Aircraft noise annoyance - Present exposure-response relations

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Summary

In the world of noise effects research, there is some debate about the stability of exposure-response relations for aircraft noise over the years. Some recent publications found a considerably higher percentage of highly annoyed residents as compared to the so-called EU standard curve for aircraft noise as well as to Annex E of ISO 1996:1-2016. Other recent publications maintain that exposure-response relations are stable, except for studies performed in high-rate change conditions (e.g. public discussions about airport expansion plans). Differences between datasets and studies used to support one or the other position in the debate are examined, and factors contributing to the differences between old and recent exposure-response relations are explored. It is shown that the rate of airport change does in fact contribute much to the difference between old and recent curves, however, other factors, like methods and variables for estimating aircraft noise (e.g. calculating aircraft noise levels at large distances from the airport, estimating the fleet mix and number of events), design for the selection of participants, type of study, and societal values may contribute, too.

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1. Introduction

The term “aircraft noise annoyance” considered here describes the reaction of residents in the vicinity of airports when given the question how much they felt bothered, disturbed or annoyed by aircraft noise over the past 12 months, when they were at home i.e., the typical ICBEN question [1]. More specifically, we are dealing mainly with systematic surveys and the percentage of survey participants using the scale positions ≥73 percent of the response scale during the surveys, i.e. the percent “Highly Annoyed” (%HA). It has often been observed that the %HA increases systematically with increasing continuous sound levels, like L_{den}, L_{day} or $L_{p\mathrm{A24hrs}}$, and the slope of this increase is steeper for aircraft noise than with road traffic or railway noise at comparable noise levels. A prominent set of exposure-response relations was published by Miedema & Oudshoorn [2] and has become the so-called “EU standard curves”. Comparable tales can be found in Annex E of ISO-1996-1, 2016 [3]. However, since 2004, several meta-analyses have shown that – at comparable L_{den} levels - the %HA by aircraft noise is higher in newer studies as compared to the old studies used in the Miedema & Oudshoorn analysis [c.f. 4-6]. On the other hand, critics of the “trend assumption” [7] maintain that generally, the exposure-response relations between aircraft noise levels and %HA are stable over time, except for “change” situations at the airport under study (see below). In the present paper, we back up the exposure-response curve presented in the WHO review on noise annoyance [6] by 7 additional datasets, and conclude that the assumption of an aircraft noise annoyance trend seems to be true even under relatively “stable” airport conditions. However, the factors contributing to the increase of %HA by aircraft noise are only partly understood, and some of them are to be discussed here.

2. Exposure-response data from 19 aircraft noise studies 2001-2015

The exposure-response relation (ERR) published in the WHO annoyance review [6] is based on separate ERRs of 12 aircraft noise surveys performed in the years 2000-2014, aggregating data from 17,094 study participants. In the present paper, we added ERRs from 7 recent aircraft noise studies to the WHO dataset: the second round of the “Lärmstudie 2000” [8] (called Zurich 2003 here), the 4 NORAH-surveys [9] performed at Frankfurt (2013), Berlin-Schönefeld (2012), Cologne/Bonn (2013) and Stuttgart (2013), the British SoNA study (2013, 9 airports [10]), and the Swiss SiRENE surveys [11], performed 2015 at the Zurich, Bale, and Geneva airports. The combined dataset aggregates data from 39,309 participants.

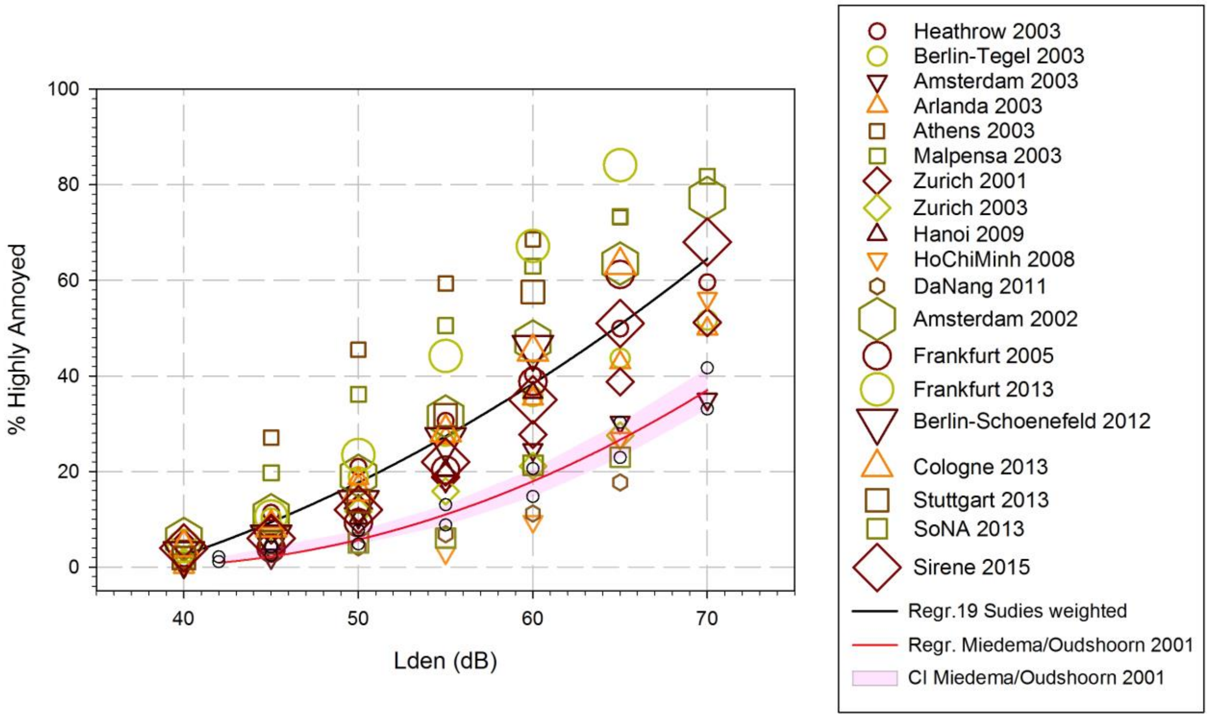

Figure 1: Exposure-response relations for %HA and L_{den} from 19 aircraft noise surveys performed 2001-2015. The size of the symbols corresponds to the respective study sample size. The black and red curves both show quadratic regressions: the black curve relates to the new dataset; the red curve relates to the Miedema/Oudshoorn analysis [2].

Looking at Figure 1, it is evident that most of the %HA data points are located above the so-called EU standard curve for aircraft noise at comparable L_{den} levels, although there are a few points (from rather small studies) below the old curve. Unfortunately it seems impossible to perform a statistical analysis on the difference between two ERRs when one of them is based not on independent observed values, but on values predicted by the regression equation for each of the studies - as in case of our dataset (for details see [6]). Nevertheless, most of our colleagues agree that the %HA at comparable L_{den} levels today is higher than estimated in the EU standard curve.

It should be noted that the ERR calculation used here includes weighting the studies according to sample size (Sqrt N/10), i.e., large studies (e.g., Amsterdam 2002, Berlin-Schoenefeld 2012, SiRENE 2015) have a greater impact on the results, as compared to small studies.

The discussion about possible causes of the difference between old and new ERRs is going on for about 15 years now, and we do not see any comprehensive, all-enlightening answers today. The many factors which have been discussed until today can be grouped according to

1. *methodological differences* between studies (e.g., sound calculation methods, response rate and participant selection, answer formats);
2. *situational or contextual differences* between studies (e.g. change-rate of the airport, changes in the composition of the aircraft fleet);

3. *societal changes* (e.g. changes in the health-related values shared by a society).

2.1 Methodological differences between aircraft noise studies

Some of the methodological differences between past and present aircraft noise studies have been discussed by several papers, e.g., by Janssen et al. 2011 [12] and Guski 2017 [13]. Janssen et al. (2011, [12]) concentrated on methodological characteristics of the surveys, like type of contact, response rate, and type of annoyance scale. It turned out that all of the three study characteristics showed a change over the years 1967-2005. “While in previous years the type of contact was primarily face-to-face and sometimes through telephone, recent surveys usually involve postal questionnaires. Also, response rates were higher in some of the older surveys than in later surveys. Another study characteristic that has changed over the years is the type of annoyance scale” [12, p. 1958]. While earlier surveys often used verbal scales with 4 or 5 categories, more recent surveys either exclusively used scales with 11 categories, or used a verbal scale together with a numerical 11-point scale. In meta-analyses type of contact proved to be a source of heterogeneity: both face-to-face interviews and telephone surveys were associated with lower annoyance compared to postal surveys. Also, where response rate was known, higher response rates were significantly associated with a decrease in reported annoyance, and annoyance judgments on the 11-point scales were significantly higher compared to verbal 4-point or 5-point scales. Although the use of scales was associated with the study year in the main analysis, a separate analyses of studies involving either verbal or numerical scales still showed an increase in mean annoyance over the years. Recently, [14] also reported higher annoyance scores associated with 11-point scales in comparison to 5-point scales in postal interviews. However, while the response scale factor seemed to be most clearly related to the annoyance trend in the multi-level analysis of Janssen et al. [12], it does not seem to be a satisfactory explanation for the trend.

In exploring other methodological differences between old and new aircraft noise studies, Guski [13] mentions (a) the sampling strategies, and (b) the methods for estimating the aircraft noise in residential areas. With respect to sampling strategies, sample selection in terms of extreme exposure groups (e.g., “noisy” and “quiet” areas) were rather common in the early aircraft noise effects surveys. That is, residential areas with low and medium noise exposure were rare. Today, a stratification according to noise levels is more common – and its application is usually restricted to a single airport. That is, the sampling strategy may lead to equal numbers of participants at each of the level classes under study. However, in case a continuous sound level (e.g., $L_{p\mathrm{Aeq,24hrs}}$ or L_{den}) is the stratification criterion, the components of the continuous sound level (maximum level, number and duration of events) are highly inter-related, and their effects cannot be studied separately. The two large British aircraft noise studies, ANIS [15] and ANASE [16] use a different stratification concept which tries to disentangle maximum levels and number of events as far as possible. They first constructed at matrix by event sound level (L) and number of movements (N). Then, to ensure that, within each stratum, all residents of every candidate residential area have the same probability of selection, a stratified random sample of areas was drawn. The ANASE report [16] showed that an increase of %HA can be observed at comparable $L_{p\mathrm{Aeq}}$ levels when comparing the old ANIS data with the new ANASE data; however, if the formula for estimating the continuous sound levels is changed by increasing the weight given to the number of flights, the “annoyance trend” disappeared. This result increases the already existing doubts about the validity of the usual L_{pAeq} formula as a predictor for noise annoyance, especially the low weight given to the number of events.

With respect to changed methods for estimating the aircraft noise level at the ground, it should be noted that these estimations require local data on flight tracks, aircraft fleet mix, aircraft profiles, and terrain as inputs, to name but a few, and such data often were not available with sufficient quality in the early days. In addition, some of the upgrades in computer programs led to a decrease of continuous sound levels. For instance, some of the continuous sound levels calculated between 1990 and 2008 by means of the old German AzB (1975) were up to 3 dB higher as compared to the new AzB (2008). The Swiss FLULA initially did not correct for thrust reduction after departures until 1999 – which means that continuous sound levels at larger distances from the airport are lower now as compared to before. In both cases, some of the calculated continuous sound levels were higher at former times than they are calculated today.

2.2 Situational/contextual differences between aircraft noise studies

As mentioned above, some critics of the “aircraft noise annoyance trend” remarked that many surveys published recently were performed in a special airport condition, when residents awaited or experienced a considerable expansion of the airport. Defining the “considerable expansion” is no easy task in view of the almost regular annual increase of the number of flights (5-10% per year, at least until 2009) at most of the airports studied. In combination with the gradual change of the aircraft fleet composition from more noisy to somewhat quieter aircraft, the increase of aircraft movements usually did not increase the annual continuous aircraft sound levels. Some airports even reported a decrease of continuous sound levels. However, residents reported that noise was getting worse over the years, and spontaneous noise complaints of residents increased especially in situations of impending operational changes at the airport, i.e., even before the operational changes were executed.

In this situation, Janssen & Guski [17] proposed (p.8) “to call airports 'low-rate change (LRC) airports', as long as there is no indication of a sustained abrupt change of aircraft movements, or the published intention of the airport to change the number of movements within 3 years before and after the study. An abrupt change is defined here as a significant deviation in the trend of aircraft movements from the trend typical for the airport. Each trend is calculated by means of total movement data during a five year period. If the typical trend is disrupted significantly and permanent, we call this a 'high-rate change (HRC) airport'. We also classify this airport in the latter category, if there has been public discussion about operational plans within 3 years before and after the study."

Although this definition is not clear-cut in all aspects, it has been applied in a small number of publications, including the WHO evidence review on noise annoyance [6]. In the latter review, we found 5 studies published between 2000-2014 which were clearly done at LRC airports, and 5 other ones which were done at HRC airports. All 10 studies are of good scientific quality according to the scoring systems used in the review, and used comparable data assessment methods, and their definition of “High Annoyance” relates to ≥73% of the response scale. We observed a considerable difference between 5 so-called “High-rate-change” (HRC) and 5 “low-rate change” (LRC) situations. Today, we are able to add 8 comparable HRC and LRC studies to the dataset and estimate ERRs for 18 datasets (9 HRC and 9 LRC studies).

The LRC studies were performed at Heathrow (2003), Berlin-Tegel (2003), Hanoi (2009), Ho Chi Minh (2008), Da Nang (2011), Cologne/Bonn (2013), Stuttgart (2013), at 9 British airports (SoNA 2013), and at 3 Swiss airports (SiRENE 2015). The HRC studies were performed at Amsterdam-Schiphol (2002 and 2003, before and after the implementation of the 6^{th} runway), Stockholm-Arlanda (2003, before implementing a new runway), Athens-Venizelos (2003, two years after opening the airport) Zurich (2001 and 2003, after flight route changes and during public discussions), Frankfurt (2005 and 2013, before and after the implementation of a new runway), and Berlin-Schoenefeld (2012, during public discussions about changing the airport to the major Berlin airport). The results are presented in Figure 2.

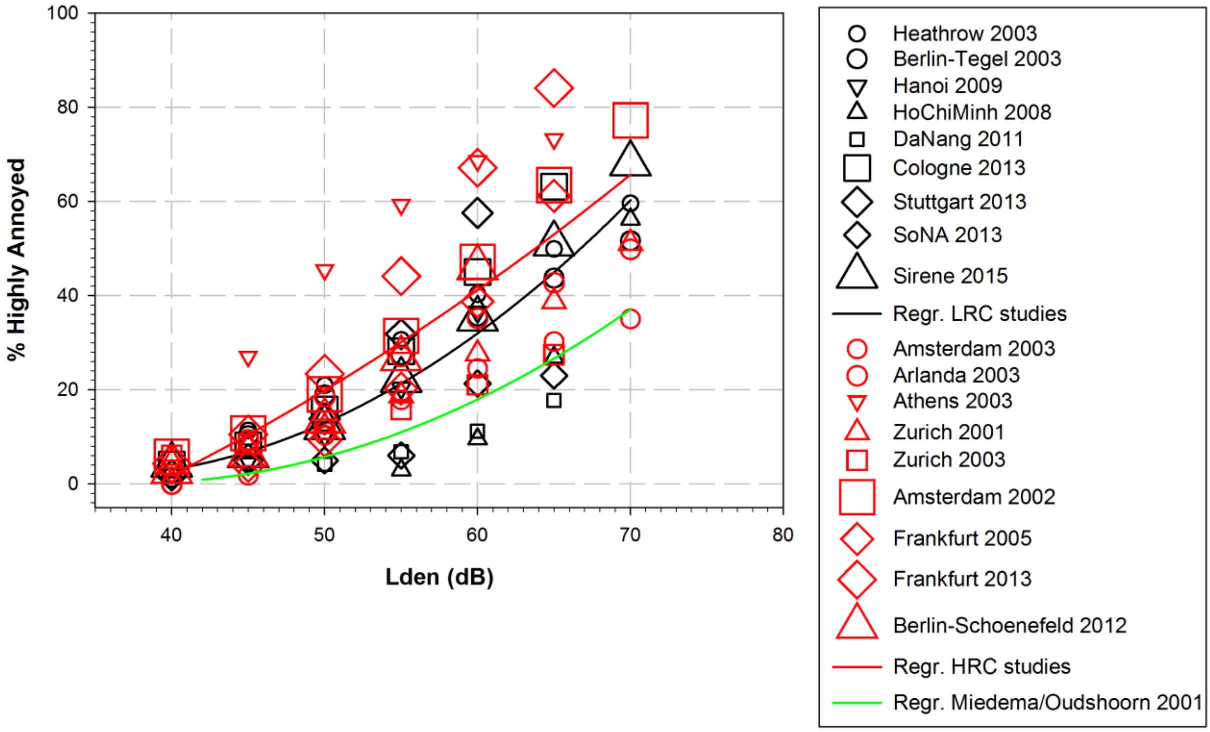

Figure 2. Exposure-response data form %HA and Lden from 9 HRC studies. The black curve represents the quadratic fit for LCR studies, the red curve represents the quadratic fit for HRC studies. For comparison, the general EU-standard curve [2] is shown (green).

The comparison between the black and red curves in Figure 2 shows higher %HA for HRC situations vs. LRC situations at comparable L_{den} levels. However, even the LRC curve is higher than the EU-standard [2]. It should be noted that there is a certain confounding of HRC/LRC and "large study/small study": The set of LCR studies comprises 15,792 participants, i.e., an average of 1,745.7 participants per study, and the set of HRC studies comprises 22,764 participants, i.e., an average of 2,529.3 participants per study. Since the studies are weighted according to sample size in Figures 1 and 2, this means that the ERR of the total dataset (Figure1) may be somewhat biased due to the influence of (mostly large) HRC studies.

2.3 Societal changes to be considered

In political contexts, it is sometimes heard that people may have become more sensitive to noise in the last years. Whatever this expression may mean exactly, there is no indication in past noise surveys that personal noise sensitivity generally has increased over time. However, we may interpret this expression in the sense that people have become more attentive to environmental dangers to their individual health and well-being. In addition, the World Values Survey [17] reports an increase in emancipative values, they combine "an emphasis on freedom of choice and equality of opportunities. Emancipative values, thus, involve priorities for lifestyle liberty, gender equality, personal autonomy and the voice of the people." This is by far no proof of a connection between the increase of personal autonomy and voice of the people – as stated in surveys – on one side, and the increase of noise annoyance in surveys on aircraft and railway noise at the other. It might be that the effects of an increase in personal autonomy and voice is restricted to the minority of politically active citizens, and does not carry over to annoyance judgments of many residents taking part in noise surveys. However, we should keep an eye on this issue.

Conclusions

Recent publications found a considerably higher percentage of highly annoyed residents as compared to the so-called EU standard curve for aircraft noise This is partly due to the rate of change of the airports under study. However, even in relatively stable conditions, an increase of the %HA at comparable continuous sound levels can be observed.

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