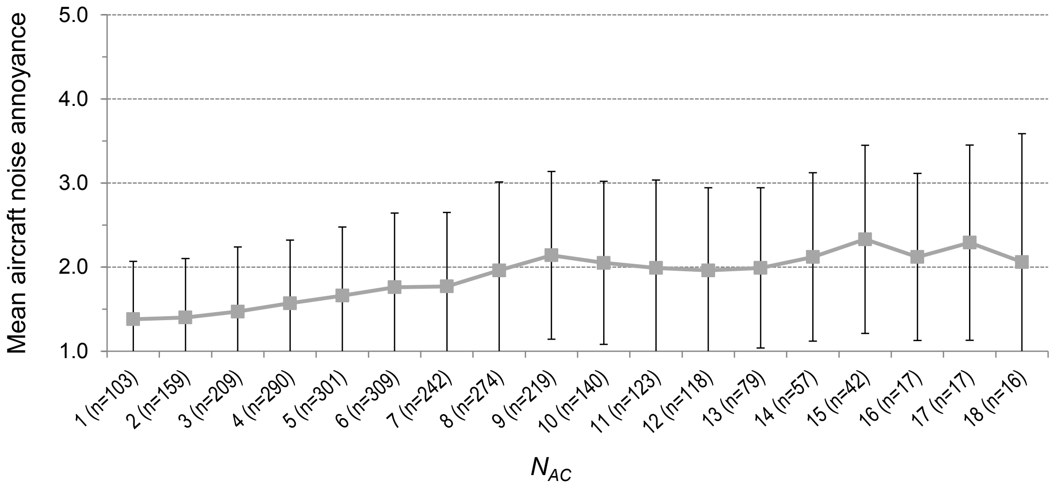

Figure 20. The relation between the N_{AC} and mean one-hour aircraft noise annoyance ratings (with standard deviations). Annoyance was assessed by the question "Thinking about the past hour, how much did aircraft noise as a whole bother, disturb or annoy you?" 1 = "not at all" - 5 = "extremely". Mean annoyance ratings are only given for N_{AC}-values with a sample size of $n \geq 10$. $N = 2,715$.

To test the relation between acoustical parameters and one-hour annoyance ratings statistically, a GEE analysis was performed for each of the available noise descriptors described in Table 18. Since the acoustical parameters are likely to be highly correlated, the effect of each acoustical parameter on annoyance was assessed in separate GEE analyses to avoid problems with multicollinearity. Table 19 depicts the results of these separate analyses. Since the GEE analyses were calculated only for the purpose of pre-selection, intercepts are not presented. Only 2,678 and not the full sample of 2,719 examination periods were used here, because no valid slope of rise could be extracted for 41 periods and the sample needed to be identical for the comparison of the fit of different models.

Table 19

Generalized Estimating Equations (GEE) analyses to test the contribution of diverse acoustical parameters on aircraft noise annoyance in the preceding hour, N = 2,678

Parameter	*B*	*SE*	*p*	*QIC*
Number of aircraft (N_{AC})/number above threshold (NAT_{xx})				
N_{AC}	0.053	0.007	< .001	2,228.95
NAT_{55}	0.054	0.007	< .001	2,224.62
NAT_{60}	0.059	0.008	< .001	2,216.10
NAT_{65}	0.066	0.009	< .001	2,199.26
NAT_{70}	0.086	0.015	< .001	2,232.33
NAT_{75}	0.103	0.034	.003	2,345.66
NAT_{80}	0.186	0.070	.008	2,345.44
NAT_{85}	0.279	0.228	.220	2,352.10
Time with aircraft noise				
total AC time [min]	0.041	0.006	< .001	2,270.36
mean AC times [s]	0.000	0.002	.871	2,357.11
Energy equivalent sound pressure levels (L_{Aeq})				
$L_{Aeq,total}$	0.052	0.009	< .001	2,273.30
$p\ L_{Aeq,total}$	0.025	0.003	< .001	2,163.29
$L_{Aeq,bkgd}$	0.007	0.009	.438	2,358.58
$L_{Aeq,AC}$	0.047	0.006	< .001	2,226.54
$p\ L_{Aeq,AC}$	0.026	0.003	< .001	2,124.99

Note. Annoyance was assessed by the question “Thinking about the past hour, how much did aircraft noise as a whole bother, disturb or annoy you?” 1 = “not at all” - 5 = “extremely”. Only examination periods with a valid slope of rise were analyzed.

Continuation of Table 19

Generalized Estimating Equations (GEE) analyses to test the contribution of diverse acoustical parameters on aircraft noise annoyance in the preceding hour, N = 2,678

Parameter		B	SE	p	QIC
Maximum sound pressure levels (L_{Amax}) and statistical metrics (L_X)					
	L_1	.045	.008	< .001	2,256.27
	$p\ L_1$	.025	.003	< .001	2,147.08
	$L_{0.1}$	.027	.006	< .001	2,307.02
	$p\ L_{0.1}$	.023	.003	< .001	2,175.31
	$max\ L_{Amax,AC}$	.027	.006	< .001	2,302.10
	$p\ max\ L_{Amax,AC}$	.023	.002	< .001	2,169.05
	$mean\ L_{Amax,AC}$	.026	.008	.002	2,330.29
	$p\ mean\ L_{Amax,AC}$	.022	.003	< .001	2,193.73
(Maximum) Aircraft to background noise ratio (*SNR* and *MNR*)					
	SNR	.032	.006	< .001	2,299.15
	max SNR	.021	.006	< .001	2,338.74
	mean SNR	.014	.008	.085	2,353.41
	max MNR	.018	.005	< .001	2,337.93
	mean MNR	.012	.007	.100	2,354.28
Slope of rise					
	max Rise	.318	.093	< .001	2,334.03
	mean Rise	.140	.141	.320	2,352.12

Note. Annoyance was assessed by the question "Thinking about the past hour, how much did aircraft noise as a whole bother, disturb or annoy you?" 1 = "not at all" - 5 = "extremely". Only examination periods with a valid slope of rise were analyzed.

As Table 19 shows, the *outdoor* noise metric that best predicts one-hour aircraft noise annoyance is the number of aircraft fly-overs with a peak level above 65 dB(A), the NAT_{65}. The contribution of this parameter to annoyance ratings is superior to the contribution of the more common metrics N_{AC}, NAT_{70}, $L_{Aeq,AC}$, and the maximum aircraft noise level ($max\ L_{Amax,AC}$). In total, however, the results of the GEE analyses indicated that all personalized parameters, i.e., noise indicators that consider the recent whereabouts (indoors vs. outdoors) and the attenuation due to different window positions, produced a better model fit than parameters describing only the outdoor exposure. According to the model fit indicator *QIC*, the personalized aircraft noise exposure, $p\ L_{Aeq,AC}$ was the best single predictor for one-hour annoyance ratings. Therefore, in the next step, the $p\ L_{Aeq,AC}$ was used as first predictor for the basic acoustical model. In an iterative process, additional predictors with a significant effect on annoyance were introduced stepwise in the model depending on its contribution to the model fit improvement and its *p*-value. The predictor that contributed the most to an improvement of the model fit and that was significant at least on a 5 % level was selected as second predictor for the model. As a measure for the improvement of the model fit the conventions postulated by Burnham and Anderson (2004) were applied[16]. The same procedure was used for the third predictor. No significant contribution to the model fit was found for a forth predictor.

This iterative process resulted in an acoustical prediction model consisting of the $p\ L_{Aeq,AC}$, the N_{AC}, and the NAT_{70}. The three predictors were selected for subsequent combined models. When only the 2,678 assessment periods with a valid slope of rise were considered, the *QIC* was 2,048.63. The lower *QIC*-value indicates a clear improvement of the model fit compared to the fit of a model containing the $p\ L_{Aeq,AC}$ as only predictor (cf. Table 19). The final acoustical model was based on all 2,719 examination periods. The corresponding *QIC* was 2,063.27. Regression coefficients, standard errors and *p*-values for this model are reported in Table 20.

Table 20

Prediction model for short-term noise annoyance ratings using only acoustical predictors, N = 2,719

Predictor	*B*	*SE*	*p*
Intercept	0.886	0.087	< .001
$p\ L_{Aeq,AC}$	0.020	0.002	< .001
N_{AC}	0.028	0.007	< .001
N_{AT70}	0.034	0.016	.029

Note. Annoyance was assessed by the question “Thinking about the past hour, how much did aircraft noise as a whole bother, disturb or annoy you?” 1 = “not at all” - 5 = “extremely”.

[16] These conventions refer to the Δi values between the AIC – here the QIC – scores of the best model and a model *i* that is compared to the best model. According to Burnham and Anderson (2004), $\Delta_i \leq 2$ indicates that both models are comparable and having substantial support. $4 \leq \Delta_i \leq 7$ indicates that model *i* has considerably less support and $\Delta_i \geq 10$ indicates that model *i* has essentially no support.

Effect of the time of day and the day of the week

The presumed predictor *time of day* was operationalized as categorical variable with 17 categories corresponding to the time periods from 07:00 to 24:00. As the air traffic density and, thus, the exposure differed between certain times of day, the personalized aircraft noise level ($p\ L_{Aeq,AC}$) needed to be considered when the effect of the time of day on annoyance was tested. In a GEE model with *time of day* and $p\ L_{Aeq,AC}$ as predictors of one-hour annoyance ratings, *time of day* was a significant predictor, Wald-χ^2 (16, N = 2719) = 34.91, p = .004). The corresponding *QIC* was 2,136.80. Figure 21 depicts the estimated model-based marginal mean values of rated annoyance during the preceding hour with the effect of the acoustical parameter $p\ L_{Aeq,AC}$ controlled for. As Figure 21 shows, the mean ratings varied only slightly during daytime and around the score 2 which corresponds to "slight annoyance". The highest difference was 0.71 (between 07:00 – 08:00 and 13:00 – 14:00) on a scale from 1 to 5.

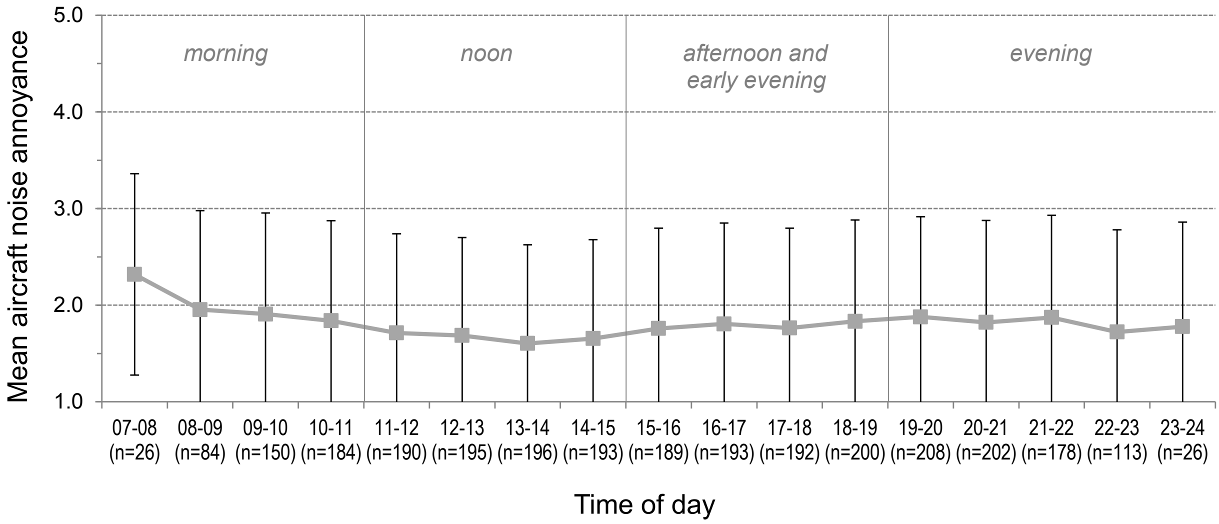

Figure 21. Estimated marginal mean ratings (with standard errors) for one-hour aircraft noise annoyance for 17 examination periods during the day. Estimated marginal means were controlled for the effect of $p\ L_{Aeq,AC}$ with $p\ L_{Aeq,AC}$ set to 32.35 dB (= arithmetic mean). One hour annoyance was assessed by "Thinking about the past hour, how much did aircraft noise as a whole bother, disturb or annoy you?" 1 = "not at all" - 5 = "extremely". Mean annoyance ratings are reported only for time periods with a sample size of $n \geq 10$. N = 2,719.

In order to simplify the model and, thus, the interpretation, in a next step, the 17 time periods were combined into the four categories "morning" = 07:00 – 11:00, "noon" = 11:00 – 15:00, "afternoon and early evening" = 15:00 – 19:00, and "evening" = 19:00 – 24:00 (cf. Figure 21). This transformed and less complex categorical variable likewise had a significant impact on one-hour annoyance ratings in a GEE analysis with $p\ L_{Aeq,AC}$ included in the model, Wald-χ^2 (3, N = 2719) = 13.79, p = .003. The model fit slightly improved for the transformed variable (*QIC* = 2,131.41). One-hour annoyance varied during the day: Estimated marginal means differed slightly but significantly between the categories “noon” and “morning” (p < .001) as well as between “noon” and “ afternoon and early evening” and “noon” and “evening” (p = .048 and p = .046, respectively) assessed via pairwise contrast comparisons.

In an additional GEE analysis, the effect of the day of the week was tested. It was analyzed whether annoyance ratings given on weekdays differ from ratings given at the weekend. When the $p\ L_{Aeq,AC}$ was considered in the prediction model, no significant effect for the predictor *day of the week* was found (Wald-χ^2 (1, N = 2719) = 1.59, p = .207).

Effect of the type of activity

Before the influence of carrying out a certain activity on one-hour annoyance ratings was analyzed, firstly, it was examined which activities are carried out how often in the course of the day. As Table 22a and 22b depict, the frequencies vary considerably depending on the time of the day. Moreover, the figures show that the aircraft noise exposure level, $L_{Aeq,AC}$, alternates as well and that a higher aircraft noise exposure coincides with times when certain activities are carried out more often. Above all, this applies to physical activity around noon, listening to radio or watching TV in the late evening, and eating in the early evening. Some activities were carried out exclusively or predominantly inside the house as, for instance, personal care or listening to the radio and watching TV. Hence, it seemed reasonable to consider both the whereabouts of the participants and the variations of the aircraft noise level when the effect of the type of the intended activity on short-term annoyance is aimed to be assessed. Therefore, the $p\ L_{Aeq,AC}$, was included in the following analyses.

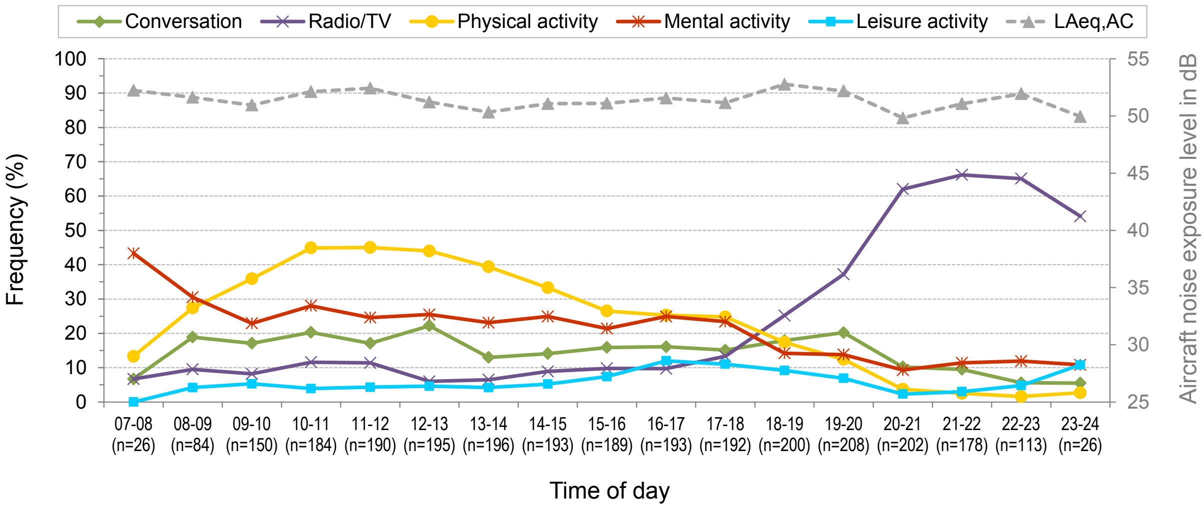

Figure 22a. Mean frequencies (%) how often several activities are carried out at different times of the day in comparison to the mean aircraft noise exposure level at these times. Activities were assessed by the question “What have you (mostly) been doing in the last hour?” Respondents could choose multiple activities from a list. Mean annoyance ratings are reported only for time periods with a sample size of $n \geq 10$. N = 2,719.

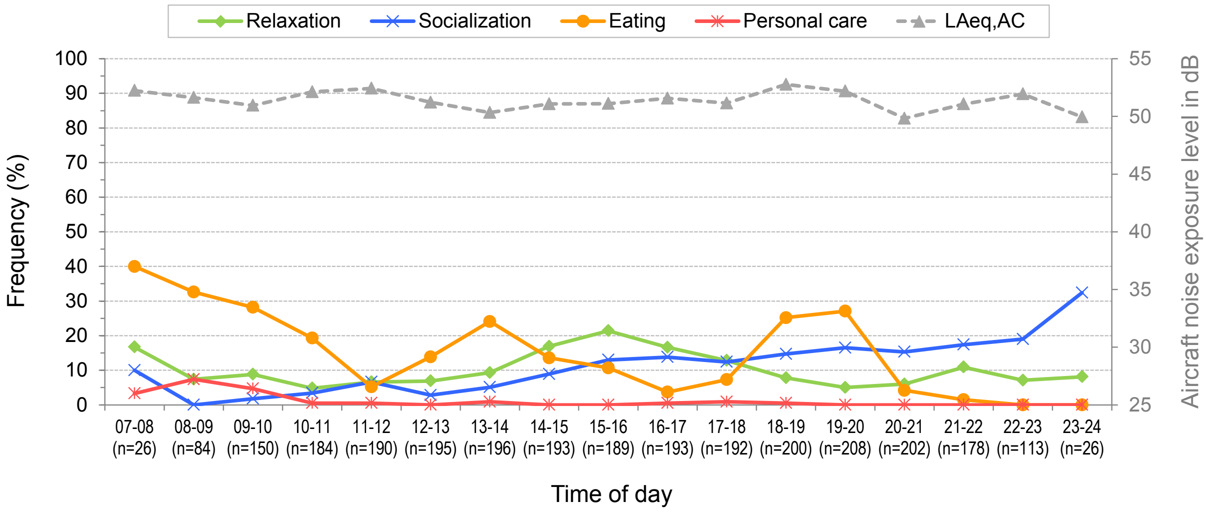

Figure 22b. Mean frequencies (%) how often several activities are carried out at different times of the day in comparison to the mean aircraft noise exposure level at these times. Activities were assessed by the question "What have you (mostly) been doing in the last hour?" Respondents could choose multiple activities from a list. Mean annoyance ratings are reported only for time periods with a sample size of $n \geq 10$. $N = 2{,}719$.

For a statistical analysis of the effect of the type of activity on one-hour annoyance ratings, again the GEE approach was applied. When asked about the activity they have mostly been carrying out during the past hour, participants could choose multiple activities. Each activity was reflected by a separate variable coded with either 0 = "activity was not carried out" or 1 = "activity was carried out". Table 21 shows the results of this GEE analysis. The fit of this model was $QIC = 2{,}053.11$. This value indicates that the current model including the $p\ L_{Aeq,AC}$ and information about the activity in the past hour predicts one-hour annoyance considerably more precisely than the $p\ L_{Aeq,AC}$ alone. Besides the $p\ L_{Aeq,AC}$, only the activities *watching TV/listening to radio*, *physical activity*, *relaxation*, and *eating* had a significant effect on short-term annoyance due to aircraft noise. These four activity variables were selected for subsequent models combining both acoustical and non-acoustical predictors[17].

Figure 23 depicts the estimated marginal mean annoyance ratings for diverse activities with the effect of the $p\ L_{Aeq,AC}$ controlled for. As the figure shows, short-term annoyance was highest when the intended activity was *relaxation*. Annoyance was lowest when the respondents indicated to have carried out *physical activities*.

[17] The corresponding *QIC* for the model containing only the $p\ L_{Aeq,AC}$ and the activities *watching TV/listening to radio*, *physical activity*, *relaxation*, and *eating* was 2,054.81.

Table 21

GEE analysis to test the contribution diverse activities on aircraft noise annoyance in the preceding hour, N = 2,719

Variable	*B*	*SE*	*p*
Intercept	0.851	0.090	< .001
Conversation	0.036	0.049	.464
TV/radio	0.183	0.053	< .001
Mental work	0.093	0.053	.080
Physical activity	-0.160	0.051	.002
Leisure activity	-0.008	0.089	.928
Relaxation	0.336	0.066	< .001
Socializing	-0.030	0.055	.590
Eating	0.142	0.046	.002
Personal care	0.186	0.143	.194
$p\ L_{Aeq,AC}$	0.026	0.003	< .001

Note. Annoyance was assessed by the question "Thinking about the past hour, how much did aircraft noise as a whole bother, disturb or annoy you?" 1 = "not at all" - 5 = "extremely".

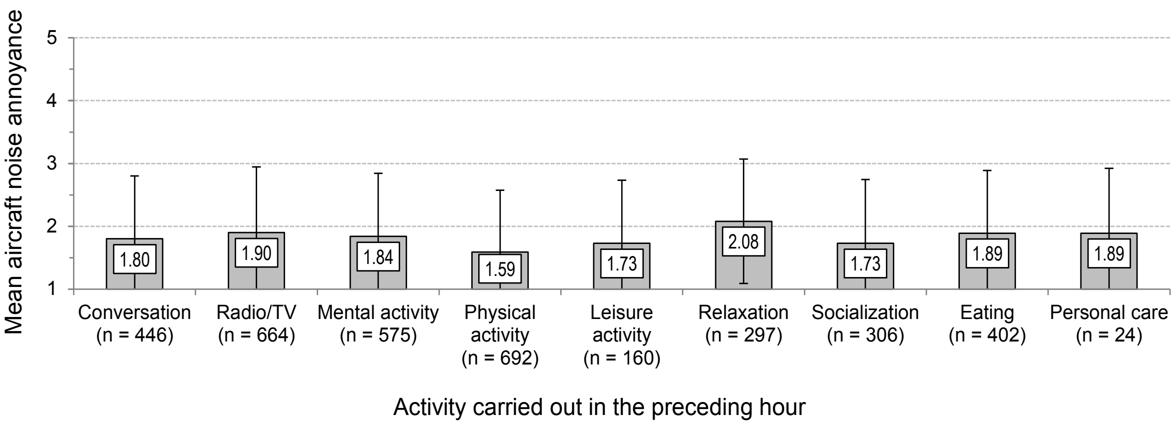

Figure 23. Estimated marginal mean ratings (with standard errors) for one-hour aircraft noise annoyance for nine activities examined in the field study. Respondents could choose multiple activities from a list. Estimated marginal means were controlled for the effect of $p\ L_{Aeq,AC}$ with $p\ L_{Aeq,AC}$ determined at 32.35 dB (= arithmetic mean). One hour annoyance was assessed by "Thinking about the past hour, how much did aircraft noise as a whole bother, disturb or annoy you?" 1 = "not at all" - 5 = "extremely". Mean annoyance ratings are based on 2,719 examination periods.

8.4.2 A combined model of acoustical and situational non-acoustical parameters

For a more complex model predicting one-hour aircraft noise annoyance by acoustical and non-acoustical parameters, the significant predictors from the pre-selection phase were integrated into a common model. This combined prediction model consists of the acoustical predictors *personalized aircraft noise exposure* ($p\ L_{Aeq,AC}$), the *number of aircraft in total* (N_{AC}), and the *number of aircraft with a peak level above 70 dB(A)* (NAT_{70}) as well as the situational non-acoustical predictors *time of day*, and the activity variables *watching TV/listening to radio*, *physical activity*, *relaxation*, and *eating*. Table 22 shows the results of the GEE analysis testing this model.

Table 22

GEE analysis testing the contribution of acoustical and non-acoustical predictors on aircraft noise annoyance in the preceding hour, N = 2,719

Variable	*B*	*SE*	*p*
Intercept	0.798	0.091	< .001
$p\ L_{Aeq,AC}$	0.021	0.002	< .001
N_{AC}	0.027	0.006	< .001
N_{AT70}	0.036	0.015	.019
Time of day			
Morning	0.149	0.066	.023
Noon	-0.007	0.054	.890
Afternoon and early evening	0.003	0.039	.936
Evening	0[a]		
TV/radio	0.142	0.043	< .001
Physical activity	-0.201	0.043	< .001
Relaxation	0.321	0.057	< .001
Eating	0.096	0.040	.016

Note. [a] This coefficient is set to 0, because it is the reference group. Annoyance was assessed by the question “Thinking about the past hour, how much did aircraft noise as a whole bother, disturb or annoy you?” 1 = “not at all” - 5 = “extremely”.

The model had a fit of *QIC* = 1,976.91. This value indicates that the predictive power of this model which includes both acoustical and situational non-acoustical predictors is higher compared to a mere acoustical model (cf. Section 8.4.1, *Effect of acoustical parameters*). Interactions of the factor *time of day* with each activity variable, of the factor *time of day* with each acoustical variable as well as interactions of each acoustical variable with each activity variable were tested for their effect on short-term annoyance. Extending the model by any of the listed interaction terms, however, did not improve the model fit.

8.4.3 Final model: Predicting short-term annoyance by acoustical, situational, and time-invariant variables

The present model has included only non-acoustical variables with hourly changing characteristics so far. This composition enables the model to predict variations in annoyance ratings not only between subjects but also within subjects. After finding a major contribution of rather time-invariant personal factors, such as attitudes, evaluations, and traits to long-term annoyance in the telephone study (cf. Part A, Section 5.4), the question arose whether those variables likewise contribute to short-term annoyance. Although stable personal factors cannot account for variations within the ratings made by one individual, they were presumed to explain variations in the ratings between individuals. Therefore, the inclusion of those rather time-invariant and person-related variables in the prediction model for one-hour annoyance was expected to improve the model fit.

An additional GEE analysis was performed for a model containing the acoustical and situational non-acoustical parameters from Section 8.4.2 plus the eight rather time-invariant and person-related predictors proved to significantly influence *long-term aircraft noise annoyance* in the telephone study. These eight predictors were a) the *perception of airport actions* to improve the residents' situations, b) the *perception of negative aspects of the local air traffic*, c) the *attitude towards the airport*, d) the *presence and evaluation of domestic noise insulation*, e) the *application of coping measures*, f) the *satisfaction with the residential area*, g) the *environmental conscience*, and h) the respondent's general *sensitivity to noise* [18]. Out of these rather stable personal factors, only the variables *presence and evaluation of domestic noise insulation* and *noise sensitivity* significantly affected one-hour annoyance ratings. When these two variables were considered, the predictor *time of day* has no longer a significant influence on annoyance (p = .077) and was therefore removed from the model in the following step. The results of this GEE analysis can be found in Appendix E.

[18] The ninth non-acoustical predictor *degree of urbanization* of the area was not included as all participants lived in neighborhoods that were classified as "suburban area".

Table 23 shows the regressions coefficients, their standard errors and *p*-values of the model containing only the significant predictors. The fit of the model was *QIC* = 1,708.27. This *QIC*-value refers to a sample of only 52 participants and 2,566 examination periods. For three participants, data for the variable *presence and evaluation of domestic noise insulation* was missing due to a software error. The *QIC* of the model containing only acoustical parameters and situational non-acoustical factors (cf. Section 8.4.2) was 1,848.22 for this sample of 2,566 assessment periods. This indicates that the inclusion of *presence and evaluation of domestic noise insulation* and *noise sensitivity* clearly improved the prediction of one-hour annoyance due to aircraft noise. The model summarized in Table 23 is regarded as the final prediction model for short-term annoyance.

Table 23

GEE analysis testing the contribution of acoustical as well as situational and time-invariant non-acoustical predictors on aircraft noise annoyance during the preceding hour, N = 2,566

Variable	*B*	*SE*	*p*
Intercept	-0.211	0.318	.507
$p\ L_{Aeq,AC}$	0.020	0.002	< .001
N_{AC}	0.025	0.006	< .001
N_{AT70}	0.044	0.014	.002
TV/radio	0.151	0.046	< .001
Physical activity	-0.190	0.045	< .001
Relaxation	0.320	0.062	< .001
Eating	0.020	0.040	.004
Presence and evaluation of noise insulation			
No insulation	-0.063	0.124	.612
Not highly satisfied	0.379	0.155	.015
Highly satisfied	0[a]		
Noise sensitivity	0.295	0.095	.002

Note. [a] This coefficient is set to 0, because this parameter is redundant. Annoyance was assessed by the question “Thinking about the past hour, how much did aircraft noise as a whole bother, disturb or annoy you?” 1 = “not at all” - 5 = “extremely”.

8.4.4 The effect of psychological strain due to the field study procedure

The participants of the field study rated their psychological strain that was produced by the study procedure on average with 2.33 (SD = 0.84, Min = 1, Max = 4) on a scale ranging from 1 = "not at all" to 5 = "extremely" demanding. This value indicates that the study procedure on average was "slightly" demanding. Nevertheless, the question remained whether the perceived psychological strain due to the study procedure had an effect on short-term aircraft noise annoyance ratings. For this purpose, the contribution of the self-rated psychological strain due to the study procedure to one-hour aircraft noise annoyance was tested together with the influence of all predictors listed in Table 23 in Section 8.4.3 in an additional GEE model. With the effect of all other predictors controlled for, the self-rated psychological strain due to the study procedure was a significant predictor of one-hour annoyance ratings (B = .169, SE = 0.058, p = .003). The positive regression coefficient indicates that annoyance was rated higher when the field study procedure was perceived as more demanding. The effect of all other acoustical and non-acoustical predictors listed in Section 8.4.3 on annoyance ratings did not change considerably. The model fit further increased (QIC = 1,672.41) compared to the fit of the model described in Section 8.4.3.

8.5 Research question B 2: The relation between short-term and long-term annoyance due to aircraft noise

In the following section, the relation between the aircraft noise-induced annoyance during very short periods and the annoyance across a long period is addressed. For this purpose, tests for possible mean differences between the two annoyance measures as well as correlation analyses were performed.

8.5.1 Representativeness of aircraft noise exposure during the field study

When investigating the link between the annoyance during short terms, i.e., one hour, and the annoyance rated with regard to the past 12 months, it is important to consider the representativeness of the noise exposure measured in the field study for the noise exposure of an entire year. The L_{Aeq} measured for the four examination days and nights (hereinafter called *field study* L_{Aeq}) was compared with the L_{Aeq} for the six months with the highest air traffic density per year (in the following referred to as *long-term* L_{Aeq}) which was extracted from a noise contour map (see Part A, Section 4.1.2). This comparison became necessary mainly because of an unforeseeable shift of the operation direction at Cologne/Bonn Airport: The assumption was that the operation of the air traffic via the cross-wind runway at several days during the field study had led to a remarkable reduction of the aircraft noise exposure at certain study sites. Figure 24 depicts the discrepancy between the *long-term* L_{Aeq} and the *field study* L_{Aeq}. The differences that result from subtracting the *field study* L_{Aeq} from the *long-term* L_{Aeq} are depicted in Figure 24 as bar graphs. The graphs show that the *field study* L_{Aeq} was predominantly lower than the *long-term* L_{Aeq}. The magnitudes of the differences between the *long-term* L_{Aeq} and *field study* L_{Aeq} ranged between 0 and 11 dB. The mean difference for the magnitude was 2.5 dB. 48 participants (87.3%) were exposed to a *field study* L_{Aeq} that did not differ by more than 5 dB from the *long-term study* L_{Aeq}.

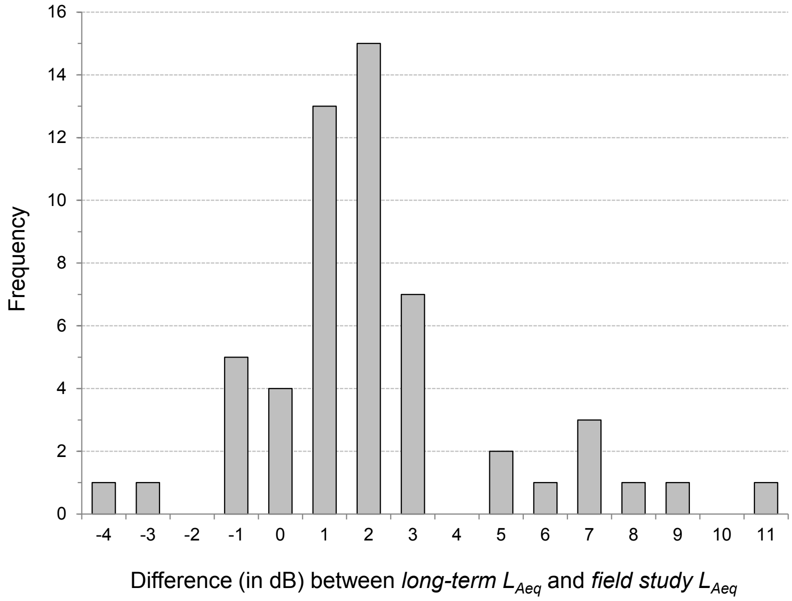

Figure 24. Differences between the *long-term* L_{Aeq} and the *field study* L_{Aeq} in dB. The differences result from subtracting the *field study* L_{Aeq} from the *long-term* L_{Aeq}. $N = 55$.

As a consequence, the investigations of the following subsections include only participants who were exposed to an aircraft noise exposure during the field study days that did not differ by more than 5 dB from the long-term exposure. For those 48 individuals, the following analyses are based on all examination periods during which the participants had stayed in the nearer neighborhood ($n = 2{,}525$).

8.5.2 The relation between daytime short-term annoyance, sleep quality, and long-term annoyance

Mean rated general long-term annoyance for the selected 48 participants was 3.31 ($SD = 0.85$) on a scale from 1 to 5. General aircraft noise annoyance for the entire sample of the field study ($N = 55$) was 3.20 on average ($SD = 0.87$). In terms of the semantic five-point answer scale, interviewees rated themselves as “moderately” bothered, disturbed or annoyed with regard to the past 12 months. The same 48 participants rated their one-hour annoyance due to aircraft noise with 1.82 (*SD* = 0.54) on average, what corresponds to a rather “slight” annoyance. A two-tailed t-test did not show significant differences between the two examination areas Cologne - Rath/Heumar (*n* = 9) and Siegburg - Stallberg/Kaldauen (*n* = 39) neither for long-term annoyance ratings ($t(46) = -1.22$, $p = .227$) nor for short-term annoyance ratings ($t(46) = 0.23$, $p = .818$). Hence, the participants living in the two different areas are treated as one sample.

The mean ratings of short-term versus long-term annoyance differed by 1.49. The mean difference was statistically significant in a paired t-test, $t(47) = -13.84$, $p < .001$ (two-tailed testing). Despite the considerable mean difference, the participants’ mean one-hour annoyance rating and the general long-term annoyance rating given at the beginning of the field study were positively correlated (Pearson), $r(46) = .50$ ($p < .001$). When the participants’ mean one-hour annoyance rating was treated as a predictor for the long-term annoyance rating in a linear regression model (see Table 24), the model accounted for 23.7 % of the variance in the long-term annoyance ratings.

Table 24

A linear regression model for the prediction of general aircraft noise annoyance in the past 12 months by mean short-term annoyance, N = 48

Predictor	*B*	*SE*	β	*p*
Intercept	1.87	0.38		< .001
Participants’ mean one-hour annoyance	0.79	0.20	0.50	< .001

In order to address the question whether long-term ratings reflect rather a kind of average annoyance across a number of short-term noise situations or whether it is rather based on extreme situations, also the relation between the participants’ highest short-term annoyance rating and the long-term annoyance rating was investigated. The average of the participants’ maximum ratings was 3.48 (*SD* = 1.01) and, thus, by .17 points higher than the mean for long-term annoyance ratings. In a paired t-test, this mean difference was not statistically significant, $t(47) = 1.05$, $p = .298$ (two-tailed). Nevertheless, the correlation (Pearson) between the respondents’ *maximum* one-hour rating of the field study and the general annoyance rating for the past 12 months was only $r(46) = .32$, ($p = .029$). Thus, this correlation was considerably lower than the correlation between the *mean* short-term and the long-term annoyance ratings. The participants’ mean one-hour annoyance rating was therefore regarded as better predicting long-term aircraft noise-induced annoyance and used for further analyses.

As already described in Section 8.3, one-hour annoyance ratings were given mainly during 08:00 and 24:00. As a consequence, the participants' mean one-hour annoyance rating over the four examination days only refers to times when the participants were awake and, thereby, to daytime annoyance. However, the general annoyance rating given for the past 12 months was presumed to include both daytime and night-time annoyance and disturbance. Therefore, in the next step, the subjective *sleep quality* during the field study nights[19] was used as additional predictor besides the participants' mean short-term annoyance rating in a linear regression model. In this model, the mean one-hour annoyance rating and self-rated sleep quality were significant predictors of general aircraft noise annoyance rated for the past 12 months. The results of this multiple linear regression analysis are shown in Table 25.

Table 25

A linear regression model for the prediction of general aircraft noise annoyance during the past 12 months by short-term annoyance ratings and self-rated sleep quality, N = 48

Predictor	*B*	*SE*	β	*p*
Intercept	3.83	0.75		< .001
Participants' mean one-hour annoyance	0.54	0.20	0.34	.011
Participants' mean self-rated sleep quality	-0.04	0.01	-0.38	.005

While short-term annoyance is related positively to long-term annoyance, self-rated sleep quality is related negatively to long-term annoyance: The better the sleep quality during the field study nights was rated the lower was the reported general annoyance during the past 12 months. Self-rated sleep quality and mean one-hour annoyance explained 34.6 % of the variance in the long-term annoyance ratings. The increase in R^2 which is an indicator for the variance explanation was significant (p = .005).

The predictors mean *one-hour annoyance* and mean self-rated *sleep quality* were significantly correlated with $r(46) = .41$ (p = .003) using Pearson's correlation coefficient.

[19] The participants rated their sleep quality by six items with a scale ranging from 0 to 10, so that the sum score can vary between 0 (= worst possible sleep quality) and 60 (= best possible sleep quality).

8.6 Research question B 3: Evaluation of aircraft noise authorities

The following section addresses the perception and evaluation of aircraft noise authorities. First, it is examined how respondents rate the amount of influence certain authorities have on the aircraft noise exposure at Cologne/Bonn Airport. The results are compared to the perceived amount of effort these authorities invest in the consideration of the needs and opinions of the residents. The second part of the section focuses on the results of the questionnaire that was developed to measure the construct *fairness*. Results on the psychometric quality of the questionnaire and data on the relation between fairness evaluations and reported long-term annoyance are described in detail. The analyses are based on the whole sample of 55 participants.

8.6.1 Research question B 3.1: Evaluation of authorities' influence on aircraft noise exposure and of their will to act in the residents' interest

Respondents were asked about authorities whom they attest a high control over aircraft noise exposure in the vicinity of the airport Cologne/Bonn. Up to five authorities could be mentioned. In the next step, respondents rated how much control these authorities have over the noise exposure and how much they actually consider the residents' needs with regard to the aircraft noise exposure. The different authorities were enumerated in varying numbers as shown by Figure 25. Most often the airport management or airport operator of Cologne/Bonn Airport was mentioned (n = 42). In total, the 55 respondents made 145 enumerations. Besides the authorities listed in Figure 25, further authorities were mentioned. The biggest groups within the class "others" were "policy (makers)" with 20, "economy" with three, and "government" with another two enumerations. These three responses were too unspecific to clearly assign them to a category. Consequently, their attested control over the aircraft noise exposure was not compared to their effort for a consideration of the residents.

Figure 25 reveals a big discrepancy between a high perceived amount of control of certain authorities and little perceived effort made by those authorities to consider the residents' opinions. Exceptions are action groups, which in view of the residents have little control but high effort to tackle noise problems, and municipal authorities, seen as fairly balanced in control and effort.

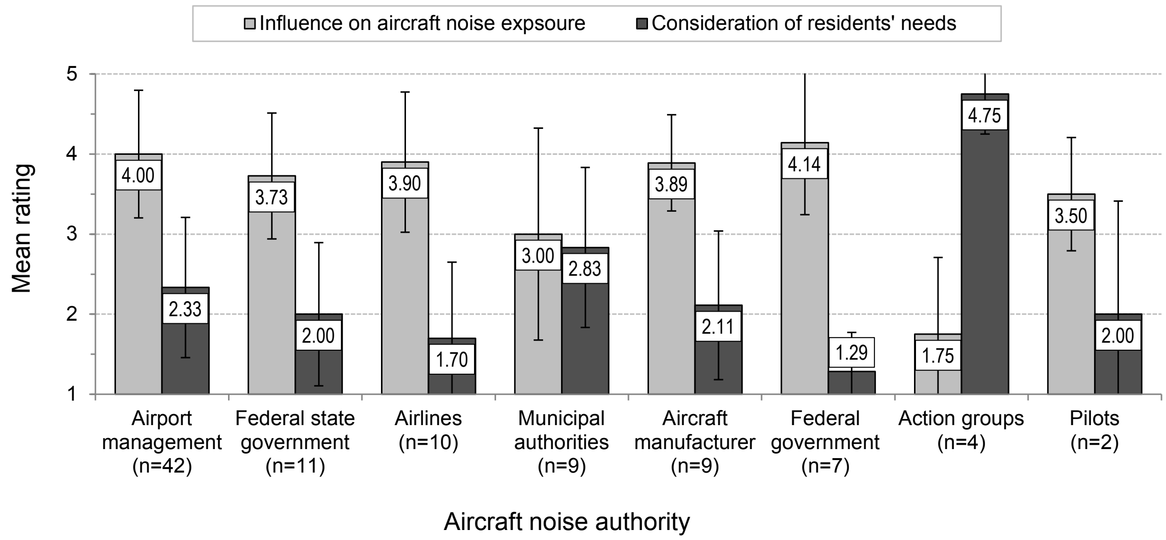

Figure 25. Respondents' evaluation of the influence of authorities on aircraft noise exposure ("How much control exactly do you think these authorities have over aircraft noise? 1 = no control at all – 5 = complete control") in comparison to the perceived consideration of residents' perspectives ("How much do you think any of these authorities take into account the individual opinions of the residents? 1 = not at all – 5 = extremely").

In addition, it was analyzed whether the perceived authorities' effort to act in the residents' interest which is regarded as one aspect of the construct *trust in authorities* is related to long-term aircraft noise-induced annoyance. A Pearson correlation analysis showed no relation, $r(143) = .03$, $p = .810$, when the category of authority is not considered. When the effect of the trust in authorities was analyzed separately for the different aircraft noise authorities, by tendency, but not at a significance level of 5 %, a negative relation was found between annoyance and the perceived efforts of the airport management ($r(40) = -.21$, $p = .184$), the federal state government ($r(9) = -.36$, $p = .278$), airlines ($r(8) = -.48$, $p = .159$), and the federal government ($r(5) = -.50$, $p = .257$). In contrast, for municipal authorities ($r(7) = .44$, $p =.239$), aircraft manufacturer ($r(7) = .37$, p = .322), and action groups ($r(2) = .93$, $p = .073$), a positive relation to annoyance ratings was found by tendency. However, none of the coefficients were significant either. Since the category "pilots" was mentioned only twice, a correlation analysis did not seem reasonable.

8.6.2 Research question B 3.2: Perceived fairness of air traffic-related decision-making and the allocation of aircraft noise at Cologne/Bonn Airport

Before the association between diverse dimensions of fairness, aircraft noise-induced annoyance, and further fairness outcomes is presented, item and scale statistics as well as data on the construct validity of the fairness questionnaire that was newly developed in this thesis (cf. Section 7.4.1) are reported first.

Item analysis

A relatively high number of the 55 participants (n = 6 and n = 8, resp.) could not rate their degree of agreement to item 4 (*consistency over people*) and item 6 (*accuracy*), respectively and gave the response “do not know”. The item means were generally rather low except for items 2 (*process control*), 4, and 6 showing means in the center of the five-point scale. With exception for item 2 that has a rather symmetric distribution and the items 4 and 6 which were left-skewed, all other items were skewed to the right as can be seen in Table 26. None of the items showed a normal distribution in a Kolmogorov-Smirnov using a 5 % level of significance. With regard to the difficulty of an item, generally, items are preferred with an item difficulty between $p_i = .2$ (high difficulty) and $p_i = .8$ (low difficulty) (Bortz & Döring, 2006). Except for the items 4 and 6, the items of the fairness questionnaire showed a very high (item 3, *decision control*) to moderate (item 2, *process control*) item difficulty. Measures of central tendency and dispersion, the skewness of the distribution of the items scores as well as the item difficulty are summarized in Table 26.

Table 26

Item statistics of the fairness questionnaire

Item (Fairness standard)	*n*	*M*	*SD*	*Range*	Skewness	Difficulty
1 (Equality)	55	2.15	1.11	1-5	0.96	.29
2 (Process control)	53	2.77	1.34	1-5	0.08	.44
3 (Decision control)	54	1.59	0.71	1-3	0.79	.15
4 (Consistency over people)	49	3.51	1.23	1-5	-0.45	.63
5 (Accuracy)	52	2.46	1.09	1-5	0.66	.37
6 (Accuracy)	47	3.19	0.90	1-5	-0.40	.55
7 (Correctability)	53	2.32	1.24	1-5	0.68	.33
8 (Justification)	55	1.87	1.06	1-5	1.44	.22
9 (Truthfulness)	52	2.10	1.27	1-5	1.12	.27
10 (Global fairness rating)	53	2.36	1.00	1-5	0.76	.34

Note. Fairness was rated indicating the degree of agreement to a certain statement. The scale ranged from 1= “strongly disagree” – 5 = “strongly agree”.

Scale analysis

Cronbachs's α as measure for internal consistency was calculated for the two subscales *procedural fairness* and *informational fairness* as postulated by theory (Colquitt, 2001, see Section 2.8). As the *distributive fairness* was ascertained by only one item, no analysis of consistency was calculated. The same applies to measures for discriminatory power and homogeneity.

The internal consistency for the *procedural fairness* subscale with four items (n = 48) was α = .68 after excluding item 4 and 6 from the scale due to a negative and a very low discriminatory power ($r_{i(t-i)}$ = -.42 and $r_{i(t-i)}$ = .12), respectively. In consideration of the context and the small number of items comprised by the scale, a value of α = .68 corresponds to an acceptable consistency (for a discussion on the interpretation of alpha-coefficients, see Schmitt, 1996). Discriminatory power of the four items of the resulting subscale ranged from $r_{i(t-i)}$ = .44 (item 3) to $r_{i(t-i)}$ = .54 (item 2) that corresponds to a moderate to high discriminatory power (Weise, 1975). The homogeneity of the scale was $\bar{r}_{ii'}$ = .36 indicating very homogenous items (Briggs & Cheek, 1986).

Internal consistency of the *informational fairness* subscale (n = 52) which comprised only the two items 8 and 9 was α = .62 and the discriminatory power of the items was $r_{i(t-i)}$ = .45. In this case of a subscale with only two items, the homogeneity equals the correlation coefficient between item 8 and 9 that was $r_{ii'}$ = .45 what corresponds to a high homogeneity of the scale.

Validity

An explorative principle components analysis with three factors preset (n = 46) was calculated to test the multidimensionality of the fairness construct[20]. Only 7 items of the fairness scale were considered. Items 4 and 6 were excluded from the analysis in advance because of their inhomogeneity with respect to the other fairness items. Item 10 was a global direct fairness item and served as control item.

The three extracted factors in total explained 68.3 % of the variance of the whole scale. Factor 3 (*distributive fairness*) had an eigenvalue of 0.93 meaning that the Kaiser-Guttman criterion (eigenvalue > 1) was not satisfied. Therefore, this factor is only of minor importance and accounts just for a small part of the item variance (Bühner, 2004). After a VARIMAX

[20] For a confirmation of the factor structure that has been postulated by theory and a previous meta-analysis on fairness constructs (cf. Colquitt, 2001), a confirmatory factor analysis would have been the correct approach. But due to the small sample size, the calculation of a confirmatory factor analysis as, for instances by means of a path analysis was not feasible (for the discussion about adaquate sample sizes, see Bühner, 2004). Therefore, an explorative principle component analysis was calculated testing whether the three fairness dimensions distributive, procedural, and informational fairness match with a pre-set three factor structure.

rotation, all variables loaded highest on the three factors as predicted by a previous meta-analysis (Colquitt, 2001). Only item 2 loaded comparably high on factor 1 and 2. Communalities were all above .6. Table 27 shows the factor loadings greater than .4 and communalities for every fairness item.

In order to test the relation between the fairness dimensions and to underpin the results of the multidimensional construct found in the principle component analysis, scores of the subscales were related to each other using Pearson's *r*. *Distributive fairness* did correlate neither with the score of the subscale *procedural fairness* ($r(52) = .01$, $p = .921$) nor with the score of the subscale *informational fairness* ($r(53) = .05$, $p = .693$). The correlation between *procedural fairness* and *informational fairness* in contrast was high, $r(52) = .50$ ($p < .001$).

An analysis of the Pearson correlation between the global direct fairness statement and the score for *distributive fairness* showed no significant coefficient $r(51) = .04$ ($p = .794$). In contrast, the correlation analysis of the scores of the subscales *procedural fairness* and *informational fairness* with the global fairness rating revealed moderate relations, $r(50) = .43$ ($p = .002$) and $r(51) = .30$ ($p = .027$), respectively.

Table 27

Three factor structure after VARIMAX rotation with factor loads and communalities, N = 46

Item	Factor 1 (procedural fairness)	Factor 2 (informational fairness)	Factor 3 (distributive fairness)	Communality
		Factor loadings		
1			.94	.88
2	.59	.51		.62
3	.68			.61
5	.75			.62
7	.74			.60
8		.78		.70
9		.86		.75
		Eigenvalues		
	2.75	1.10	0.93	

Relation to outcomes

In order to examine the relation of the distinct fairness dimensions to the outcomes in the context of noise exposure, Pearson correlation coefficients were calculated between the sub-scale values and the rated *general aircraft noise annoyance*, *aircraft noise annoyance at night*, the *satisfaction with the residential area*, and the *attitude towards the airport*. In addition, the correlations between the global fairness rating and the same outcomes were calculated. The results of these analyses are given in Table 28. No significant coefficients between the score of a fairness dimension and the presumed outcomes were found with exception for the relation between *procedural fairness* and *trust in authorities*. The higher the procedural fairness of aircraft noise authorities was rated, the higher was the reported trust. *Satisfaction with the residential area* was related in the expected positive direction, but not statistically significant, to *distributive fairness* and *procedural fairness*. The *attitude towards the airport* was related by tendency negatively to *distributive fairness* meaning that the general attitude towards the airport is more negative when the distributive fairness of the aircraft noise allocation is judged as high. This is a rather counterintuitive result and possibly due to chance.

Since almost no significant correlations were found in the correlation analyses, a power test was calculated using the free software G*Power 3.1 (Faul, Erdfelder, & Lang, 2009). For bivariate correlations that were significant on a 5 % level (one-tailed testing), and coefficients basically not higher than $r = .21$, the statistical power was 46.3 %. This means that because of the small sample size, there was an only a little chance to detect significant coefficients.

Table 28

Pearson's correlation analysis between fairness dimensions and expected outcomes, N =52-55

Presumed outcomes	Distributive fairness	Procedural fairness	Informational fairness	Global fairness rating
General annoy-ance	.08 ($p = .541$)	-.04 ($p = .791$)	.01 ($p = .962$)	-.43 ($p = .001$)
Annoyance at night	.04 ($p = .794$)	-.10 ($p = .496$)	-.06 ($p = .682$)	-.36 ($p = .009$)
Satisfaction with residential area	.17 ($p = .224$)	.16 ($p = .249$)	.03 ($p = .816$)	.26 ($p = .063$)
Trust in authorities	.12 ($p = .395$)	.55 ($p < .001$)	.13 ($p = .353$)	.36 ($p = .007$)
Attitude towards airport	-.21 ($p = .116$)	.11 ($p = .441$)	-.12 ($p = .368$)	.37 ($p = .006$)

In contrast to the indirect measures, the relations between the global, direct fairness rating ("In general, I feel fairly treated concerning aircraft noise") and the presumed outcomes almost always were significant at a 5 % level as shown in Table 28. Only the correlation coefficient between the statement to the global fairness item and the *satisfaction with residential area* was not statistically significant. *General aircraft noise annoyance* and *annoyance at night* were lower when the respondents agreed that they generally feel fairly treated with regard to aircraft noise. The s*atisfaction with the residential area, trust in authorities* as well as the *attitude towards the airport* were higher or more positive, respectively, when the respondents perceived a fair treatment. Except for the correlation between *trust in authorities* and *procedural fairness*, the coefficients for the direct fairness measure were consistently higher than for the indirect measures.

9 Discussion and conclusion of the field study

This section discusses the methods and results of the in-depth study on aircraft noise annoyance that was conducted in the field. Conclusions are drawn with respect to future research and attempts for a reduction of the community annoyance due to aircraft noise.

9.1 Discussion of the methodology

9.1.1 Participant selection

Healthy participants aged between 18 and 70 years were considered in the field study. Strict criteria for the selection of participants were applied. Exclusion criteria included, for instance, physical and sleeping disorders, a hearing threshold that exceeds a limit according to age, regular working at night, and also caring for small children up to an age of eight years. The exclusion of parents of young children influenced the age distribution. Individuals in the parental age between 25 and 44 years were underrepresented. Strictly speaking, the results of the short-term annoyance examinations are valid only for a large part of the population at Cologne/Bonn Airport but not to the population as a whole. However, comparing the long-term annoyance over the past 12 months with the mean ratings of the field studies in the telephone survey reveals only small deviations. Both general and night-time annoyance was rated slightly lower in the field study sample. It seems plausible that these deviations rather result from the expanded examination areas in Siegburg - Stallberg, Siegburg - Kaldauen, and Cologne - Rath/Heumar including sites with a lower long-term aircraft noise exposure than in the telephone study. Therefore, in general, it is concluded that no severely biased annoyance ratings were obtained in the field study.

All findings on short-term annoyance induced by aircraft noise are based on a sample from the vicinity of Cologne/Bonn Airport. Although, there have been examination periods with a very high air traffic density, compared to other national and international airports such as Frankfurt Airport or London Heathrow Airport, the airport Cologne/Bonn is less busy. Prior research suggested that the contribution of single aircraft noise metrics (e.g., the NAT_{70} vs. the L_{Aeq}) to long-term aircraft noise annoyance depends on the air traffic density operated at an airport (Rylander & Björkman, 1997; Schreckenberg & Meis, 2007a). A similar effect might exist for short-term aircraft noise annoyance as well. Hence, the recommendation is to make an attempt for the replication of the prediction model developed in this thesis at airports with a higher and lower air traffic density. Two examples are the airports London Heathrow and Stockholm Arlanda which were tested in the framework of the COSMA-project, too, with the same methodology for the recording of the aircraft noise exposure and the assessment of annoyance.

9.1.2 Acoustical measurement

Unlike in several recent studies on annoyance and health-related noise effects (Babisch et al., 2013; Kroesen et al., 2008; Schreckenberg & Meis, 2006; Wirth et al., 2004), for the estimation of the participants' individual aircraft noise exposure, the present field study performed *measurement*s at every study site instead of calculations. The aircraft noise level was recorded outside the participant's dwelling in a free-field position. In order to achieve a realistic estimation of the aircraft noise exposure perceived by the individual, the outdoor to indoor attenuation data as well as information about the participant's whereabouts were taken into account. Nevertheless, the person's exposure to aircraft noise levels could only be approximated. Firstly, the attenuation measurement was performed only in two rooms of the dwelling. These were the room the participant usually stays in most of the day – most frequently the living-room – and the bedroom. Secondly, the whereabouts were obtained by asking the participant whether he or she has predominantly stayed inside or outside the house. Asking individuals about specific rooms they have stayed in was expected to be too much intruding the sphere of privacy. Non-intruding newly developed activity monitoring systems might be an alternative given the sensitive use of this data and the prevention of misusing them for spying into private homes. Scholl et al. (2012) report, for example, about laser systems radio-mapping for a wireless localization of indoor activities.

The calculation instead of a measurement of the indoor aircraft noise level, moreover, showed the drawback that any data of the indoor background noise level could be ascertained. Carrying out domestic activities may produce a high noise as well and may have masked the aircraft noise completely. A similar relation between outdoor and indoor exposure was demonstrated recently for noise from a near highway (Fidell, Sneddon, & Harrison, 2013). This circumstance might have led to an underestimation of the exposition effect on annoyance. To gain information about the indoor background noise level, one or more indoor microphones have to record the sound pressure level in the main habitable room(s) and the sleeping room. Such a procedure, however, would have moved beyond timely and financial resources of the present project. For future field studies using a similar procedure, a supplementary indoor microphone besides the outdoor microphone is highly recommended to determine indoor levels. This would provide data on a possible masking of aircraft fly-over sounds by background noise.

9.1.3 Hourly assessment of annoyance during the day

Although the completion of the questionnaire for the assessment of aircraft noise-induced annoyance took only few minutes per hour, in total of the four examination days with 10 to 15 assessment periods each, the study protocol might be laborious for the participants. The hourly survey required the participants to stay at home or in the near neighborhood as often as possible. Moreover, the assessment task itself that was preceded by a well hearable signal tone presumably had the potential to disturb or interrupt an intended activity. The responses to the question about the strain that was induced by the study protocol revealed that the field study in total was perceived as “slightly” straining. Nevertheless, a positive relation between the reported strain and the rated one-hour aircraft noise annoyance was found: The more laborious the field study examinations were perceived as, the higher was the reported short-term annoyance. The variable *psychological strain due to the study protocol* was a significant predictor of one-hour annoyance ratings even when the effect of acoustical parameters, the type of activity carried out as well as the participant’s sensitivity to noise and the presence and evaluation of noise insulation devices was controlled for. It seems reasonable to conclude from these results that the real status of short-term annoyance in the population might have been overestimated. With regard to future studies using a similar design, a way needs to be found to reduce the strain due to the study protocol. For instance, the annoyance assessments could be better integrated into the participants’ daily routine by leaving up the time of the assessment to the individuals so that intended activities do not need to be interrupted.

9.1.4 Statistical analyses using Generalized Estimating Equations

Generalized Estimating Equations (GEE) were applied to estimate the regression coefficients of the diverse predictors. This approach facilitates the assessment of the effect of metric and categorical variables in a repeated measurement setting without the need to make assumptions about the normality of residuals. Although the *QIC* can be calculated and compared in order to indicate the fit of a prediction model, GEE analyses have the disadvantage that no effect sizes for the variance explanation of a model exist. A review of statistical literature by the author of this thesis revealed that measures of variance explanation are not established yet. Thus, the amount of variance in annoyance ratings that is accounted for by acoustical and non-acoustical variables cannot be compared between models for long-term and short-term aircraft noise annoyance. Conclusions about the relative impact of single predictors or predictor classes are therefore limited.

9.2 Discussion and conclusion of the results of the research questions

9.2.1 Research question B 1: Predictors of short-term annoyance due to aircraft noise

The effect of acoustical parameters

The contribution of each of 30 noise indicators to short-term annoyance induced by aircraft noise was assessed. According to the *QIC* and the conventions postulated by Burnham and Anderson (2004), the number of aircraft fly-overs with a peak level above 65 dB(A), the NAT_{65}, had the highest predictive power for one-hour annoyance among all outdoor noise metrics. Besides the NAT_{65}, the total number of aircraft fly-overs, N_{AC}, and the number of aircraft fly-overs with a peak level above the thresholds 55 and 60 dB(A), the NAT_{55} and NAT_{60}, are better or equivalent predictors compared to the energy equivalent sound pressure level of aircraft noise, $L_{Aeq,AC}$. This finding emphasizes the impact of the number of moderately noisy aircraft fly-overs in comparison to the $L_{Aeq,AC}$. To some extent, this relation is in line with the findings of the short-term annoyance examinations in the field presented by Schreckenberg and Meis (2006). By now, the authors are the only researchers who addressed short-term annoyance using an approach comparable to that of the present study. The results reported by Schreckenberg and Meis (2006) indicated that the NAT_{55} generally has almost the same influence on annoyance ratings as the $L_{Aeq,AC}$. In the morning and late evening hours, the effect of the NAT_{55} is even superior to the influence of the $L_{Aeq,AC}$.

Furthermore, the contribution of the NAT_{65} to annoyance ratings is much higher than the effect of the maximum aircraft noise level across the entire examination period, the *max* $L_{Amax,AC}$, and considerably higher than the effect of the number of aircraft noise events above a threshold of 70 dB(A) or more, the NAT_{70}, NAT_{75}, NAT_{80}, and NAT_{85}. On the one hand, these results support the assumption that a higher number of (medium noisy) aircraft and the resulting reduction of repose times time is more important for short-term annoyance than the maximum levels of single fly-overs (Schreckenberg & Meis, 2006). Additional support proceeds from the present finding that the total time with aircraft noise per hour, which is the complement to the repose time, was a considerably better predictor than the *max* $L_{Amax,AC}$. On the other hand, the results contradict the findings of a previous laboratory study on short-term annoyance that emphasize the supremacy of maximum levels over the number of aircraft noise events (Vogt, 2005).

In sum, it seems reasonable to challenge the formerly prevailing assumption that in laboratory settings, the number of noise events is more important than in the field (Fields,

1984) at least with regard to annoyance due to aircraft noise. Quite the contrary, the present study underlines the contribution of number-related noise metrics to annoyance in the field. Moreover, on the basis of the present results, the equivalent sound pressure level as best predictor of annoyance ratings is queried. This has already been emphasized by prior research with regard to both general annoyance (Björkman, Ahrlin, & Rylander, 1992; Kastka, 1999) and nocturnal annoyance (Quehl & Basner, 2006). The present findings have practical implications, above all with regard to the determination of noise abatement zones and potential approaches for a reduction of the community annoyance due to aircraft noise.

For further noise indicators including a) the total and background energy equivalent sound pressure level ($L_{Aeq,total}$ and $L_{Aeq,bkgd}$), b) the total outdoor level that is exceeded in only 1 % or 0.1 % of the time (L_1 and $L_{0.1}$), c) the ratio of the (maximum) aircraft noise level to the background noise level (*SNR, MNR*), and d) the slope of rise of the aircraft noise events, the present results suggest a comparably low contribution to short-term annoyance. The *QIC* values were considerable higher (Δ > 10 points) than for the total N_{AC}, the NAT_{55} to $NAT_{65,}$ and the $L_{Aeq,AC}$.

As described above, not only outdoor noise metrics but also estimates for an individual's actual (indoor) aircraft noise exposure were available in the form of personalized energy equivalent noise levels ($p\ L_{Aeq,total}$ and $p\ L_{Aeq,AC}$), maximum levels ($p\ max\ L_{Amax,AC}$ and $p\ mean\ L_{Amax,AC}$), and statistical metrics ($p\ L_1$ and $p\ L_{0.1}$). These personalized parameters considered the whereabouts and a possible attenuation of the outdoor noise level as consequence of different window positions. The score of the *QIC* as indicator for the model fit clearly showed that all personalized noise metrics predict one-hour annoyance ratings much more precisely than indicators for the mere outdoor noise exposure. Thus, participants seem to build their annoyance rating upon the aircraft noise level which they immediately hear and which is not necessarily the same as the outdoor level. Therefore, the assumption that the aircraft noise exposure measured outside of the house generally better represents an individual's perception of the noise exposure (cf. Stearns et al., 1983) can be queried.

Out of the personalized aircraft noise parameters and, thus, the best predictor of one-hour aircraft noise annoyance in total was the personalized aircraft noise exposure level, $p\ L_{Aeq}$. Like for outdoor noise indicators, the energy equivalent noise levels contributed much higher to annoyance ratings than the maximum aircraft noise level and the statistical metrics L_1 and $L_{0.1}$.

An improvement of the prediction of aircraft noise annoyance ratings was achieved by a consideration of the N_{AC}, the NAT_{70} in addition to the $p\ L_{Aeq,AC}$. These three parameters made up the acoustical prediction model. Including additional acoustical parameters did not further enhance the predictive quality of this model. The regression coefficients of the model can be interpreted as followed: The $p\ L_{Aeq,AC}$ is the main predictor for short-term annoyance. The higher it is, the higher is the reported annoyance. When the effect of the $p\ L_{Aeq,AC}$ is controlled for, the number of aircraft sound events in the given time is decisive. That means that for time periods with an equal energy-equivalent aircraft noise levels, a higher number of aircraft fly-overs result in a higher annoyance rating. When also the effect of the number of aircraft noise events is controlled for, then the number of noisy aircraft noise events with a peak level above 70 dB is crucial. The higher this number is the higher annoyance is rated. This finding again underlines the importance of the number of aircraft noise events for short-term annoyance due to aircraft noise. Thus, the results support the general assumption that the impact of acoustical parameters on annoyance is underestimated when the noise exposure is operationalized by equivalent sound pressure levels only (Guski, 1993). Moreover, the findings underpin the general postulation that supplementary noise descriptors besides the L_{Aeq}, such as the number of (medium and loud) noise events, should be taken into account when noise effects are investigated (Interdisziplinärer Arbeitskreis für Lärmwirkungsfragen beim Umweltbundesamt, 1990; Ising & Kruppa, 2002).

The effect of the time of day

The effect of the time of day found in the field study was statistically significant but rather small. When the effect of the personalized aircraft noise exposure level was controlled for, annoyance was lowest shortly after noon (13:00 – 14:00) and highest in the morning (07:00-08:00). A particularly enhanced annoyance in the evening and night as it was suggested by prior works (Hoeger, 2004; Hoeger et al., 2002) and also by the results of the telephone study presented in this thesis (see Section 5.3.2) could not be confirmed. The results of the present field study rather support the finding of Stearns et al. (1983) who revealed a significant but small increase of annoyance ratings in the time between 22:00 and 07:00. Similarly, Schreckenberg and Meis (2006) found slightly enhanced annoyance ratings in the early morning and in the evening.

Interestingly, when the presumably time-invariant personal factors *noise sensitivity* and *presence and evaluation of domestic noise insulation* are included in the prediction model for short-term annoyance, the time of day is no longer a significant predictor at a 5 % level. Nevertheless, the effect was maybe underestimated due to two reasons. Firstly, only short-term annoyance due to aircraft noise was assessed during the participant's individual "daytime", i.e., when he or she was awake. Short-term annoyance was not assessed during the individual “night”, i.e., when the participants intended to sleep. As mentioned earlier, at least for individuals not working in night shifts, it is the night sleep that is assumed to be particularly susceptible to noise (e.g., Basner et al., 2008; Griefahn, 2000; Porter et al., 2000). Secondly, with regard to annoyance ratings in the evening, results might have been slightly underestimated due to the examination protocol. Höger (2004) as well as Porter, Kershaw, and Ollerhead (2000) concluded that especially after a busy working day, individuals expect their homes to be quite and restful and a source for recreation. During the field study days, the participants were not able to carry out occupational work as usual in terms of a normal working day (except for the few self-employed). Hence, relaxing activities including leisure activities were not restricted to the time after work that is presumably the (early) evening hours. The results of the hourly annoyance survey revealed that the participants actually carried out leisure activities during the whole day and relaxing activities mainly during the afternoon. A future study should therefore also consider participants who are away for work during the morning and afternoon.

The effect of the day of the week

According to the results of a GEE analysis, concerning short-term annoyance it is not decisive whether a person is exposed to aircraft noise on weekdays or at the weekend. This result counters prior findings on short-term annoyance in the field (Schreckenberg & Meis, 2006). Furthermore, this result seems to contradict the postulation that the weekend is related to expectations for rest and relaxation (Porter et al., 2000) and that the time at the weekend coincides with activities particularly prone to be disturbed by noise as, for instance, sleeping longer or communication activities (Fields, 1985). Nevertheless, the effect of the day of the week might have been underestimated and the lack of a significant influence might be the consequence of the field study protocol. By requesting the participants to stay at home and not go to work for four days, a kind of artificial weekend might have been created. At least theoretically, those participants who did not work at home from a home office were able to carry out activities during the entire field study which are typical for the weekend, such as leisure activities, conversation, relaxation, and sleeping longer. In addition, presumably the explanation for only slightly higher annoyance in the evening is appropriate here as well: The presumed special need for rest and quietness at the end of the day/week is probably preceded by a more or less straining and noisy working day (cf. Hoeger, 2004; Porter et al., 2000).

The effect of the intended activity

Results of the field study indicated, that aircraft noise-induced annoyance rated over a period of one hour depends on the intended activity that was disturbed by the noise. When the effect of the personalized aircraft noise level, L_{Aeq}, is controlled for, carrying out *physical activities* reduced annoyance whereas being engaged in the activities *listening to the radio or watching TV*, *relaxation,* or *eating* significantly raised annoyance. Especially the finding that eating has a moderating effect on short-term annoyance was very surprising as this activity has not been regarded as particularly susceptible to an interference by noise. However, eating has already been shown to be one of the activities most disturbed by aircraft noise in the short-term annoyance examinations by Schreckenberg und Meis (2006).

Conversation, socialization, personal care as well as carrying out *mental activities* or *leisure activities* did not affect annoyance significantly. The lack of a significant effect of conversation disturbance on annoyance contradicts prior research and expectations. Besides relaxation and sleep, conversation and active communication is presumed to be most susceptible to the disturbance or interruption by noise (e.g., Finke et al., 1975; Hall et al., 1985; Kloepfer et al., 2006). Therefore, a causal relation between communication or speech interference and annoyance has been postulated by several authors in the past (Taylor, 1984; Hall et al., 1985; Guski, 1991).

Notwithstanding the above, the fact that aircraft noise is more annoying when listening to the radio or watching TV than when communicating to another person is not implausible, after all. When a very noise aircraft fly-over interferes with the conversation between human individuals so that the listener has missed important information, he or she has the chance to ask for the repetition of what was said. Simultaneously, the speaker can adjust the speaking volume. In contrast, an immediate repetition of the information sent by a radio or TV emission is hardly feasible meaning that this information is lost (Kloepfer et al., 2006). At least for short-terms, this circumstance might produce feelings of annoyance, bother or upset more probable than the need to repeat a sentence that was already said. Moreover, due to the intermittent nature of aircraft noise exposure, the adaption of the volume of the TV and radio must be performed again and yet again. The frequent necessity to adapt the volume has already been concluded to cause higher disturbance ratings for aircraft noise compared to the rather continuous road traffic noise exposure in prior research (Felscher-Suhr et al., 1996)

As already mentioned, higher aircraft noise-induced annoyance was reported when the respondent was engaged in eating. This result is counterintuitive if one assumes that the proper activity is not interfered with by the noise as it would be the case, for instance, for speech and communication. Possibly eating is considered as a kind of social event that is related to conversation which is in turn regarded as susceptible to interference by noise. Notwithstanding, in the present study, the aircraft noise occurring during active communication was not perceived as significantly more annoying than the noise occurring during other activities. Hence, the finding that the activity *eating* influences the perception and evaluation of the noise cannot be justified entirely. Instead, from this result, the general conclusion is drawn that the interference or disturbance of an activity is no precondition for the feeling of annoyance. Possibly, the higher annoyance during eating is not the consequence of disturbance but of belying an individual's expectation to be able to eat in a quiet and peaceful atmosphere.

A combined model including acoustical and situational non-acoustical factors

Including the non-acoustical situational factors *time of day* and the intended *type of activity* clearly improved the prediction of one-hour annoyance ratings compared to a mere acoustical model. Different from a standard multiple regression analysis, for a GEE analysis, the amount of variance in the annoyance ratings that is explained by this combined model cannot be estimated and compared to the variance accounted for by the acoustical predictors alone. According to the conventions by Burnham and Anderson (2004), it can be concluded that the change in the *QIC* score indicates a considerable improvement of the fit of the model.

Nevertheless, the present result emphasizes the high contribution of non-acoustical *situational* factors to aircraft noise-induced annoyance. To the author's knowledge, the impact of acoustical parameters and the factors *time of day* and intended *activity* have not been examined in a combined model, yet. For the additional contextual factor *degree of urbanization* of the residential area, a significant effect on long-term annoyance due to aircraft noise was found in the telephone study presented earlier in this thesis (see Section 5.4) as well as in prior research (Lercher et al., 2008). Anyhow, the influence of this factor on short-term annoyance could not be investigated as the two examination areas of the in-depth field study did not differ with regard to their degree of urbanization. At last, it is important to note, that an individual's whereabouts (indoors vs. outdoors) and the several window positions when being indoors (closed, partially open, open), which are likewise rather situational factors, had a significant effect on short-term annoyance as well. Their contribution to annoyance can be derived from the fact that the personalized acoustical parameters which take into account the whereabouts and window positions predicted short-term annoyance ratings distinctly more precise than each of the outdoor noise parameters. In sum, the results of the field study support the postulation that non-acoustical variables referring to the context of the noise situation should be considered besides person-related factors, such as attitudes and traits, when annoyance and disturbance due to noise are examined (Fields, 1993; Felscher-Suhr et al., 1996).

The effect of time-invariant personal factors and a final model

After showing the contribution of *situational* non-acoustical factors to short-term annoyance ratings, it was investigated whether variables presumably stable over a certain period of time can further increase the predictive power of the model. The person-related and rather time-invariant variables a) *suggestions for airport actions to improve the residents' situation*, b) *perception of negative aspects of the local air traffic*, c) *attitude towards the airport*, d) *presence and evaluation of domestic noise insulation*, e) *application of coping measures*, f) *satisfaction with the residential area*, g) *environmental conscience*, and h) *noise sensitivity* which have been found to be significantly influencing long-term aircraft noise annoyance were added to the existing model. Among these eight variables, only *noise sensitivity* and the *presence and evaluation of domestic noise insulation* significantly affected short-term annoyance ratings and further enhance the fit of the prediction model. This finding suggests that a large part of personal factors, above all, attitudes and evaluations cannot be validly measured with the available questionnaires in field settings or do not play an important role for the judgment of aircraft noise-induced annoyance during short periods. The latter would somewhat contradict the results of previous laboratory studies that found a relation between the individual's general attitude towards the noise source and annoyance during short terms (Djokvucic et al., 2004; Jonsson & Sörensen, 1970; Öhrstrom et al., 1988). Anyhow, the studies listed were all carried out in laboratory settings. It is not clear whether these findings are transferable to the short-term annoyance due to aircraft noise exposure in the domestic living environment. A study on short-term noise annoyance conducted at the participants' homes likewise showed that attitudes (operationalized as fears concerning the air traffic and confidence in noise authorities) had no or only a small effect on one-hour annoyance (Schreckenberg & Schuemer, 2010).

Surprisingly, when noise sensitivity was introduced in the model the effect of the time of day on annoyance ratings was no longer statistically significant. On the one hand, this result supports previous studies emphasizing the impact of noise sensitivity on annoyance both across long periods (Job, 1988; Miedema & Vos, 2003) and short terms (Öhrstrom et al., 1988; Schreckenberg & Schuemer, 2010). On the other hand, this finding points to a relation between the general sensitivity to noise and the susceptibility to noise during certain times of the day. An explanation of this effect could be the assumption that the time of day is a significant influence factor only for individuals who are generally highly susceptible to noise. To the author's knowledge, this question has not been addressed in prior literature on noise sensitivity yet.

The model comprising the acoustical parameters $p\ L_{Aeq,AC}$, N_{AC}, NAT_{70}, and the situational factor *type of intended activity* as well as the person-related and rather time-invariant variables *noise sensitivity* and *presence and evaluation of domestic noise insulation* together constitute the final prediction model of short-term annoyance due to aircraft noise over a period of one hour. Compared to the first model that contained only acoustical parameters of aircraft noise, the predictive power of the final model has increased tremendously. The results emphasize the remarkable contribution of non-acoustical variables on aircraft noise-induced annoyance as it has already been concluded in prior works (e.g., Fields, 1993; Guski, 1999; Lercher, 1996b; Miedema & Vos, 1999; Stallen, 1999).

9.2.2 Research question B 3: The relation between short-term and long-term annoyance due to aircraft noise

The field study examinations addressed the question how, i.e., through which psychological mechanism short-term and long-term annoyance ratings are related. It was investigated whether long-term annoyance judgments reflect a kind of average rating across a variety of situations including times of lower and higher annoyance or whether long-term judgments are rather based on extreme situations. For this purpose, correlation coefficients and mean differences were calculated between the participants' long-term ratings and their *average* short-term annoyance ratings across the four field study days. The same calculations were performed for long-term ratings and the *highest* annoyance ratings across the field study. The relation between the average short-term annoyance rating and the long-term annoyance rating was moderate (r = .50). This finding is very similar to the coefficient Schreckenberg and Schuemer (2010) found in the vicinity of Frankfurt Airport (r = .53). In contrast, correlating every participant's highest annoyance rating to the long-term annoyance rating produced a considerably lower coefficient in the present study (r = .32). Unfortunately, a comparable measure was not reported by Schreckenberg and Schuemer (2010). Taken together, the results suggest that respondents actually are capable to abstract across situations of higher and lower annoyance instead of referring to extreme situations exclusively.

However, a significant correlation only shows that the scores of two variables vary together, but does not provide any information about absolute values. Therefore, mean differences were analyzed in addition. Although only those participants were tested who were exposed to an aircraft noise exposure during the field study that was representative for several months of the year, short-term and long-term annoyance ratings differed significantly in their means. Short-term ratings were much lower than long-term ratings. Thus, long-term annoyance due to aircraft noise does not simply equal the average short-term annoyance across several days. The significant difference in the means of short-term and long-term annoyance ratings is consistent with the results of a previous study that investigated the relation between annoyance due to railway noise in the past night and long-term annoyance rated with regard to the past 12 months (Pennig et al., 2012). Both this finding and the results of the present thesis support the mechanisms postulated by Porter, Kershaw, and Ollerhead (2000). Their model states three stages of annoyance induced by aircraft noise: a) acute annoyance, b) short-term annoyance, and c) chronic annoyance. Acute annoyance during the night that is caused, for example, by several awakenings accumulates to short-term annoyance. The feeling of short-term annoyance after several disturbed nights aggregate into chronic annoyance. The results of the present study indicate that this model might be applicable for short-term daytime annoyance and disturbance as well: Acute annoyance due to the interference of noise with an intended activity might accumulate to short-term annoyance for the period of one hour or one day. This feeling of short-term annoyance piles up over weeks and months and might then result in a chronic or long-term annoyance rating that is considerable higher than the single short-term ratings would be. Up to which score this accumulation process continues, however, remains open. The model postulated by Porter et al. (2000) makes no assumption about this issue. In order to obtain a broader knowledge about the relation between the noise exposure and short-term and long-term annoyance, a panel study across one year would be necessary. While the noise exposure is monitored, annoyance could be assessed in all seasons then including times of an enhanced air traffic density, such as the summer holidays.

Besides the relation between short-term annoyance during the daytime and general long-term annoyance, also the contribution of the *subjective sleep quality* during the field study nights to long-term annoyance was investigated. The results revealed a significant effect of the self-rated sleep quality on general long-term aircraft noise annoyance. The size of effect expressed as standardized regression coefficient was very similar for daytime short-term annoyance and subjective sleep quality ($\beta = 0.34$ and $\beta = -0.38$, respectively). Mean daytime short-term annoyance and mean self-rated sleep quality together accounted for 34.6 % of the variations in the ratings of aircraft noise-induced annoyance over 12 months. This percentage corresponds to a remarkable increase of the predictive power compared to the basic model which predicts long-term annoyance only by the mean daytime short-term annoyance.

Two conclusions can be drawn from these findings. Firstly, a perceived decrease in the individual sleep quality due to nocturnal aircraft noise is a crucial determinant of general long-term noise annoyance as already postulated by several researchers (Izumi & Yano, 1991; Porter et al., 2000; Taylor, 1984). Secondly, daytime short-term annoyance and the decreased subjective sleep quality due to aircraft noise contribute in relatively equal shares to long-term aircraft noise annoyance. From the perspective of psychological effects of aircraft noise, it seems advisable to expand the granting of effective domestic noise insulation. Currently, in accordance with the German Aircraft Noise Act (Gesetz zum Schutz gegen Fluglärm, Bundesministerium der Justiz, 2007), noise insulation is granted by the local airport only for bedrooms in noise protection areas. These areas are defined mainly by a night-time equivalent level above 50 dB(A) for new or considerably expanded airports, and above 55 dB(A) for existing airports. The results of the hourly examinations revealed that residents most often stay inside the house at daytime even during the warm seasons. Therefore, a reconsideration of the granting or at least of the subsidization of noise insulation for habitable rooms, i.e., mainly the living-room and home office, is recommended.

9.2.3 Research question B 3: Evaluation of aircraft noise authorities

Research question B 3.1: Evaluation of authorities' influence on aircraft noise exposure and of their will to act in the residents' interest

Asking respondents about the amount of control they ascribe to a noise authority on the one hand and about the amount of effort this authority invests to act in the residents' interest on the other hand discovered remarkable discrepancies for most of the authorities. With exceptions for municipal authorities and action groups, the authorities' control is rated much higher than the amount of effort they invest in the view of the airport residents for their needs. Only for action groups, the perceived effort was rated higher than the amount of perceived control. The question about the perceived amount of effort to meet the residents' interest was designed to represent one aspect of the construct *trust in authorities* which is regarded as significant influence factor of long-term (aircraft) noise annoyance (Guski, 1999; Lercher, 1996b; Stallen, 1999). For the present study, however, a significant relation to aircraft noise annoyance ratings was found neither across all authorities nor when the authorities were considered separately.

The two questions about the amount of control and consideration of residents' views were preceded by an open question. The participants were requested to name authorities or institutes that have the most influence on the aircraft noise exposure in their view. An interesting detail of this analysis was the frequency how often the diverse authorities were mentioned as an authority having control over the aircraft noise exposure. By far, the airport management was named most often. The German federal government and the federal state government were enumerated comparably seldom. This finding underlines the complexity and the lacking transparency of the decision-making processes on air traffic at Cologne/Bonn Airport. Obviously, the influence of the airport management on the decision-making on air traffic and the control over the allocation of aircraft noise in the vicinity of the airport is overestimated. In contrast, the major population seems not to be aware of the high influence of the authorities who set the legal basis for the decision-making processes, i.e., mainly the federal government and the federal state government. As a consequence, the complexity of these responsibilities and power relations should be communicated in an appropriate manner to interested residents. It seems crucial to illustrate a) who is responsible for which decision and b) which noise abatement strategies are feasible in which term. As already discussed in Section 6.2.4, due to little confidence in the noise authorities, the initiation of an entity that is perceived as neutral by both the residents and the profiteers of the airport might become necessary.

Research question B 3.2: Perceived fairness of air traffic-related decision-making and the allocation of aircraft noise at Cologne/Bonn Airport

With few exceptions, fairness research has basically been restricted to the organizational and legal context so far. Research on fairness in connection with aircraft noise exposure only focused on single aspects of fair procedures (Maris et al., 2007a; Maris et al., 2007b). As no suitable survey instrument existed, a questionnaire was developed and tested to examine the impact of a broad range of fairness standards in the context of aircraft noise exposure.

Mainly low means show that the decision-making considering air traffic and the allocation of noise exposure at Cologne/Bonn Airport are perceived as not fair by most residents. This outcome might be explained to some parts by the history of the airport (cf. Köln Bonn Airport, 2014). Cologne/Bonn Airport was founded in 1950 for commercial use. During the 12 years prior to this date, the airport was used exclusively as military airfield. In 1953, the cross wind runway was built. Since that time, no major expansions in terms of an additional runway were conducted. Nevertheless, the flight density has changed dramatically during the decades. An official plan approval procedure with hearings of the municipal authorities and residents has never been given at any time. Ignoring the population in decision-making procedures might, in turn, have led to learned helplessness and the fact that the residents are hardly interested in the airport decision-making. Maybe, this accounts for the relatively high number of "do not know" answers given to several fairness statements. Moreover, the non-involvement of the airport residents might have resulted in the belief that "one cannot change anything anyway". This is reflected by the very low mean of the item representing perceived *decision control*.

The internal consistency and homogeneity of the subscales were satisfying to high after clearing the questionnaire from a statement about the consistency of applied procedures over the residents (item 4) and a statement about the accuracy of information sampling of the authorities prior to the decision-making (item 6). The negative discriminatory power of item 4 suggests that this item was misinterpreted and should be re-formulated prior to a future use of the questionnaire. The same applies to item 6 which had a very low discriminatory power. The item analysis revealed that a considerable proportion of participants had difficulties to answer these two items and therefore used the response option "do not know". This shows that interviewees obviously could judge certain fairness criteria less easily than others. Similar conclusions could be drawn from the experiences of a small-scale pilot test of the fairness questionnaire. Interviewees were not able to rate the fulfillment of the *ethicality rule*, *consistency (over time) rule*, and *bias suppression rule* (Leventhal, 1980) as well as the *interpersonal fairness* criteria *propriety* and *respect* (Bies & Moag, 1986). The precondition of judging *interpersonal fairness* is the personal contact to a noise authority and this was given for none of the respondents of the pre-test. Taken together, the findings from the pilot test and the item analysis of the final questionnaire version, an equipollence of the different fairness criteria cannot be concluded at least with regard to the context of aircraft noise exposure.

Fairness was found to be not a homogenous construct but to rather comprise distinct dimensions. In a principle component analysis, the hypothesis on the multi-dimensionality of the construct *fairness* could largely be confirmed. Three factors were extracted that correspond to the dimensions *distributive, procedural,* and *informational fairness.* The stability of the three-factor structure, however, seems to be rather low as only two of the three factors had an eigenvalue above 1 and therefore play an important role for the explanation of variance in the item scores. Since *interpersonal fairness* could not be assessed in the sample due to the lack of personal contact of airport residents to noise authorities, only the three dimensions *distributive, procedural,* and *informational fairness* were examined. An additional constraint is the very small sample size of 55 participants that could be tested in the framework of the field study. With the increase of the sample size in a factor analysis, the quality of the factor solution, i.e., the stability and accuracy of recovering the true population structure, improves. For the discussion about an appropriate sample size see MacCallum, Widaman, Zhang, and Hong (1999).

For the given reasons, testing a revised version of the newly developed questionnaire is necessary with a significant larger sample of airport residents. A revised version of the fairness scale is currently used in a large-scale study ($N \approx 7000$) on annoyance, decreased cognitive performance, and impaired health due to transportation noise in the vicinity of Frankfurt Airport, (the NORAH-study: see Schreckenberg et al., 2011). After the release of the data in 2015, a confirmation of the factor structure will be attempted preferably by a confirmatory factor analysis.

The subscales *distributive, procedural,* and *informational fairness* were moderately or not related. This result is in line with a meta-analysis on the dimensionality of the fairness construct (Colquitt et al., 2001) emphasizing the multidimensionality of *fairness*. *Procedural* and *informational fairness* were related moderately to each other. *Distributive fairness* did not correlate with any subscale at all. Thus, combining the subscales to one common scale does not seem reasonable.

Furthermore, the relation of the scores of the fairness subscales to possible outcomes of a fair allocation of aircraft noise and a fair decision-making were investigated. A high *distributive fairness* was assumed to be related positively to the reported *satisfaction with the residential area* as well as to be negatively related to *aircraft noise annoyance* in general and with respect to the night-time period. The first assumption was supported by tendency. The latter hypothesis, in contrast, could not be supported at all: No significant relation was found between any fairness dimension and the two annoyance ratings. Thus, the significant effect of a fair procedure on annoyance which was found in a laboratory setting (Maris et al., 2007b) could not be demonstrated in the present field survey.

Between *procedural fairness* and *trust in authorities* as well as between *informational fairness* and *trust,* a positive relation was assumed. A likewise positive relation was hypothesized between *procedural fairness* and the *attitude towards the airport* and between *informational fairness* and the *attitude towards the airport*. However, the only statistically significant correlation was found between *procedural fairness* and *trust in authorities*. The results on the relation between the *informational fairness* of the noise authorities' communication and the presumed outcomes were not significant and rather inconsistent. Thus, the postulation of the impact of a transparent information policy on annoyance and a good neighborhood with the airport (cf. Haugg et al., 2003; Maziul & Vogt, 2002; Vogt & Kastner,

2000) cannot be supported directly in the present study. Nevertheless, an indirect relation is concluded as the general feeling of a fair treatment with regard to aircraft noise is determined to some extent by the perceived informational fairness of the noise authorities' communication. Moreover, the general belief that one is fairly treated significantly contributes to general and nocturnal annoyance due to aircraft noise.

Besides the low statistical power resulting from the small sample size, a reason for the lack of significant relations, above all between perceived *procedural* and *informational fairness*, and annoyance, might be the relatively little direct concernment of the residents by decision-making processes. In analogy to the psychological stress theory (see, e.g., Folkman, 1984; Folkman & Lazarus, 1988), it is concluded that a certain level of threat is the precondition for a significant effect of fairness on aircraft noise annoyance in the field. That means that the individual must face a change in aircraft noise exposure that is judged as potentially harmful and thus as exceeding the individual's resources. Cologne/Bonn Airport is a steady-state airport. No major changes, such as an expansion or the construction of a new runway, have been made during the recent past or have been planned for the near future. To shed more light on the impact of the different fairness criteria in the context of transportation noise exposure, further research is recommended. The examination of *fairness* with all its facets should not be restricted to the vicinity of steady-state airports, such as the airport Cologne/Bonn. Instead, communities need to be considered where major changes are planned or have currently established and where these changes are linked to the deterioration of the noise situation of certain residents. Such an example is Frankfurt Airport. Residents there are presumably more conscious of the decision-making and communication by noise authorities. Consequently, a higher effect of perceived fairness on aircraft noise annoyance is expected.

With one exception, contrary to the indirect measures, the correlations between the direct global fairness judgment and the outcomes *aircraft noise annoyance*, *trust in authorities,* and *attitude towards the airport* were statistically significant. The correlation between the direct measure and reported *satisfaction with the residential area* just missed the 5 % significance level. The coefficients between the direct measure and the multiple outcome measures were generally higher than the coefficients of the indirect measures. At least for the context of aircraft noise exposure, this finding clearly counters the conclusion of a meta-analysis on fairness stating that indirect fairness measures generally correlate higher to outcomes than direct measures (Colquitt et al., 2001).

Taking into account the relatively low correlations ($r \leq .43$) between the scores for *distributive, procedural,* and *informational fairness,* and the global, direct fairness rating, the conclusion is that the global fairness judgment is based not solely on rational considerations but on broader attitudes as well. The correlations between the general belief that one is fairly treated with regard to aircraft noise (= global fairness rating) and the reported *attitude towards the airport* (r = .37) and the *trust in authorities* (r = .36) suggests that, at least to some extent, the global fairness judgment equals a kind of personal attitude. Globally rated fairness presumably reflects general attitudes and convictions as, for instance, “The airport is good for the region” or “The noise authorities always have a vested interest”. Such evaluations are assumed to be the product of socialization processes and are not necessarily linked to rational considerations (Guski et al., 1999). The latter could account for the relatively low correlations between the rational fairness criteria, such as a truthful information (Bies & Moag, 1986) or control in the decision-making (Thibaut & Walker, 1975), and the global fairness judgment.

With respect to the content of the fairness questionnaire, it seems reasonable to add supplementary items. Above all, this applies to the fairness dimension *distributive fairness* that has been represented by only one item so far. Within this framework, a subsequent project should investigate the residents’ understanding of a fair noise allocation at major airports in more detail. The following questions should be focused. According to the residents, which changes in the aircraft noise exposure have to be achieved in order that a community feels fairly treated regarding the aircraft noise? With respect to a steady aircraft noise exposure, which actions have to be undertaken by the noise authorities before a community perceives a given air traffic density and the resulting aircraft noise as acceptable? Could financial or other compensation enhance the acceptance of the noise and the belief that one is fairly treated? In addition, the attitudinal components of the global fairness judgment need further investigation. One important issue in this context is the question about specific factors causing a positive or negative attitude. Again, the ultimate question is how noise authorities achieve credibility and trustworthiness and, thus, a good neighborhood relation to the residents of a noise source.

Although supported only partly by the results of this study, still, the assumption is that a good relation between the airport and its residents can be obtained only by an open and truthful communication. A candid communication climate needs to be established between the decision-makers and profiteers of the airport on the one hand (i.e., for instance, the airport operator, the federal (state) government and the municipal authorities of Cologne and Bonn) and the residents who take the burden of the noise exposure on the other hand. A future project should develop and evaluate possible communication schemes. On an international platform, an attempt to establish such a communication and information program is currently made in the framework of the OMEGA-project (Hooper et al., 2009). However, the results and implications have not been published yet.

10 Overall conclusion

The telephone survey and the in-depth study in the field which were presented in this thesis addressed the examination of aircraft noise-induced annoyance over long terms (one year) and very short periods (one-hour assessment periods during four days) in the vicinity of Cologne/Bonn Airport.

Both the results of the telephone and the field study showed the limited contribution of outdoor equivalent sound pressure levels to annoyance ratings. The results regarding short-term annoyance revealed a clear supremacy of parameters which are related to the number of aircraft noise events. The findings suggest the consideration of the number of fly-overs above a peak level of 65 dB(A) besides the equivalent sound pressure level in future policy-making such as the determination of noise abatement zones. The higher susceptibility to the number of noise events than to the equivalent level is concluded to be a major reason for the deviation of current annoyance-scores from established European exposure-response curves which are based on studies of the 1960s to the early 1990s. The rise in the air traffic density has obviously resulted in higher annoyance even though the maximum levels of single aircraft have been significantly reduced and the equivalent continuous sound pressure levels have remained relatively constant across the past decades. With regard to the minimization of community annoyance, the reduction of the number of fly-overs over an area seems to be the method of choice. This would require the re-arrangement of existing starting and approaching routes, the streamlining of flight schedules as well as the substitution of current air fleets by quiet aircraft with higher capacities of transporting. The implementation of the suggested measures is presumed to last decades. In times of a high need for mobility and transport and, as a consequence, continuously growing air traffic, it is questionable whether each of these noise abatement measures is viable at all.

The findings of the telephone and field study stressed the contribution of non-acoustical factors besides acoustical parameters to aircraft noise-induced annoyance. For long-term annoyance rated over the past 12 months, personal and social variables as, for instance, airport- and aviation-related attitudes and evaluations are crucial besides the noise exposure. Situational and contextual factors, such as the degree of urbanization of the neighborhood and the quality of domestic noise insulation, contribute statistically significant to long-term annoyance as well. Nevertheless, their impact is smaller than that of the personal and social factors. With regard to annoyance during short periods, the highest influence arises from acoustical parameters and situational non-acoustical factors which are the type of activity carried out as well as the whereabouts of the respondents and, thereby, the insulation from noise. The contribution of personal and social factors on annoyance during short periods is limited to the individual's general sensitivity to noise and the subjective evaluation of the domestic noise insulation. From these findings the conclusion is drawn that the impact of personal and social factors on aircraft noise-induced annoyance is higher across long terms than across short-terms.

The results of the field study suggest that activity interference or interruption is not necessarily a precondition of annoyance as often assumed in prior research. Instead, the results demonstrate that a sequence of aircraft noise events can be perceived as annoying even though the noise is not suitable to disturb or interrupt an activity in the nearer sense. Therefore, it seems reasonable to conclude that short-term annoyance can occur not only as secondary but already as primary effect of noise.

Data of a model predicting an individual's long-term annoyance rating by his or her mean short-term annoyance rating across the four study days indicate that long-term annoyance results to a considerable part from the annoyance during shorter periods. Notwithstanding, a significant mean difference between short-term and long-term ratings was revealed showing higher annoyance for long terms. The conclusion is that the long-term ratings of aircraft noise-induced annoyance do not simply reflect the short-term annoyance that was averaged across a period of several days. Instead, an accumulation of the annoyance in several noise situations is assumed. How these single noise situations are aggregated and presented internally as well as up to which annoyance level this accumulation proceeds seem to be determined by personal and social factors. The present results have implications for the transfer of findings from short-term annoyance examinations to long terms such as one year. Even in a domestic setting while carrying out everyday activities, respondents rated their short-term annoyance significantly different from their long-term annoyance. Since laboratory studies can recreate only a small range of these natural activities, it is queried that the results of short-term assessments in a laboratory setting are suitable to validly predict annoyance in the home environment across months and years.

Furthermore, long-term annoyance due to aircraft noise was shown to be significantly related to subjective sleep quality during the field study nights. The contribution of this factor to long-term annoyance was comparable to the impact of daytime short-term annoyance. This finding underlines the worthiness of the protection of the individual's night sleep. At the same time, the result prompts the protection of the respondents from noise during daytime activities as well.

A significant influence variable for long-term annoyance due to aircraft noise is the respondent's belief that he or she is fairly treated in terms of aircraft noise exposure. On the one hand, the feeling of being fairly treated is determined by rational fairness standards. These are, for instance, the perceived truthfulness of the noise authorities' communication and information, the amount of personal control on airport-related decision-making procedures, and the perceived accuracy and comprehensiveness of information the authorities built their decisions on. On the other hand, the fairness judgment seems to be influenced by more general attitudes concerning the aircraft noise authorities. From these findings, starting points for the achievement of a good neighborhood between the airport and its residents as well as for the reduction of community annoyance in the short to medium term can be derived: Noise authorities should involve the residents in the airport-related decision-making. They must make an honest attempt to build trust in airport residents and convey the feeling that they really consider the needs and views of the airport communities. For a minimization of aircraft noise annoyance at Cologne/Bonn Airport, the results of the telephone and field study suggest a) an open and timely communication on current actions at the airport and future airport scenarios, b) a transparent and comprehensible illustration of the amount of control the single authorities have over the aircraft noise exposure, i.e., who is responsible for which decision, c) consultation and involvement of the residents, for instance, with respect to an appropriate domestic noise insulation, and d) an extensive description of current and potential noise abatement measures in connection with the time frame of their implementation as well as a truthful explanation why certain measures cannot be implemented (yet). It is important to emphasize that these actions are not a substitute of physical noise abatement measures, such as the optimization of aircraft operations and technologies, but a complement.

With regard to the relations of acoustical and non-acoustical variables to annoyance, the conclusions of this thesis are summarized using an often cited model on the short-term and long-term effects of noise on man by Guski (1999). Figure 26 depicts this model that was adjusted and supplemented on the basis of the findings presented and discussed in the preceding chapters. The modifications are marked in blue and are shortly outlined hereinafter. A further category of intervening variables was added to the conceptual model that was named *situational factors*. This category contains the variables *intended activity*, *time of day*, *insulation*, and *urbanization of the area*. As described above, these variables have contributed both to short-term and long-term annoyance. Moreover, the construct *short-term annoyance* is stated as a kind of a short-term effect of noise besides actual activity interference. In addition, the model was supplemented with the variables *environmental conscience* and *evaluation of residential area* as well as the construct *fairness* to the categories *personal* and *social factors*, respectively. Furthermore, the arrow leading from *personal factors* to the psychological short-term effects (interference, annoyance) was changed as the results of the field study could only partly confirm the initially postulated contribution of personal factors to the short-term effects of noise.

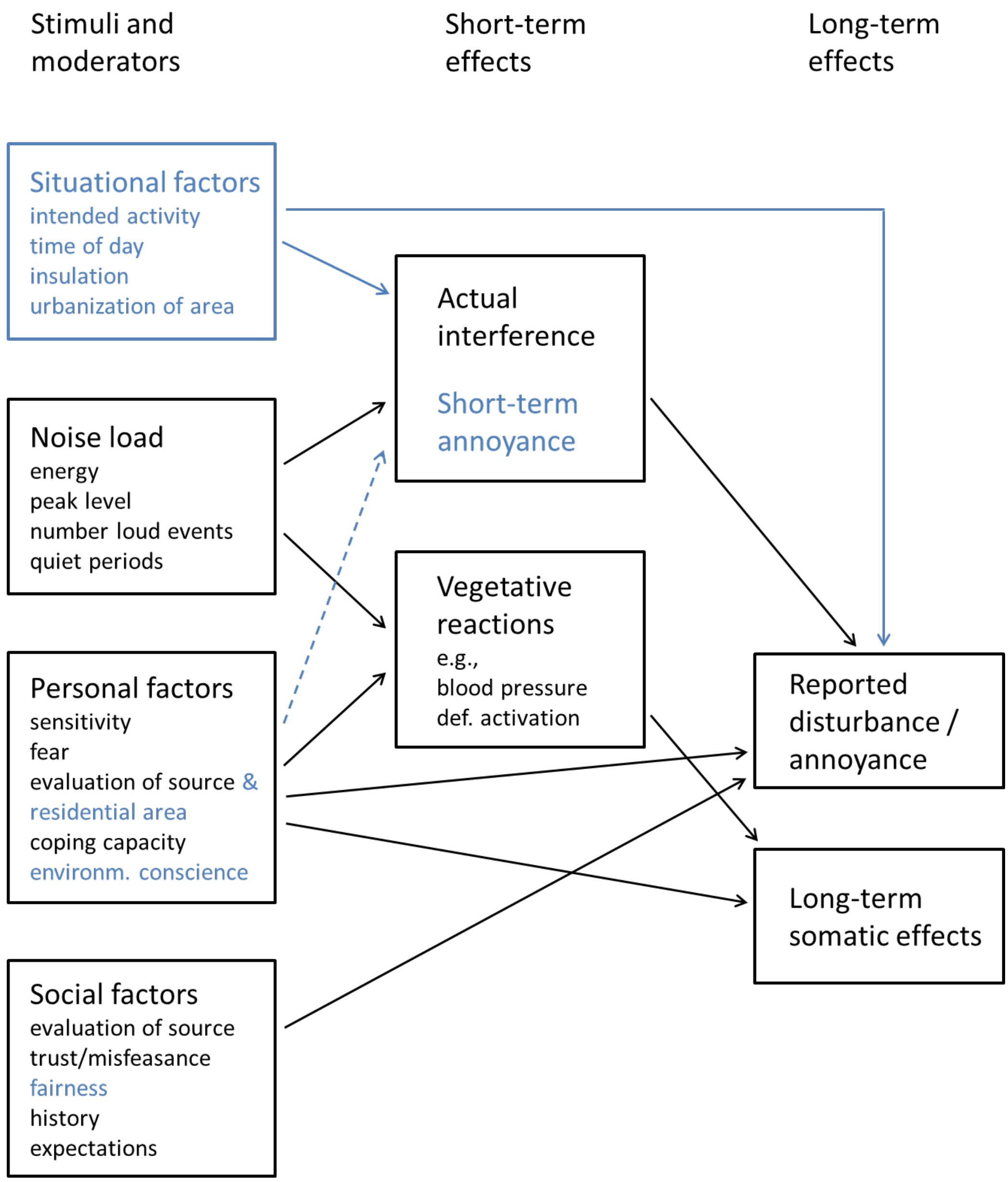

Figure 26. Adaptation and supplementation of a model for short-term and long-term reactions to noise in the context of aircraft noise exposure. Modifications of the original model (Guski, 1999, p. 47) are displayed in blue.

11 Outlook

In the framework of the present thesis, annoyance due to aircraft noise was examined extensively and the contribution of a broad range of variables to short-term and long-term annoyance was investigated. Nevertheless, some questions still remain open and new research questions arise from the present findings.

The aim of the present thesis was to investigate the effect of *aircraft* noise on annoyance. Mainly due to methodological reasons, only areas were investigated that are exposed primarily to no noise source other than air traffic. The degree of urbanization of an area was found to influence annoyance ratings. Annoyance was lowest in rural areas. This finding was attributed largely to the effect of the lower background noise level. Therefore, for future land use planning, an attempt should be made to investigate the effect of aircraft noise exposure on annoyance in the presence of additional noise. Moreover, in times of continuously growing transportation, it is important to know the total effect of combined noise sources with regard to annoyance as well as physical health.

The evaluation of the quality of domestic noise insulation devices had a significant influence on both short-term and long-term annoyance. Future work should address the key factors for a high satisfaction with the noise insulation. For instance, what is the contribution of fitting sound insulating windows and ventilation systems not only in the bedroom but also in the habitable rooms? Moreover, what is the effect of modern sound insulating windows which enable residents to partially open the windows for a better air supply but simultaneously guarantee a high insulation from aircraft noise (cf. HafenCity Hamburg GmbH & Behörde für Stadtentwicklung und Umwelt Hamburg, 2011)?

The present thesis, and so the concluding model presented in Figure 26, proceeded on the assumption that personal and social factors are predictors of aircraft noise-induced annoyance. Anyhow, the statistical approaches used in this work do not allow causal inferences. More complex interrelations, such as reciprocal effects are possibly valid for the link between annoyance, attitudes, and evaluations. The same might apply for the relation between somatic noise effects and annoyance due to aircraft noise. In order to achieve a comprehensive and valid model of the consequences of aircraft noise exposure, the conceptual model depicted in Figure 26 needs to be tested in a path-analytic approach. The recommendation is to examine not only the direct but also the indirect and reciprocal effects of acoustical and non-acoustical factors on the psychological and somatic wellbeing.

In this work, measures to reduce community annoyance and to achieve a good neighborhood between the airport and its residents have been suggested. These measures mainly focus on an improved communication between the profiteers of the airport and the residents exposed to the aircraft noise. On the basis of the present thesis, future work should create and implement concrete information and communication schemes preferably in cooperation with communication researchers. Within this context, it seems crucial to learn about a) the specific information that is the most relevant to the airport residents, b) the preferred way of supply with this information, and c) the amount of the desired information. In the next step, the developed schemes need to be evaluated regarding their effects on the residents' acceptance of the local airport and air traffic as well as on community annoyance.

Finally, as already demonstrated in previous research, the standard European exposure-response curve clearly underestimated the percentage of residents highly annoyed by aircraft noise in this study. At least for aircraft noise exposure, the current standard curve seems to be no longer an adequate mean to estimate community annoyance. Therefore, the establishment of new curves which preferably take into account the characteristics of the airport and surrounding communities is highly recommended.

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List of appendices

Appendix A:

Questionnaire of the telephone interview

Telephone survey on aircraft noise annoyance

subject code: ________________

area code: ________________

date: ________________

time: ________________

interviewer code: ________________

Part 0 – Introduction

0.1 Hello, my name is …. I'm calling from … We are conducting an independent scientific survey on aircraft noise for the European Commission around important European airports.

Is there anyone over 18 in your household who would be comfortable sparing about 8 or 9 minutes to answer a few questions about aircraft noise?

no ☐ 0 yes ☐ 1

If "yes": **First, I would like to re-assure you that all responses are anomynised before publication.**

If "no": **I am sorry for disturbing you. Have a nice day! Goodbye.**

Part 1 – Residential area

First, can I just ask you about the area where you live?

1.1 Since when have you been living in this area?
Only if the person mentions "2009", ask: **Could you tell me the month, too?**

since approx. ____ / ____
MM YYYY

or

for ____ years

An answer to this question is mandatory!

Both for residents who have been living in this area for more than 12 months and for those who haven't, the complete interview is conducted. This information is needed solely for data analysis.

1.2 How satisfied are you with your local area?

extremely satisfied	very satisfied	moderately satisfied	slightly satisfied	not at all satisfied
☐ 5	☐ 4	☐ 3	☐ 2	☐ 1

Part 2 – Noise annoyance

Next, we have some questions about aircraft noise annoyance.

2.1 Thinking about the last 12 months, when you are at home, how much does aircraft noise bother, disturb or annoy you?
Read out!

extremely	very	moderately	slightly	not at all
☐ 5	☐ 4	☐ 3	☐ 2	☐ 1

An answer to this question is mandatory! If the participant answers with "not at all", skip question 2.3-2.5!

2.2 Are you bothered, disturbed or annoyed by any other noises around here?
Don't read out!

no ☐ 0	yes ☐ 1

If „yes", go to question 2.2.1 and afterwards to question 2.2.2!
If "no", go to question 2.3!

2.2.1 What are these other sources? *If the person mentions more than 3 sources of noise, ask:* **Which of them are the three most annoying ones?**
Don't read out!
An answer to this question is mandatory!

road traffic (incl. city buses and trams)	☐ 1
railway/trains	☐ 2
industry/factory	☐ 3
neighbours	☐ 4
playgrounds	☐ 5
restaurants and discotheques	☐ 6
sports venues	☐ 7
building construction	☐ 8
other: ________	☐ 9

2.2.2 Thinking about the last 12 months, when you are at home, how much does noise from … *(the source that the person has mentioned)* **bother, disturb or annoy you?**
Read out!

extremely	very	moderately	slightly
☐ 5	☐ 4	☐ 3	☐ 2

Don't ask about annoyance for more than three sources of noise!

2.3 *Ask this question just in case the person is at least "slightly" bothered, disturbed or annoyed!*

Let's go back to aircraft noise. Thinking about the last 12 months, when you are at home, how much does noise from aircraft bother, disturb or annoy you at night between 10 p.m. and 06 a.m.?
Read out!

extremely	very	moderately	slightly	not at all
☐ 5	☐ 4	☐ 3	☐ 2	☐ 1

2.4 *Ask this question just in case the person is at least "slightly" bothered, disturbed or annoyed!*
On normal weekdays, are there any particular time periods when aircraft noise is more annoying? Please try to give me concrete times of day.

If the person does not know how to answer, say: **Examples for concrete times of day might be "9 – 10 a.m." or "4 – 7 p.m."**

Don't read out! Multiple answers are possible.

06 a.m. to 02 p.m.		*02 p.m. to 10 p.m.*		*10 p.m. to 06 a.m.*	
1. 6-7 a.m.	☐ 1	9. 2-3 p.m.	☐ 1	17. 10-11 p.m.	☐ 1
2. 7-8 a.m.	☐ 1	10. 3-4 p.m.	☐ 1	18. 11-12 p.m.	☐ 1
3. 8-9 a.m.	☐ 1	11. 4-5 p.m.	☐ 1	19. 00-1 a.m.	☐ 1
4. 9-10 a.m.	☐ 1	12. 5-6 p.m.	☐ 1	20. 1-2 a.m.	☐ 1
5. 10-11 a.m.	☐ 1	13. 6-7 p.m.	☐ 1	21. 2-3 a.m.	☐ 1
6. 11-12 a.m.	☐ 1	14. 7-8 p.m.	☐ 1	22. 3-4 a.m.	☐ 1
7. 12 a.m.–1 p.m.	☐ 1	15. 8-9 p.m.	☐ 1	23. 4-5 a.m.	☐ 1
8. 1-2 p.m.	☐ 1	16. 9-10 p.m.	☐ 1	24. 5-6 a.m.	☐ 1

2.5 *Ask this question just in case the person is at least "slightly" bothered, disturbed or annoyed!*
On normal weekends, are there any particular time periods when aircraft noise is more annoying? Please try to give me concrete times of day.

If the person does not know how to answer, say: Examples for concrete times of day might be "9 – 10 a.m." or "4 – 7 p.m."

Don't read out! Multiple answers are possible.

06 a.m. to 02 p.m.		*02 p.m. to 10 p.m.*		*10 p.m. to 06 a.m.*	
1. 6-7 a.m.	☐ 1	9. 2-3 p.m.	☐ 1	17. 10-11 p.m.	☐ 1
2. 7-8 a.m.	☐ 1	10. 3-4 p.m.	☐ 1	18. 11-12 p.m.	☐ 1
3. 8-9 a.m.	☐ 1	11. 4-5 p.m.	☐ 1	19. 00-1 a.m.	☐ 1
4. 9-10 a.m.	☐ 1	12. 5-6 p.m.	☐ 1	20. 1-2 a.m.	☐ 1
5. 10-11 a.m.	☐ 1	13. 6-7 p.m.	☐ 1	21. 2-3 a.m.	☐ 1
6. 11-12 a.m.	☐ 1	14. 7-8 p.m.	☐ 1	22. 3-4 a.m.	☐ 1
7. 12 a.m.–1 p.m.	☐ 1	15. 8-9 p.m.	☐ 1	23. 4-5 a.m.	☐ 1
8. 1-2 p.m.	☐ 1	16. 9-10 p.m.	☐ 1	24. 5-6 a.m.	☐ 1

Part 3 – Coping measures

3.1 Do you do anything about the aircraft noise?
Don't read out!

no ☐ 0 yes ☐ 1

If "yes", go to question 3.1.3

3.1.3 What do you do about the aircraft noise?
Don't read out!

1.	close windows	☐ 1
2.	use earplugs	☐ 1
3.	speak more loudly in conversations	☐ 1
4.	retreat into quieter rooms	☐ 1
5.	avoid using garden, patio, balcony	☐ 1
6.	turn up the sound of radio/TV	☐ 1
7.	use tranquillizer/sleeping pills	☐ 1
8.	others: ____________________	☐ 1
9.	others: ____________________	☐ 1
10.	others: ____________________	☐ 1

An answer to this question is mandatory!

Part 4 – Attitudes

Now, some questions about how you feel about … airport in general.

4.1 What is your attitude towards … airport?

very positive	rather positive	neither negative nor positive	rather negative	very negative
☐ 5	☐ 4	☐ 3	☐ 2	☐ 1

4.2 Next, I am going to ask you about positive and negative aspects of the local airport and air traffic.

4.2.1 Let's start with the positive aspects. In your opinion, do you see concrete positive aspects of the airport and air traffic?

no ☐ 0 yes ☐ 1

If "yes": **What are they?**

Don't read out!

1.	economic development	☐ 1
2.	shopping facilities	☐ 1
3.	accessibility to travel	☐ 1
4.	good infrastructure	☐ 1
5.	availability of jobs	☐ 1
6.	availability of goods	☐ 1
7.	cosmopolitan atmosphere	☐ 1
8.	others: _____	☐ 1

4.2.2 Do you see concrete negative aspects of the airport and air traffic in your opinion?

no ☐ 0 yes ☐ 1

If "yes": **What are they?**

Don't read out!

1.	aircraft crashes	☐	1
2.	health risks for residents	☐	1
3.	environmental risks	☐	1
4.	decrease in property prices	☐	1
5.	decreasing quality of life	☐	1
6.	traffic congestion	☐	1
7.	others: ______	☐	1

4.3 Have you any suggestions for something the airport can do for you.
Don't read out!

no ☐ 0	yes ☐ 1

If "yes": **What are they?**

1.	reduce noise	☐	1
2.	freeze status quo	☐	1
3.	monetary compensation	☐	1
4.	change aircraft fleet	☐	1
5.	inform comprehensively/transparently	☐	1
6.	flight punctuality	☐	1
7.	change approach/departure routes; arranging flight paths over thinly populated areas	☐	1
8.	guarantee safety	☐	1
9.	financial grants for insulation	☐	1
10.	decision rights in aircraft routes	☐	1
11.	reducing the number of flights during the night	☐	1
12.	others: ______________________	☐	1

4.4 If decisions concerning air traffic have to be made, what do you think is more important: environmental issues or economic issues?

environmental issues	☐ 1	economic issues	☐ 2
both in equal shares	☐ 3	don't know	☐ -2

4.5 Have you read, seen or heard any items concerning the local airport, aircraft noise or air traffic in general during the last weeks?
Don't read out!

no ☐ 0	yes ☐ 1

If "yes", go to question 4.5.1 and afterwards to question 4.5.2

4.5.1 What were they about?
Don't read out!

1.	aircraft crash	☐
2.	advertisement	☐
3.	building activities at airport	☐
4.	new aircraft technology	☐
5.	health consequences of air traffic	☐
6.	air pollution caused by air traffic	☐
7.	air traffic policy	☐
8.	others: ____________________	☐

An answer to this question is mandatory!

Please consider: If only news concerning the volcanic ash is mentioned, please ask about further topics. Media coverage about the volcanic ash might have outshined other also important topics.

4.5.2 Was the news about … *(ask for each topic that was mentioned)* **rather positive, rather negative or not relevant for you?**
Don't read out!

negative ☐ 1	positive ☐ 2	not relevant ☐ -1

An answer to this question is mandatory!

Part 5 – Demographic data

As in every survey, some demographic data are required now.

5.1 Every person is responsive to noise in a different way. What would you say, how sensitive to noise are you in general?

extremely sensitive	very sensitive	moderately sensitive	slightly sensitive	not at all sensitive
☐ 5	☐ 4	☐ 3	☐ 2	☐ 1

5.2 How old are you?

_____ years

or

_____ year of birth

An answer to this question is mandatory!

5.3 *Gender? Don't ask, just record unless you are not sure!*

male ☐ 1 female ☐ 2

An answer to this question is mandatory!

5.4 Do you have any hearing problems?

no ☐ 0 yes ☐ 1

If "yes", got o question 5.41! If "no", go to question 5.5.
If the participant answers "yes", he/she is not being asked about interest in field study!

5.4.1 Do you use a hearing aid?

no ☐ 0	yes ☐ 1

5.5 Are you a tenant or homeowner?
Don't read out!

tenant ☐ 1	owner ☐ 2

5.6 As far as you know, has your home had noise insulation fitted?
Don't read out!

no ☐ 0	yes ☐ 1	don't know ☐ -2

If "yes", go to question 5.7 and afterwards to question 5.8! If "no" or "don't know", go to question 5.9.

5.7 Has the local airport paid for the noise insulation?
Read out (except "don't know")!

no ☐ 0	to some extent ☐ 1	completely ☐ 2	don't know ☐ -2

5.8 How satisfied are you with the noise insulation?

extremely satisfied ☐ 5	very satisfied ☐ 4	moderately satisfied ☐ 3	slightly satisfied ☐ 2	not at all satisfied ☐ 1

5.9 Is your employment or that of any member of your household connected in any way with the local airport?

no ☐ 0 yes ☐ 1

5.10 How many air trips did you make as a passenger during the last 12 months? One trip includes outward and return flights.

approx. _____ trips

5.11 What is the highest level of education you have completed? I'm going to read out a list, so please let me know:

Which of these categories best applies to you?

still pupil/student	☐	1
without school qualification	☐	2
GCSE/O-Level/O-grade	☐	3
A-Level/vocational A-Level	☐	4
university/polytechnic degree	☐	5
refused to answer	☐	-999
no categorisation possible	☐	-3

An answer to this question is mandatory!

Unless "still pupil/student" is mentioned, ask question 5.12. If "still pupil/student" is mentioned, go to question 5.14.

5.12 Are you currently employed?

no ☐ 0 yes ☐ 1 *refused to answer* ☐ *-999*

An answer to this question is mandatory!

If "no" go to question 5.12.1, if "yes" go to question 5.12.2.
If "refused to answer" go to 5.14.

5.12.1 Which of these categories best applies to you?
Read out (except "no answer")

still in training	☐ 1
temporarily unemployed (e.g. parental care, new job in the near future)	☐ 2
pensioner	☐ 3
housewife/househusband	☐ 4
never been employed so far	☐ 5
refused to answer	☐ -999

An answer to this question is mandatory!

Continue with question 5.14

5.12.2 What is your current profession?
Read out (except "no answer").

Are you …

blue-collar worker	☐ 1
white-collar worker	☐ 2
civil servant	☐ 3
self-employed	☐ 4
executive	☐ 5
no categorisation possible	☐ -3
refused to answer	☐ -999

An answer to this question is mandatory!

Continue with question 5.13.

5.13 Do you do shift work?

no ☐ 0 yes ☐ 1

If "yes", go to question 5.13.1! If "no", go to question 5.14!
If the participant answers "yes", he/she is not being asked about interest in field study!

5.13.1 Which of these categories best applies to you?

shift work without night shift	☐	1
shift work with night shift	☐	2
permanent late shift	☐	3
permanent early shift	☐	4
permanent night shift	☐	5

5.14 In order to get more information about how much time you are exposed to aircraft noise every day, we need to know how much time you actually spend in your home environment and how much time you spend elsewhere.
Therefore, may I ask you: How many hours per day do you spend away from your home and neighbourhood on normal weekdays?

____ hours	refused to answer	☐	-999

5.15 How many hours per day do you spend away from your home and your neighbourhood on normal weekends?

____ hours	refused to answer	☐	-999

5.16 How many people (including yourself and any children) constantly live in your household?

overall:	____
over 18 years (adults)	____
14 -18 years (adolescents)	____
under 14 years (children)	____

Part 6 - Closure of the interview

6.1 Do you have any further comments about aircraft noise?

____

____

Please consider: If comments only regarding the volcanic ash are mentioned, please ask about further aspects.

6.2 *Is there any reason to reject the current interviewee from the field study (e.g. for language reasons etc.)? Don't read out!*

no ☐ 0	yes ☐ 1

An answer to this question is mandatory!

If "yes", say **"That is the end of the interview and we would like to thank you for your assistance. Thank you very much! Have a nice day! Goodbye."**

If "no", go to 6.3.

6.3 That is the end of the interview and we would like to thank you for your assistance. Over the next few months we will be looking for people prepared to take part in a further study which will involve measurements carried out in your own home. Would it be alright for someone from … to contact you again to provide further details of this study?

no ☐ 0	yes ☐ 1

An answer to this question is mandatory!

If "yes": **Thank you very much. We would like to assure you that your contact details will be kept separately from your answers to the questionnaire. This is to preserve anonymity. That is the end of the interview, thank you very much.** *Note if respondent seemed to be particularly interested. (Could be useful for prioritisation later).*

If "no": **That is no problem. That is the end of the interview, thank you very much.**

If the person asks for more detailed information, give some general information about the procedure of the study (see instruction sheet).

6.4 *Have there been any peculiarities during the interview?*

Appendix B:

Socio-demographic statistics of the telephone interview samples in the six examination areas

	Age			Gender		Home-ownership		Employment rate		Length of residence		
Area	*M*	*SD*	*Range*	*N* female	%	*N* owner	%	*N* employed	%	*M*	*SD*	*Range*
Siegburg - Stall-berg/Kaldauen	58.1	15.5	19-90	129	59.4	161	74.9	80	37.4	28.2	17.5	0.7-72
Cologne - Ostheim/ Neubrück/ Mülheim	62.3	16.0	18-90	150	69.1	123	56.7	69	32.1	28.7	15.3	0.7-76
Cologne - Rath/Heumar	60.3	16.5	18-95	127	58.8	145	67.1	84	39.3	28.2	18.1	1.4-95
Hennef - Heisterbach/ Happerschoß	51.3	13.4	18-82	117	58.2	165	82.1	125	63.1	22.2	16.9	0.3-75
Cologne - Wahnheide	58.1	14.9	20-91	124	62.0	124	62.9	79	41.1	28.6	15.6	2.0-73
Odenthal, Bergisch Gladbach - Schildgen	61.2	13.8	18-91	133	63.0	179	85.6	72	35.0	29.2	16.1	1.6-80

Appendix C:

Correlation between long-term aircraft noise annoyance ratings and mentioning a certain time of day as particularly annoying with regard to aircraft noise

Time of day	Correlation to general annoyance		Correlation to night-time annoyance	
	Weekdays	Weekend	Weekdays	Weekend
06-07	.16***	.16***	.13***	15***
07-08	.15***	.16***	.08**	.11***
08-09	.13***	.15***		
09-10	.12***	.14***		
10-11	.11***	.14***		
11-12	.11***	.14***		
12-13	.11***	.13***		
13-14	.12***	.14***		
14-15	.13***	.13***		
15-16	.16***	.19***		
16-17	.23***	.23***		
17-18	.26***	.28***		
18-19	.28***	.29***		
19-20	.25***	.26***		
20-21	.25***	.24***	.18***	.18***
21-22	.26***	.24***	.21***	.20***
22-23	.28***	.29***	.31***	.30***
23-00	.33***	.33***	.38***	.36***
00-01	.35***	.34***	.41***	.38***
01-02	.35***	.33***	.40***	.38***
02-03	.38***	.34***	.42***	.37***
03-04	.40***	.37***	.46***	.42***
04-05	.38***	.35***	.44***	.40***
05-06	.31***	.29***	.34***	.32***

Note. ** $p < .01$, *** $p < .001$.

Appendix D:

Questionnaires of the field study

A. Opening Questionnaire

1. Residential area

First, can I just ask you about the area where you live?

1.1 How long have you been living in this area?
Only if the person mentions "2010 or 2011", ask: **Could you tell me the month, too?**

Don't read out!

since approx. ____ / ____
MM YYYY

or

for ____ years

An answer to this question is mandatory!

1.2 How satisfied are you with your local area?
Read out!

extremely satisfied	very satisfied	moderately satisfied	slightly satisfied	not at all satisfied
☐ 5	☐ 4	☐ 3	☐ 2	☐ 1

2. Long-term noise annoyance

Next, we have some questions about aircraft noise annoyance.

2.1 Thinking about the last 12 months, when you are at home, how much does aircraft noise bother, disturb or annoy you overall?
Read out!

extremely	very	moderately	slightly	not at all
☐ 5	☐ 4	☐ 3	☐ 2	☐ 1

An answer to this question is mandatory! If the participant says "not at all", skip questions 2.3-2.5!

2.1.1 And what was more important for the judgement you have just announced: the aircraft noise level inside the house or outside the house?

inside the house ☐ 1	outside the house ☐ 2	both ☐ 3

2.2 Are you bothered, disturbed or annoyed by any other noises around here?
Don't read out!

no ☐ 0	yes ☐ 1

If „yes", go to question 2.2.1 and afterwards to question 2.2.2!
If "no", go to question 2.3!

2.2.1 What are these other sources? *If the person mentions more than 3 sources of noise, ask:* **Which of them are the three most annoying ones?**
Don't read out!

1. road traffic (incl. city buses and trams)	☐ 1
2. railway/trains	☐ 1
3. industry/factory	☐ 1
4. neighbours	☐ 1
5. playgrounds	☐ 1
6. pubs/nightclubs	☐ 1
7. sports venues	☐ 1
8. building constructions	☐ 1
9. other: ________	☐ 1

2.2.2 Thinking about the last 12 months, when you are at home, how much does noise from … *(the source that the person has mentioned)* **bother, disturb or annoy you?**
Read out!

extremely	very	moderately	slightly
☐ 5	☐ 4	☐ 3	☐ 2

Don't ask about annoyance for more than three sources of noise!

2.3 *Ask this question only when the person is at least "slightly" bothered, disturbed or annoyed!*

Let's go back to aircraft noise. Thinking about the last 12 months, when you are at home, how much does noise from aircraft bother, disturb or annoy you at night, 22 o'clock till 6 o'clock?
Read out!

extremely	very	moderately	slightly	not at all
☐ 5	☐ 4	☐ 3	☐ 2	☐1

2.4 *Ask this question only when the person is at least "slightly" bothered, disturbed or annoyed!*
On normal weekdays, are there any particular times when aircraft noise is more annoying?

If the person does not know how to answer or if they just indicate e.g. "in the mornings" or "in the afternoon", say: **Please try to give me concrete times of day. Examples for concrete times of day might be "9 – 10 a.m." or "4 – 7 p.m."**

Don't read out! Multiple answers are possible.

06 a.m. to 02 p.m.		*02 p.m. to 10 p.m.*		*10 p.m. to 06 a.m.*	
1. 6-7 a.m.	☐ 1	9. 2-3 p.m.	☐ 1	17. 10-11 p.m.	☐ 1
2. 7-8 a.m.	☐ 1	10. 3-4 p.m.	☐ 1	18. 11-12 p.m.	☐ 1
3. 8-9 a.m.	☐ 1	11. 4-5 p.m.	☐ 1	19. 00-1 a.m.	☐ 1
4. 9-10 a.m.	☐ 1	12. 5-6 p.m.	☐ 1	20. 1-2 a.m.	☐ 1
5. 10-11 a.m.	☐ 1	13. 6-7 p.m.	☐ 1	21. 2-3 a.m.	☐ 1
6. 11-12 a.m.	☐ 1	14. 7-8 p.m.	☐ 1	22. 3-4 a.m.	☐ 1
7. 12 a.m.–1 p.m.	☐ 1	15. 8-9 p.m.	☐ 1	23. 4-5 a.m.	☐ 1
8. 1-2 p.m.	☐ 1	16. 9-10 p.m.	☐ 1	24. 5-6 a.m.	☐ 1

2.5 *Ask this question only when the person is at least "slightly" bothered, disturbed or annoyed!*
On normal weekends, are there any particular times when aircraft noise is more annoying?

If the person does not know how to answer or if they just indicate e.g. "in the mornings" or "in the afternoon", say: **Please try to give me concrete times of day. Examples for concrete times of day might be "9 – 10 a.m." or "4 – 7 p.m."**

Don't read out! Multiple answers are possible.

06 a.m. to 02 p.m.		*02 p.m. to 10 p.m.*		*10 p.m. to 06 a.m.*	
1. 6-7 a.m.	☐ 1	9. 2-3 p.m.	☐ 1	17. 10-11 p.m.	☐ 1
2. 7-8 a.m.	☐ 1	10. 3-4 p.m.	☐ 1	18. 11-12 p.m.	☐ 1
3. 8-9 a.m.	☐ 1	11. 4-5 p.m.	☐ 1	19. 00-1 a.m.	☐ 1
4. 9-10 a.m.	☐ 1	12. 5-6 p.m.	☐ 1	20. 1-2 a.m.	☐ 1
5. 10-11 a.m.	☐ 1	13. 6-7 p.m.	☐ 1	21. 2-3 a.m.	☐ 1
6. 11-12 a.m.	☐ 1	14. 7-8 p.m.	☐ 1	22. 3-4 a.m.	☐ 1
7. 12 a.m.–1 p.m.	☐ 1	15. 8-9 p.m.	☐ 1	23. 4-5 a.m.	☐ 1
8. 1-2 p.m.	☐ 1	16. 9-10 p.m.	☐ 1	24. 5-6 a.m.	☐ 1

3. Disturbance

3.1 Still thinking about the last 12 months, when you are at home, how much does aircraft noise disturb you in the following situations? Please indicate if a situation is not relevant for you.
Read out!

		extremely	very	mode-rately	slightly	not at all	*not relevant*
1.	Indoor communication (e.g. talking, telephoning).	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ -1
2.	Listening to radio/watching TV indoors.	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ -1
3.	Mental work indoors (e.g. reading, working at the computer)	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ -1
4.	Physical work indoors (e.g. housework, hobbies, DIY etc.)	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ -1
5.	Indoor leisure activities (e.g. painting, playing an instrument, tinkering)	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ -1
6.	Relaxing indoors	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ -1

7.	Socialising with friends indoors	☐ 5	☐ 4	☐ 3	☐ 2	☐1	☐ -1
8.	Eating indoors	☐ 5	☐ 4	☐ 3	☐ 2	☐1	☐ -1
9.	Outdoor communication (e.g. talking, telephoning).	☐ 5	☐ 4	☐ 3	☐ 2	☐1	☐ -1
10.	Listening to radio/watching TV outdoors.	☐ 5	☐ 4	☐ 3	☐ 2	☐1	☐ -1
11.	Mental work outdoors (e.g. reading, working at the computer)	☐ 5	☐ 4	☐ 3	☐ 2	☐1	☐ -1
12.	Physical work outdoors (e.g. gardening, hobbies, DIY etc.)	☐ 5	☐ 4	☐ 3	☐ 2	☐1	☐ -1
13.	Leisure activities outdoors (e.g. painting, sports)	☐ 5	☐ 4	☐ 3	☐ 2	☐1	☐ -1
14.	Relaxing outdoors	☐ 5	☐ 4	☐ 3	☐ 2	☐1	☐ -1
15.	Socialising with friends outdoors	☐ 5	☐ 4	☐ 3	☐ 2	☐1	☐ -1
16.	Eating outdoors	☐ 5	☐ 4	☐ 3	☐ 2	☐1	☐ -1
17.	Falling asleep	☐ 5	☐ 4	☐ 3	☐ 2	☐1	☐ -1
18.	Sleep in the first half of the night	☐ 5	☐ 4	☐ 3	☐ 2	☐1	☐ -1
19.	Sleep in the second half of the night	☐ 5	☐ 4	☐ 3	☐ 2	☐1	☐ -1
20.	others: ______	☐ 5	☐ 4	☐ 3	☐ 2	☐1	☐ -1

4. Coping measures

4.1 Do you do anything particularly about the aircraft noise?
If the person does not know what to answer say: "When the aircraft noise occurs, do you do anything to make the situation more pleasant for you?"

Don't read out!

no ☐ 0 yes ☐ 1

If "yes", go to question 4.1.1

4.1.1 What would that be?
Don't read out!

1.	close windows	☐ 1
2.	use earplugs	☐ 1
3.	speak more loudly in conversations	☐ 1
4.	retreat into quieter rooms	☐ 1
5.	avoid using garden, patio, balcony	☐ 1
6.	turn up the sound of radio/TV	☐ 1
7.	use tranquillizer/sleeping pills	☐ 1
8.	others: ______	☐ 1
9.	others: ______	☐ 1
10.	others: ______	☐ 1

5. Attitudes

Now, some questions about how you feel about … Airport in general.

5.1 What is your general attitude towards the airport?

very positive	rather positive	neither negative nor positive	rather negative	very negative
☐ 5	☐ 4	☐ 3	☐ 2	☐ 1

5.2 And, in terms of specific positive and negative aspects of … Airport?

5.2.1 Do you see any positive aspects of the airport and air traffic?

no ☐ 0	yes ☐ 1

If "yes": **What are they?**

Don't read out!
Multiple answers are possible

1.	economic development	☐ 1
2.	shopping facilities	☐ 1
3.	accessibility to travel	☐ 1
4.	good infrastructure	☐ 1
5.	availability of jobs	☐ 1
6.	availability of goods	☐ 1
7.	cosmopolitan atmosphere	☐ 1
8.	others: _____	☐ 1
9.	differentiates between air traffic and the airport itself	☐ 1

5.2.2 Do you see any negative aspects of the airport and air traffic in your opinion?

no ☐ 0 yes ☐ 1

If "yes": **What are they?**
Don't read out!

1.	aircraft crashes	☐ 1
2.	health risks for residents	☐ 1
3.	environmental risks	☐ 1
4.	decrease in property prices	☐ 1
5.	decreasing quality of life	☐ 1
6.	traffic congestion	☐ 1
7.	noise	☐ 1
8.	others: _____	☐ 1

5.3 If decisions concerning air traffic have to be made, what do you think is more important: environmental or economic issues?
Don't read out!
If the person says e.g. "It's three quarters environmental and one quarter economic", take this answer and adjust it to the following scale. In this example, you would have to choose answer "environmental issues"!

environmental issues	☐ 1	economic issues	☐ 2
both in equal shares	☐ 3	don't know	☐ -2

6. Demographic data

As in every survey, some demographic data and in addition some data about your home are required now.

6.1 How old are you please?
Don't read out!

	______ years
or	
	______ year of birth

6.2 *Gender? Don't ask, just record!*

male ☐ 1	female ☐ 2

6.3 Are you or anyone you live with, the tenant or the home owner here?
Don't read out!

tenant ☐ 1	owner ☐ 2

6.4. Does your home have …
Read out! Multiple answers possible.

1.	secondary glazing	☐ 1
2.	double-glazed windows	☐ 1
3.	triple-glazed windows	☐ 1
4.	roof insulation	☐ 1
5.	ventilation system	☐ 1
6.	others: ____________________	☐ 1
7.	don't know:	☐ -2

If at least one category was affirmed, go to question 6.4.1. If no category was affirmed go to question 6.6.1!

6.4.1 Was this installed for:
Read out! Only one answer possible.

1.	home improvement	☐ 1
2.	general noise reduction/insulation	☐ 2
3.	aircraft noise reduction	☐ 3
4.	others: ______________________	☐ 4
5.	don't know	☐ -2

If answer 2 or 3 was given, go to question 6.4.2 f. If other answers were given, go to question 6.6.1!

6.4.2 In which rooms do you have this noise insulation?
Don't read out!

1.	bedroom	☐ 1
2.	living room	☐ 1
3.	kitchen	☐ 1
4.	children's room	☐ 1
5.	work room	☐ 1
6.	bathroom	☐ 1
7.	guestroom	☐ 1
8.	others: ______________________	☐ 1

6.5 Has the local airport paid a contribution towards the noise insulation?
Read out (except "don't know")!

no ☐ 0	to some extent ☐ 1	completely ☐ 2	don't know ☐ -2

6.6 How satisfied in general are you with the noise insulation?
Read out!

extremely satisfied	very satisfied	moderately satisfied	slightly satisfied	not at all satisfied
☐ 5	☐ 4	☐ 3	☐ 2	☐ 1

6.6.1 What is usually the position of your windows during the warm seasons in your bedroom at night? *Warm season means spring, summer, and autumn.*
Don't read out!

open/partially open ☐ 1	closed ☐ 2	don't know ☐ -2

If "open/partially open" was answered, go to question 6.6.2, if "closed" or "don't know" was answered, go to question 6.6.3!

6.6.2 *If "open/tilted" was answered, ask*: **Is there any reason why you do not keep your windows closed?**

____

____

6.6.3 How pleasant is the indoor climate in your bedroom when you get up in the morning?
Read out!

extremely pleasant ☐ 5	very pleasant ☐ 4	moderately pleasant ☐ 3	slightly pleasant ☐ 2	not at all pleasant ☐ 1

6.7 Is your employment or that of any member of your household connected in any way with the local airport or the aviation industry?
Don't read out!

no ☐ 0	yes ☐ 1

6.8 How many air trips did you make as a passenger during the last 12 months? One trip includes outward and return flights.
Don't read out!

approx. ______ trips

6.9 What is the highest level of education you have completed? I'm going to read out a list, so please let me know:

Which of these categories best applies to you?
Read out except "refused to answer" and "no categorisation possible".

still pupil/student	☐	1
without school qualification	☐	2
GCSE/O-Level/O-grade	☐	3
A-Level/vocational A-Level	☐	4
university/polytechnic degree	☐	5
refused to answer	☐	-999
no categorisation possible	☐	-3

An answer to this question is mandatory!

Unless "still pupil/student" is mentioned, ask question 6.10. If "still pupil/student" is mentioned, go to question 6.11.

6.10 Are you currently employed?
Don't read out!

no ☐ 0 yes ☐ 1 refused to answer ☐ -999

An answer to this question is mandatory!

If "no" go to question 6.10.1, if "yes" go to question 6.10.2.
If "refused to answer" go to 6.11

6.10.1 Which of these categories best applies to you?
Read out (except "refused to answer")

still in training	☐	1
temporarily unemployed (e.g. parental care, new job in the near future)	☐	2
pensioner	☐	3
housewife/househusband	☐	4
never been employed so far	☐	5
refused to answer	☐	-999

An answer to this question is mandatory!

Continue with question 6.11

6.10.2 What is your current profession?

Are you …
Read out except "refused to answer" and "no categorisation possible".

blue-collar worker	☐	1
white-collar worker	☐	2
civil servant	☐	3
self-employed	☐	4
executive	☐	5
no categorisation possible	☐	-3
refused to answer	☐	-999

Continue with question 6.11.

6.11 In order to get more information about how much time you are exposed to aircraft noise every day, we need to know how much time you actually spend in your home environment and how much time you spend elsewhere.

Therefore, may I ask you: How many hours per day do you spend away from your home and neighbourhood on normal weekdays?
Don't read out!

____ hours	refused to answer	☐	-999

6.12 How many hours per day do you spend away from your home and your neighbourhood on normal weekends?
Don't read out!

____ hours	refused to answer	☐	-999

6.13 How many people live in your household?
Read out!

overall:	____
over 18 years (adults)	____
14 -18 years (adolescents)	____
under 14 years (children)	____

B. Morning questionnaire

1. What time did you switch off lights in order to sleep? ________ o'clock
Please use the international time designation system, e.g. 21:30 instead of 9:30 p.m.

2. How long did it take you to fall asleep? Approximately ________ minutes

3. Did you have any problems falling asleep?

no ☐ 0 yes ☐ 1

If "yes":

3.1 What was/were the reason/s?

Multiple answers possible!

aircraft noise	☐	1
other noises from outside the house/flat	☐	1
other reasons: ____________________	☐	1
I do not know	☐	-2

4. What time did you wake up definitively before getting up? ________ o'clock

5. Did you wake up during the night?

☐	no	0	
☐	yes	1	approximately _____ times
☐	I do not know	-2	

If "yes":

5.1 Reasons for waking up:

Multiple answers possible!

aircraft noise	☐	1
other noises from outside the house/flat	☐	1
other reasons: ______________	☐	1
I do not know	☐	-2

5.2 Falling asleep again was …?

10 9 8 7 6 5 4 3 2 1 0

very difficult very easy

6. Please estimate your sleep.

Falling asleep was …

10 9 8 7 6 5 4 3 2 1 0

very difficult very easy

My sleep was …

10 9 8 7 6 5 4 3 2 1 0

very disturbed very calm

Sleep depth was …

10 9 8 7 6 5 4 3 2 1 0

very shallow very deep

Sleep duration was …

10 9 8 7 6 5 4 3 2 1 0

very short very long

The restorative quality of my sleep was…

10 9 8 7 6 5 4 3 2 1 0

very low very high

Tossing and turning was …

10 9 8 7 6 5 4 3 2 1 0

very frequent very few

C. Assessment of short-term aircraft noise annoyance

Assessment of short-term aircraft noise annoyance after an interval of 1 hour

1. Thinking about the past hour, how much did aircraft noise as a whole bother, disturb or annoy you?

extremely	very	moderately	slightly	not at all
☐ 5	☐ 4	☐ 3	☐ 2	☐ 1

2. What have you (mostly) been doing in the last hour?
Multiple answers possible

1.	conversation/telephoning	☐ 1
2.	watching TV/listening to radio	☐ 1
3.	mental work (e.g. reading, working at the computer, concentrating)	☐ 1
4.	physical work (e.g. housework, gardening, handicraft activities, sports)	☐ 1
5.	leisure activities (e.g. painting, playing an instrument, tinkering etc.)	☐ 1
6.	relaxing	☐ 1
7.	socialising with friends	☐ 1
8.	eating	☐ 1
9.	others ____________	☐ 1

Ask question 2.1 and 2.2 for EVERY activity

2.1 Where have you (mostly) been during this activity?
Ask for every mentioned activity!

indoors	☐ 1
outdoors (home or nearby)	☐ 2
outdoors (away from area)	☐ 3

2.2 How much did aircraft noise disturb you during this activity?
Ask for every mentioned activity!

extremely	very	moderately	slightly	not at all
☐ 5	☐ 4	☐ 3	☐ 2	☐1

Ask the following question only if "Indoors" was mentioned in question 2.1:
3. What was the position of your windows during the past hour?

closed ☐ 1	partially open ☐ 2	☐ wide open 3

4. Has this been the assessment of short-term aircraft noise annoyance for today?

no ☐ 0	yes ☐ 1

If "yes"

The following question will be asked solely after the last assessment of short-term annoyance of the day.

5. Has there been anything that has worried or stressed you today?

no ☐ 0	yes ☐ 1

If "yes": 5.1 **When was it?** ____________________

D. Concluding questionnaire

1. Daily noise exposure

1.1 As you've been thinking about aircraft noise over the last 4 days of the study, are there any particular features of aircraft that make them most noticeable or more annoying to you?

____

____

1.2 Over the last few days of the study, is the amount of time you spent at home, or in your local area, typical for:

1.2.1 weekday?
Don't read out!

yes	☐	1
no, I usually spend less time at home.	☐	2
no, I usually spend more time at home.	☐	3
refused to answer	☐	-999

1.2.2 weekend?
Don't read out!

yes	☐	1
no, I usually spend less time at home.	☐	2
no, I usually spend more time at home.	☐	3
refused to answer	☐	-999

2. Attitudes and opinions – Part II

2.1 Please let us now have your opinion to the following statements, firstly as an individual and then thinking about the situation as a whole.

2.1.1 Thinking individually, …
Read out!

		strongly agree	slightly agree	neither agree nor disagree	slightly disagree	strongly disagree	don't know
1.	…the airport is economically important for me.	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ -2
2.	…the airport is bad for my health.	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ -2
3.	… to have an airport nearby is convenient for me.	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ -2

2.1.2 Thinking globally, …
Read out!

		strongly agree	slightly agree	neither agree nor disagree	slightly disagree	strongly disagree	don't know
1.	…the airport is important for the economic system.	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ -2
2.	…the airport is bad for residents' health.	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ -2
3.	… to have an airport nearby is convenient for residents.	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ -2
4.	…the airport is harmful to the environment.	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ -2
5.	Is there anything else that hasn't been considered? ________________						

2.2 Have you any ideas for things that the airport could do for the local community?
Don't read out!

no ☐ 0 yes ☐ 1

If "yes": **What are they?**
Don't read out! Multiple answers possible!

1.	reduce noise	☐ 1
2.	freeze status quo	☐ 1
3.	monetary compensation	☐ 1
4.	change aircraft fleet	☐ 1
5.	inform comprehensively/transparently	☐ 1
6.	flight punctuality	☐ 1
7.	change approach/departure routes; arranging flight paths over thinly populated areas	☐ 1
8.	guarantee safety	☐ 1
9.	financial grants for insulation	☐ 1
10.	decision rights in aircraft routes	☐ 1
11.	reducing the number of flights during the night	☐ 1
12.	others: ____________	☐ 1

3. Perceived control

3. Let's come back to the aircraft noise around here.

Personal control over immediate local home environment

3.1 How much control do you feel you personally have over the amount of aircraft noise you hear at home?
Read out!

complete control	much control	some control	very little control	no control at all	don't know
☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ -2

3.1.1 And why do you feel that?

____

____

Authorities' control over noise source

3.2 Which authorities or organisations do you think have the most control over aircraft noise? Please try to make a list starting with the most influential one. *(No minimum number of answer, in maximum 5 answers.)*

1) ______________________________

2) ______________________________

3) ______________________________

4) ______________________________

5) ______________________________

3.2.1 *Ask the following question for all the authorities mentioned in question 3.2*
And how much control exactly do you think these authorities have over aircraft noise?
Read out!

	complete control	much control	some control	very little control	no control at all	don't know
1) …	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ -2
2) …	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ -2
3) …	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ -2
4) …	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ -2
5) …	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ -2

Personal control over noise authorities

3.2.2 And how much do you think any of these authorities *(the authorities mentioned in question 3.2)* **take into account the individual opinions of the residents?**
Read out!

	extremely	very	mode-rately	slightly	no at all	don't know
1) …	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ -2
2) …	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ -2
3) …	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ -2
4) …	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ -2
5) …	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ -2

Perceived predictability of noise

3.3 Let us go back to the aircraft noise exposure in your home environment.
Aircraft noise can vary during the day and also from day to day. How predictable is the aircraft noise around here?

If the person has problems to answer the question, say: **There might be times when there is less aircraft noise or even no aircraft noise at all around here. How predictable is the aircraft noise for you?**
Read out!

extremely predictable	very predictable	moderately predictable	slightly predictable	not at all predictable
☐ 5	☐ 4	☐ 3	☐ 2	☐ 1

Future expectations

3.4 In the future, do you think aircraft noise is more likely to increase or decrease?

Will it…
Read out!

strongly increase	slightly increase	stay the same	slightly decrease	strongly decrease	don’t know
☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ -2

3.4.1 And do you think it will be easier or harder to get used to aircraft noise?

Will it be …?
Read out!

much easier	a little easier	the same as now	a little harder	much harder	don’t know
☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ -2

4. Fairness

4.1 Regarding … Airport and the relevant government, council and airport authorities: How transparent do you feel the allocation of responsibility is between them in terms of decision making procedures for aircraft noise?
Read out!

extremely transparent	very transparent	moderately transparent	slightly transparent	not at all transparent
☐ 5	☐ 4	☐ 3	☐ 2	☐ 1

4.2 Please let us have your personal opinion to the following statements concerning general aircraft noise decision making procedures at …
Read out!

		strongly agree	slightly agree	neither agree nor disagree	slightly disagree	strongly disagree	don't know
1.	Aircraft noise is distributed fairly amongst all residents.	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ -2
2.	When decisions concerning aircraft noise are being made, I have opportunities to express my views to the relevant people.	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ -2
3.	When decisions concerning aircraft noise are being made, I can have influence over the results of the decision process.	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ -2
4.	During these decision-making processes, the interests of some residents take precedence over the other residents' interests.	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ -2
5.	Sufficient information is gathered before decisions concerning aircraft noise are made.	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ -2
6.	In those decision-making processes, decisions are often made on the basis of inaccurate information.	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ -2
7.	I have the chance to appeal decisions that I consider are wrong.	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ -2
8.	Decisions concerning aircraft noise are explained and justified to me in detail.	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ -2
9.	I am often kept in suspense about a decision for a long time.	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ -2
10.	In general, I feel fairly treated concerning aircraft noise.	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ -2

5. Noise sensitivity

Give the netbook to the participant. This questionnaire should not be read out.

Consider each statement in the order in which it appears and do not omit any.
Try to imagine yourself in the given situation and respond spontaneously without spending too much time considering whether or not you generally agree with a given statement.
For each statement place a cross the box which best describes your opinion. We are interested in your personal opinion on each of the statements. There are no correct or incorrect responses.

		strongly agree	slightly agree	neither agree nor disagree	slightly disagree	strongly disagree
1.	I need an absolutely quiet environment to get a good night's sleep.	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
2.	I need quiet surroundings to be able to work on new tasks.	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
3.	When I am at home, I habituate to noise quickly.	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
4.	I become very agitated if I can hear someone talking while I am trying to fall asleep.	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
5.	I am very sensitive to neighbourhood noise.	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
6.	When people around me are noisy I don't get on with my work.	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
7.	I am sensitive to noise.	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
8.	My performance is much worse in noisy places.	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
9.	I do not feel well rested if there has been a lot of noise the night before.	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
10.	It would not bother me to live in a noisy street.	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
11.	For a quiet place to live I would accept other disadvantages.	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
12.	I need peace and quiet to do difficult work.	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
13.	I can fall asleep even when it is noisy.	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1

Please give the netbook to the interviewer!

6. Media coverage

6.1 Have you read, seen or heard any items concerning the local airport, aircraft noise or air traffic in general during the last weeks?
Don't read out!

no ☐ 0 yes ☐ 1

If "yes", go to question 6.1.1 and afterwards to question 6.1.2

6.1.1 What were they about?
Don't read out

1.	aircraft crash	☐
2.	advertisement	☐
3.	building activities at airport	☐
4.	new aircraft technology	☐
5.	health consequences of air traffic	☐
6.	air pollution caused by air traffic	☐
7.	air traffic policy	☐
8.	others: ________________	☐

6.1.2 Was the news about … *(ask for each topic that was mentioned)* **rather positive, rather negative or not relevant for you?**
Don't read out!

negative ☐ 1 positive ☐ 2 not relevant ☐ -1

7. Final remarks

7.1 Concerning aircraft noise annoyance, is there anything else important that might help us in our research?

____

____

7.2 Up to this point, how demanding has the field study procedure been for you?
Read out!

extremely	very	moderately	slightly	not at all
☐ 5	☐ 4	☐ 3	☐ 2	☐1

8. Negative affectivity

After all these questions about aircraft noise, would you please complete the following questionnaire about how you feel in general? This scale does not refer to aircraft noise or to the local airport.

Give the netbook to the participant. This questionnaire should not be read out.

This scale consists of a number of words that describe different feelings and emotions. Read each item and then mark the appropriate answer in the space next to that word. Indicate to what extent you generally feel this way, that is, how you feel on the average. Use the following scale to record your answers.

		extremely	very	moderately	slightly	not at all
1.	interested	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
2.	distressed	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
3.	excited	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
4.	upset	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
5.	strong	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
6.	guilty	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
7.	scared	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
8.	hostile	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
9.	enthusiastic	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
10.	proud	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
11.	irritable	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
12.	alert	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
13.	ashamed	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
14.	inspired	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
15.	nervous	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
16.	determined	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
17.	attentive	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
18.	jittery	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
19.	active	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
20.	afraid	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1

Appendix E:

GEE analysis testing the contribution of acoustical and situational as well as time-invariant non-acoustical predictors on aircraft noise annoyance in the preceding hour. N = 2,566

Variable	*B*	*SE*	*p*
Intercept	-0.217	0.309	.482
$p\ L_{Aeq,AC}$	0.020	0.002	< .001
N_{AC}	0.025	0.006	< .001
N_{AT70}	0.044	0.014	.002
Time of day			
Morning	0.109	0.066	.097
Noon	-0.043	0.052	.411
Afternoon and early evening	-0.007	0.039	.862
Evening	0[a]		
TV/radio	0.154	0.043	< .001
Physical activity	-0.194	0.046	< .001
Relaxation	0.320	0.062	< .001
Eating	0.101	0.041	.013
Presence of /Satisfaction with noise insulation			
No insulation	-0.063	0.124	.611
Not highly satisfied	0.378	0.156	.015
Highly satisfied	0[a]		
Noise sensitivity	0.292	0.095	.002

Note. [a] This coefficient is set to 0, because this parameter is redundant. Annoyance was assessed by the question “Thinking about the past hour, how much did aircraft noise as a whole bother, disturb or annoy you?” 1 = “not at all” - 5 = “extremely”.

Wissenschaftlicher Werdegang

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Eidesstattliche Erklärung

Hiermit erkläre ich an Eides statt, dass ich gemäß § 9, Abs.1 der Promotionsordnung der Technischen Universität Darmstadt vom 12. Januar 1990 (in der Fassung der VII. Änderung vom 28. September 2010) die vorliegende Dissertationsschrift selbstständig verfasst und keine anderen als die angegebenen Hilfsmittel verwendet habe. Die Stellen, die anderen Werken im Wortlaut oder dem Sinne nach entnommen sind, habe ich mit Quellenangaben eindeutig als solche kenntlich gemacht.
Die Arbeit wurde bisher keiner anderen Prüfungsbehörde vorgelegt.

Köln, den 8. Juli 2014

Dipl.-Psych. Susanne Bartels