The Aircraft Noise Paradox 13 Years Later

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ABSTRACT

Thirteen years ago, John Freytag (2001) coined the expression "aircraft noise paradox": noise levels of single planes decrease, as do the energy-equivalent noise levels in many residential areas in the vicinity of large airports, but noise annoyance judgements in systematic surveys seem to increase. Residents near European airports even tell "it's getting louder from year to year". This situation is analysed with respect to potential changes in two fields:

1. the validity of acoustic variables describing the typical "noise load" affecting residents of airports over the years, i.e., the question which content acoustic variables like LpAeq, LpAmax, L95, NNI, or NATxx do indicate, and to what extent they can be used to describe the specifics of aircraft noise as "unwanted sound", and

2. the effects of survey sampling procedures favouring certain acoustic variables (e.g., LpAeq, NNI, or NATxx) on the statistical relation between noise load and annoyance.

It is argued that the validity of energy-based acoustic descriptors of community aircraft noise decreased during the last 20-30 years due to a change in the relation between maximum noise levels and number of aircraft movements over the years. Energy-based variables should be complemented by means of "number variables" expressing the number of aircraft noise events at certain maximum noise levels.

THE AIRPORT NOISE PARADOX, AND THE 'ANNOYANCE TREND'

In 2001, the acoustic engineer John Freytag published a paper entitled 'The Airport Noise Paradox - DNL drops while problem grows'. He showed that aircraft noise levels in terms of DNL (or LpAeq) decreased over the years, while airport residents increased their activities against aircraft noise, including complaints against aircraft noise. He maintained that the validity of energy-based acoustic descriptors of aircraft noise has decreased over the years -- due to the increased number of aircraft movements which is not adequately reflected in energy-based acoustic descriptors.

Some years later, community noise experts re-analyzed systematic questionnaire surveys on aircraft noise annoyance, and found that both the percentage of highly annoyed residents, as well as the mean annoyance scores increased at comparable energy-based noise levels (e.g. Guski 2004; Van Kempen & Van Kamp 2005; Janssen et al. 2011). It should be mentioned that there was no annoyance increase in road traffic noise annoyance, but aircraft noise annoyance data was compatible with an annoyance trend (Babisch et al. 2007). Several hypotheses concerning the reasons of the so-called 'aircraft noise annoyance trend' were proposed, and some of them were tested in the old data-sets. Many authors shared the hypothesis that the increased number of aircraft noise events is the main cause of the 'annoyance trend' but they were unable to test it adequately in the old data-sets because these either did not contain data on the number of overflights or the design of the study

(especially the selection of study sites) implied a large correlation between LpAeq and number of noisy events. Today, the debate about the validity of LpAeq-based descriptors of aircraft noise goes on, and the present paper tries to take part in this discussion, posing questions about validity, and proposing ways to test it.

MEANING AND FORMS OF VALIDITY

In the area of scientific research design and experimentation, the term validity refers to whether a study is able to scientifically answer the questions it is intended to answer. In psychometrics, validity refers to the extent to which a test measures what it claims to measure. In our case, we want to know which content a long-term acoustic descriptor like Ldn, Lden, LpAeq, or the old NNI intends to describe, and how far it actually does so. In considering the many forms validity can take, I will limit myself to content validity, and criterion validity:

1. **Content validity** is said to be given if the result of a certain acoustic measurement (or calculation) fully describes the content of what it proposes to measure.
2. **Criterion Validity** is said to be given if the result of a certain acoustic measurement (or calculation) corresponds to another measurement which is known to fully describe the target content.

The validity of energy-based acoustic descriptors

According to the well-known “Levels Paper” (Environmental Protection Agency (EPA) 1974, p.10), a “complete physical description of a sound must describe its magnitude, its frequency spectrum, and the variations of both of these parameters in time. However, one must choose between the ultimate refinement in measurement techniques and a practical approach that is no more complicated than necessary to predict the impact of noise on people.” The EPA then proposed to use the energy-based LAeq in order to describe the content of a long-term acoustic situation, and this descriptor should be able to predict the impact of noise on people.

1. Content validity: The “Levels Paper” clearly states that LpAeq does not fully describe all acoustic properties of noisy situations because an approach was sought which was practical 40 years ago. Therefore, some acoustic aspects that seem to be relevant for noise effects have a low weight or are missing completely, e.g. the number of loud events, or the time structure of the events within the integrated time. In addition, two assumptions were criticised from the beginning: (a) the sound energy is most important for noise effects, and (b) the effect of a certain loud time period can be compensated for by a certain quiet time period – independent of the duration of the quiet time.
2. Criterion validity: The “Levels Paper” clearly states that LpAeq must predict the impact of noise on people. Forty years ago, spontaneous noise complaints and noise annoyance judgments in systematic surveys were the main known effects of environmental noise. Today we would add at least some health effects to the list. If we take the term “prediction” in the sense of 1974, it refers primarily to “statistical correlation” with known noise effects, and most of the correlations known in former times up to now stem from questionnaire surveys asking for noise annoyance as the main environmental noise effect. Thus, the

criterion validity of LpAeq-based acoustic descriptors can be estimated by means of correlations with annoyance data.

Caution: correlation coefficients should be used with care. They depend on many aspects of the data collection, e.g. the metric properties of the scales, and the ranges and frequency distributions in the samples used. Given adequate metric properties of the scales, correlation coefficients may still be „artifacts of the study design“ (Connor & Patterson 1976). Therefore, the correlations given in Table 1 should be used with care. The table is by no means exhaustive, it simply shows data from the few aircraft noise studies which convey Pearson correlation coefficients between at least one of four acoustic predictors and average annoyance judgments on an individual data basis.

Table 1: Correlations between acoustic predictors and aircraft noise annoyance.

Study	Year data	LpAeq,d	N (NAT)	LogN	NNI	Design
McKennell 1963	1961			.43	.45	R
MIL Res 1971	1967		.26	.23	.43	R + N
Hazard 1971	1967				.35	R + Route
Tracor 1970.1	1968	(.49)			.34	L + N
DFG 1974*	1969	.57	.55	.53	.57	L + N
Kodama 1971	1970				.67	?
Grandjean 1973	1972	.46			.53	NNI
Hede & Bullen 1982	1980	(.36)	(.26)			(L)
Gjestland 1990	1989	.42				L
Brink 2005	2001	.31	(.32)		.32	R
Schreckenberg 2007	2005	.45	(.34)			L

Legend: ( ) = not completely comparable. Design = Selection criteria for participants:
L = Noise Level, N = number of loud events, NNI = Noise and Number Index Class, R = Random.
*DFG = Deutsche Forschungsgemeinschaft.

If you take the correlation coefficients of Table 1 to be at least typical of many aircraft noise annoyance surveys, four conclusions can be drawn:

1. The correlations between individual acoustic noise descriptors and average individual noise annoyance judgments are rather low (10-45% common variance).
2. None of the four acoustic predictors shows superior criterion validity per se.
3. The preference for energy-based predictors for aircraft noise effects is questionable from a purely scientific point of view.
4. There seems to be an effect of the study design: those studies which did select their study sites primarily according to level criteria usually show maximum correlations with LAeq, while those studies which selected study sites according to number criteria (additionally) often show maximum correlations with number predictors.

Is the aircraft noise annoyance trend an artefact of LpAeq?

Returning to the possible causes of the observed annoyance trend we now could ask whether this effect is due to the design of surveys, especially in the use of LpAeq-based acoustic predictors for selecting study sites and samples. There is not much

data referring to this question, but there is one study that shows no significant difference between mean annoyance judgments which have been recorded 23 years apart, if the LpAeq-predictor is replaced by an NNI-type predictor:

The UK ANIS- and ANASE studies (Brooker et al. 1985; MVA Consultancy 2007) both have been designed in a similar way: they covered more than one airport (5; 19), and tried to disentangle the correlation between maximum levels and number of aircraft movements. Study sites were selected to cover a wide range of maximum levels of aircraft noise, as well as a wide range of numbers of overflights (with LpAmax > 65 dB) independently as far as possible. None of the reports shows individual correlations between the two selection variables and mean aircraft noise annoyance, but two figures in the ANASE report show that (a) there *is an annoyance trend* over the years, if LpAeq ist used as a predictor of annoyance (figure 9.1 in ANASE), and (b) there is *no annoyance trend*, if the weighted combination 'Average LAmax + 15 log Average Numbers (> 65 dB)' is used with the same samples (figure 9.9 in ANASE). This is just one study, and further analyses should be made, but the results point to the strong effect of the number of flight movements on average aircraft noise annoyance judgments. At present, it is unclear whether similar effects can be shown with other study samples, lower criteria for LpAmax, and other noise effects, too.

CONCLUSIONS

In my view, available data points to the decreasing validity of LpAeq-based aircraft noise descriptors over the years, because the effect of the increasing number of aircraft movements (at decreasing maximum levels) is not adequately reflected in the descriptor. In other words, LpAeq-based descriptors more and more loose the power to predict aircraft noise annoyance in the present – not to speak of the future. In order to further test the relation between other descriptors on annoyance and other aircraft noise effects, new descriptors should be calculated (e.g., LpAeq + log NAT50) and applied to existing data sets. These data sets should try to disentangle the separate effects of LpAeq (or LpAmax) and the number of aircraft movements as far as possible.

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