The types of human response to changes in noise exposure

H. E. Laszlo, A. Hansell

Imperial College London – MRC-HPA Centre for Environment and Health, St Mary's Campus, Norfolk Place, London, W2 1PG, UK, h.laszlo@imperial.ac.uk, a.hansell@imperial.ac.uk

INTRODUCTION

It has been widely recognized that annoyance is one of the most common effect of environmental noise. Noise annoyance consists of several aspects including immediate behavioral effects such as disturbance and evaluative aspects such as nuisance or unpleasantness (Guski et al. 1999). Exposure-response data show that annoyance generally increases with noise levels (Fidell 2003; Miedema &Vos 1998). Due to environmental, social and personal factors (Job 1988), large heterogeneity has been observed in these curves and the actual noise level has been found to explain only 10 to 25 per cent of an individual reaction to noise (Job 1996). In addition, annoyance may not be stable over time; some studies found that annoyance due a given aircraft noise level has been increasing over time(Babisch et al. 2009; Brink et al. 2008; Guski 2004; Masurier et al. 2007).

In the literature on human response to increased (or reduced) noise exposures, annoyance is generally considered as the main indicator of the subjective response. Vallet (1996) however found that a minimum of 6 dBA change is required in noise level before annoyance changes. Moreoverannoyance reactions for those exposed to changes in noise levels might differ from those predicted by the steady-state exposure-response curves – i.e. for people with (presumed) reasonably constant noise exposure levels (for review see Brown & van Kamp 2009a, b). It is therefore questioned whether the change in annoyance is the best indicator of human reactions to changed noise exposure.

The main aim of this paper is to review the evidence on human reactions to changes in environmental noise exposures in order to present alternative reaction measures other than annoyance. Factors that influence annoyance ratings in changed noise conditions are further discussed. The implications of the findings may help guide policy decisions when impact assessment of proposed changes takes place.

METHODS

Study search

Web of Science, PubMed and Embase were searched from 1980 to March 2011 to indentify relevant articles written in English. In addition, the reference list from relevant original research and review articles and conference proceedings (Internoise 2001-02, 2004-05, 2007-'08, '10) were reviewed. A Google hand search was also performed for grey literature. The search terms included noise, change, reaction, perception, response, annoyance, human community, individual, air, traffic, and rail.

Study selection

The following inclusion criteria were applied: (1) the study measured the change in environmental noise (community, traffic, road, aircraft and railway) exposure, (2) the change in noise level was due to (i) a new (or eliminated) source or change in intensity of the source (e.g. traffic flow change, road bypass construction, change in run-

way configuration), or (ii) some intervention (e.g. noise barrier, insulation),(3) it provided qualitative/quantitative information on reaction or response or perception due to changes in noise conditions, (4) the study quantified and/or described the relationship between changes in environmentalnoiseexposure and community or individual reaction/response/perception/use of living environment, (5) the response was measured in the same population before and after the change in noise levels, (6) the investigation was carried out on humans, and (7) the paper was written in English. Papers that contained no original data were not considered in this review. The selection of studies has conducted in two steps: first the title and abstracts of all records were checked; then the potential relevant papers were retrieved, read in full by the two reviewers and assessed against the inclusion criteria.

Data extraction and quality assessment

The studies that satisfied the inclusion criteria were grouped into four categoriesas types of measures of response: (1) changes in annoyance, (2) activity disturbance, (3) physiological and psycho-social well being, and (4) use of living environment. Since our main interest was to review different responses other than annoyance, it was decided that data would be extracted only from studies in group (2-4). Those studies investigating changes in annoyance (Group 1) were not extracted, but screened to identify factors that influence annoyance ratings in changed noise conditions. The two authors performed the data extraction independently according to a standardized format. Each study was summarized in a tabular form by extracting information on study population, study design, noise source, noise exposure, direction of change in noise exposure, reason for change in noise exposure, measures of response, method of measure the response, confounding factors and conclusion. Disagreements between the reviewers were resolved by consensus. The study quality was judgedusing guidelines of the Cochrane Collaboration(http://www.cochrane-handbook.org/).

RESULTS

The database literature searchyielded 439 records (Web of Science 236, Pubmed 69, Embase 134). Based on their abstracts 82 records found to be possibly relevant (Web of Science 16, Pubmed 4, Embase 6, Internoise proceedings 11, reference list screening 41, Google search 9). After reading the full papers, 29 records were excluded because the studies did not measure the changes in noise exposure (14), the reason of the change in noise exposure was different to that it was described in the inclusion criteria (1), the response was not measured for the same population (3), the paper was not in English (3), or the paper contained no original research (8 review papers). Seven publications were about the same two experiments. We could not retrieve four papers.

Reaction other than annoyance in changed noise conditions

Table 1 presents some results on different measures of reactions in changed noise conditions. The full tabular format summarizing the studies will be shown and the findings will be discussed at the conference in more detail.

Table 1: Studies that measured reactions to changed noise conditions other than annoyance

Reference	Noise source	Noise exposure[1]	Direction of change in noise exposure	Reason of change in noise exposure	Measures of response
Amundsen 2007	road traffic	C	reduction	Insulation, noise barrier	annoyance and sleep disturbance
Eberhardt & Akselsson 1983	road traffic	M	reduction	insulation	sleep disturbance
Fidell et al. 2000	aircraft	M	reduction and increment	airport relo-cation	sleep disturbance
Fidell et al. 2002	aircraft	C	increment	new runway opening	annoyance, sleep disturbance and speech interference
Gomez-Jacinto & Morel-Toranzo 1999	road traffic	M	reduction	insulation	arousal, disturbance of daily life, perceivedunpleasantness
Hume et al. 2004	aircraft	C	increment in air traffic movements	new runway opening	number and pattern of complaint
Krog et al. 2004, 2010	aircraft	M	reduction and increment	airport relo-cation	changes in use of outdoor recreational area
Moehler et al. 1997	railway	M	reduction	rail-grinding	annoyance, disturbance in conversation, relaxation, con-versation outdoors, disturb-ance while going to sleep
Nilsson & Ber-glund 2006	road traffic	M and C	reduction	noise barrier erection	annoyance, interference with speech communication and sleep disturbance
Ohrstrom & Bjorkman 1983	traffic	M	reduction	insulation	sleep disturbance
Ohrstrom 2004	road traffic	M and C	reduction	reduction in traffic load	annoyance, activity disturb-ance, sleep and well-being, use of living environment
Stansfeld et al. 2009	road traffic	M	reduction	introduction of a bypass	annoyance, quality of life, mental disorder

[1]M-measured, C-calculated

12 studies investigated reactions other than annoyance to changed noise conditions. The study design was a before-after type (with control group in some cases). Most of these studies measured sleep disturbance before and after changes in noise exposure were introduced. A structural equation model used by Gómez-Jacinto & Moral-Toranzo (1999) indicated that arousal and disturbance due to noise were good indicators of the perceived noise.

Factors influencing annoyance in changed noise situations

Due to the large number of factors influencing noise exposure-effect relationship, it is difficult to disentangle the effects of noise exposure on human reaction from the effect of other individual and situational factors. Moreover annoyance depends on several non-acoustical factors such as noise sensitivity and fear of noise source (Miedema & Vos 1999), attitudes towards the noise source or anticipation of the change (Brown & van Kamp 2005) or having access to the quiet side of the dwelling (Ohrstrom et al. 2006).

Little is known about factors that affecting on annoyance in a changed noise situation. According to Brown & van Kamp (2009a) one of the explanations for a changed effect in response is a change in variables that modify the exposure-response relationship before and after the change. This explanation also suggests that modifying variables become more positive when noise exposure decreases and more negative when noise exposure increases. Therefore effect modifiers may be very different and have different effect on annoyance in before and after situations. In a study on residents' reactions to the opening of a new railway, Au et al. (2005) for example found that before the opening of a new railway line, people's annoyance levels were determined by their perceived noisiness and their noise sensitivity. However, after the opening of the railway, attitude towards railway became an annoyance predictor.

In the Norway airport relocation study Krog & Engdahl (2004) found that the **situational variable** (if the response was measured before or after the relocation of the airport) was more influential on changes in annoyance than the actual noise exposure itself. However, the authors noted that the situation variable represented a different kind of change (i.e. decreased noise exposure when airport was moved and an increased noise exposure at the place where the airport was relocated). Thus the effect size of the situation may also depend on the direction of change, different expectations to sound quality and different recreational areas. It was also suggested that the time span between the relocation and the time of the after study should be taken into account.

In the same study it was found that variables that predicted annoyance with aircraft noise before the change did not predict transition from use to non-use of recreational areas after the change (Krog 2010). The probability of a transition in both noise changing situations was positively influenced only by the level of **prior experience** with the area. Kastka et al. (1995) also found that residents with experience of the 'before situation' are much more influenced by the 'before experience' even after 12 years of a noise barrier erection. The results suggest that annoyance might be influenced by previous experience or people may **adapt** to the new circumstances and judge a noise situation based on this experience; the more experienced the respondent is in the area the more likely to accept and adapt to the new situation. However Egan et al. (2003) reviewed studies on adaptation and disturbance after opening of major urban roads and foundno evidence of adaptation. A similar conclusion has been drawn by Weinstein (1982); no adaptation was observed following the opening of a new major road over a period of 4 to 16 months. Although Brown (1987) found no evidence for adaptation to increased road traffic noise between 7 and 19 months, he noted that adaptation could have occurred shortly after the change in traffic noise exposure. Findings are related to relatively long adaptations and annoyance is not studied immediately following the change (Fields 1993).

Temporal and spatial factors have been found to be important annoyance modifiers in changed noise conditions. A permanent change in noise exposure islikely to produce different reactions compared with temporary changes (Fields et al. 2000). Guski (2005) suggested that not only the type of change in noise exposure but the time history of the change (i.e. step change or gradual change) can have an effect on the reaction. Length of residency was found to be related to percentage highly annoyed (%HA) 18 months after opening a new railway; community annoyance changed among those who lived in the area before the opening and no change was observed among newcomers (Kastka et al. 1995).

Significant difference in the number of complaints per month, day-of-the-week and hour-of-the-day were found before and after opening a new runway (Hume et al. 2004). *Time of the day* dependent annoyance reactions to changed noise conditions were also observed elsewhere (Brink et al. 2008). Moreover, *seasonal effects* might distort comparisons of annoyance prevalence rates depending on the time of the interview (Fields et al. 2000).

Griffiths & Raw (1986) suggested that confounding by *dwelling orientation* can also be important in increased noise situations.When the *distance from the source* was taken into account in annoyance reactions after erecting a noise barrier, Mital & Ramakrishnan (1997) showed that only those residents who lived close to the barrier were satisfied with the noise installation. Similar conclusion about distance dependent annoyance reaction has also been drawn (Nilsson & Berglund 2006; Kastka et al. 1995). In addition, annoyance reactions varied when *indoor or outdoor* annoyance was evaluated (Nilsson & Berglund 2006).This may also be related to *window opening habits* (Ohrstrom 2004).

Since several studies on traffic volume change (Griffiths & Raw 1986, 1989) showed an excessive effect on annoyance; this was not commonly found in intervention studies; thus *different noise reduction methods* (i.e. changes in noise level and noise intervention) may not have the same effect on annoyance (Griffiths & Raw 1986; Langdon & Griffiths 1982). This might be related to the visibility of the source.

Increased **media cover** can invoke negative reactions, for example, opening of a new railway (Hume et al. 2004). Similar observations have been found in a railway extension study; both information bias and the frequency of using the new line significantly affected the respondents' annoyance reactions, but no interaction was observed between the two factors investigated (Chan & Lam 2008; Lam & Au 2008; Lam & Chan 2007). The study population was divided into two groups. An information sheet describing noise mitigation measures was provided both groups prior to the extension. However the content of the sheet was different: Group A received information about noise mitigation measures that had already been implemented, while Group B received information about possible reduction methods that had not yet been implemented. After the opening of the new railway, Group A found to be significantly more satisfied with the mitigation measures than Group B. They also noted that the effect of the two factors remained significant after a month. Additionally people who used the line more frequently were more tolerant to the noise impact of the new line.

People are more annoyed if they believe that noise could be prevented by authorities (Schreckenberg et al. 2001). It was shown that **mistrust** in the intentions of planners before a new railway was built had a great effect on annoyance; those who mistrusted the planners had more negative expectations with regard their future annoyance or future disturbance. Thus the greater the mistrustthe more the expected future disturbance exceeds the actual disturbance. In addition, the mistrust in the before situation also correlates with the later actual annoyance after the extension of the railway.

Studies that used retrospective assessment may suffer frombias that can be explained by a **response bias** model. Brown (1987) found that following an increase in noise levels, retrospective assessments of annoyance with previous low noise conditions are much lower than were assessments of the same condition made before the change occurred. In contrast, following a decrease in noise levels, retrospective annoyances of annoyance with previous high noise conditions are much higher than were assessments of the same condition made before the change occurred (Brown et al. 1985). It was also speculated the people chronically exposed to low levels of noise may use different frame of reference for annoyance scales to people who are constantly exposed to high levels of noise (Brown 1987).

CONCLUSION

Previous studies suggest that annoyance *per se* is might not be a precise estimate of human reactions in changed noise situations. It is therefore important to test other variables that can be used for this purpose. Very few studieshave been identified that address reaction measures other than annoyance in changed noise situations. The heterogeneity of study designs and outcome measures (e.g. sleep disturbance, activity disturbance, well being, etc) makes it difficult to draw any firm conclusions. The 'alternative' measures of reactions presented in this review should be further evaluated in prospective studies. Their reliability should be compared with annoyance measures as well their sensitivity to bias.

Annoyance measures are generally used both in steady state and changing noise exposure evaluation studies. However the mechanism of how residents judge their level of annoyance in response to exposure changes is not fully understood. It has been shown that annoyance is modified by several acoustical and non-acoustical factors. Guski (1999) distinguished between social and personal co-determinants of annoyance. Attitudes and expectations belong to the category of social co-determinants, while noise sensitivity or coping are stable personal factors. Social factors play a major role in predicting noise annoyance between the announcement and implementation of changes in noise exposure (Schreckenberg & Meis 2007). Thus minimizingnoise annoyance can be achieved by modifying the social co-determinants. Providing sufficient information about planned changes, increasing the trust in authorities, encouraging public engagement and discussion as well as motivating the public to use the new infrastructure all contribute to the reduction of annoyance.

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REFERENCES

Amundsen AH (2007). Effects of facade insulation on annoyance and sleep disturbances. In: Proceedings of the 36th International Congress and Exhibition on Noise Control Engineering, Turkey.

Au W, Lam K, Hui W (2005). Changes in the acoustical environment arising from new railway extension: a case study of Hong Kong. In: Proceedings of the 2005 Congress and Exposition on Noise Control Engineering, Rio de Janeiro.

Babisch W, Houthuijs D, Pershagen G et al. (2009). Annoyance due to aircraft noise has increased over the years - results of the HYENA study. Environ Int 35: 1169-1176.

Brink M, Wirth KE, Schierz C et al. (2008). Annoyance responses to stable and changing aircraft noise exposure. J Acoust Soc Am 124: 2930-2941.

Brown A (1987). Responses to an increase in road traffic noise. J Sound Vibr 117: 69-79.

Brown AL, van Kamp I (2005). Towards a design for studies of response to a change in noise exposure. In: Proceedings of the 2005 Congress and Exposition on Noise Control Engineering, Rio de Janeiro.

Brown AL, van Kamp, I (2009a). Response to a change in transport noise exposure: competing explanations of change effects. Journal Acoust Soc Am 125: 905-914.

Brown AL, van Kamp I (2009b). Response to a change in transport noise exposure: a review of evidence of a change effect. J Acoust Soc Am 125: 3018-3029.

Brown AL, Hall A, Kyle-Little J (1985). Response to a reduction in traffic noise exposure. J Sound Vibr 98: 235-246.

Chan T, Lam K (2008). The effects of information bias and riding frequency on noise annoyance to a new railway extension in Hong Kong. Transport Res Part D: Transport and Environment 13: 334-339.

Eberhardt JL, Akselsson RK (1983). The disturbance by road traffic noise of the sleep of young male adults as recorded in the home. J Sound Vibr 114: 417-434.

Egan M, Petticrew M, Ogilvie D et al. (2003). New roads and human health: a systematic review. Am J Public Health 93: 1463-1471.

Fidell S (2003). The Schultz curve 25 years later: A research perspective. J Acoust Soc Am 114: 3007-3015.

Fidell S, Pearsons K, Tabachnick BG et al (2000). Effects on sleep disturbance of changes in aircraft noise near three airports. J Acoust Soc Am 107: 2535-2547.

Fidell S, Silvati L, Haboly E (2002). Social survey of community response to a step change in aircraft noise exposure. J Acoust Soc Am 111: 200-209.

Fields JM (1993). Effect of personal and situational variables on noise annoyance in residential areas. J Acoust Soc Am 93: 2753-2763.

Fields JM, Ehrlich GE, Zador P (2000). Theory and design tools for studies of reactions to abrupt changes in noise exposure. Hampton.

Gómez-Jacinto L, Moral-Toranzo F (1999). Urban traffic noise and self-reported health. Psychol Rep 84: 1105-1108.

Griffiths ID, Raw GJ (1986). Community and individual response to changes in traffic noise exposure. J Sound Vibr 111: 209-217.

Griffiths I, Raw G (1989).Adaptation to changes in traffic noise exposure. J Sound Vibr 132: 331-336.

Guski R (1999). Personal and social variables as co-determinants of noise annoyance. Noise & Health 1(3): 45-56.

Guski R (2004). How to forecast community annoyance in planning noisy facilities. Noise & Health 6(22): 59-64.

Guski R (2005). Defining a step change of aircraft noise in residential areas. In: Proceedings of the 2005 Congress and Exposition on Noise Control Engineering, Rio de Janeiro.

Guski R, Felscher-Suhr U, Schuemer R (1999). The concept of noise annoyance: how international experts see it. J Sound Vibr 223: 513-527.

Hume KI, Morley H, Thomas C (2004). Community response to a new runway: preliminary results. In: Proceedings of the 33rd International Congress and Exposition on Noise Control Engineering, Prague.

Job RFS (1988). Community response to noise: a review of factors influencing the relationship between noise exposure and reaction. J Acoust Soc Am 83: 991-1001.

Job RFS (1996). The influence of subjective reactions to noise on health effects of the noise. Environ Int 22: 93-104.

Kastka J, Buchta E, Ritterstaedt U et al. (1995). The long term effect of noise protection barriers on the annoyance response of residents. J Sound Vibr 184: 823-852.

Krog NH, Engdahl B (2004). Annoyance with aircraft noise in local recreational areas, contingent on changes in exposure and other context variables. J Acoust Soc Am 116. 323-333.

Krog NH, Engdahl B, Tambs K (2004). Studies on aircraft noise in outdoor recreational areas. Experimental and behavioural effects of changes in noise exposure. In: Proceedings of the 33rd International Congress and Exposition on Noise Control Engineering, Prague.

Krog NH, Engdahl B, Tambs K (2010). Effects of changed aircraft noise exposure on the use of outdoor recreational areas. Int J Environ Res Public Health 7: 3890-3915.

Lam K, Au W (2008). Human annoyance response to a step change in noise exposure following the opening of a new railway extension in Hong Kong. In: 9th International Congress on Noise as a Public Health Problem (ICBEN) 2008, Foxwoods, CT.

Lam K, Chan T (2007). Effects of information bias and frequency of riding on annoyance response to a newly operated railway line. In: Proceedings of the 36th International Congress and Exhibition on Noise Control Engineering (Vol. 14), Turkey.

Langdon F, Griffiths I (1982). Subjective effects of traffic noise exposure, II: Comparisons of noise indices, response scales, and the effects of changes in noise levels. J Sound Vibr 83: 171-180.

Masurier LP, Bates J, Taylor J et al. (2007). ANASE. Attitudes to Noise from Aviation Sources in England. Final Report for Department for Transport (p 144). Norwich.

Miedema HME, Vos H (1998). Exposure-response relationships for transportation noise. J Acoust Soc Am 104: 3432-3445.

Miedema HME, Vos H (1999). Demographic and attitudinal factors that modify annoyance from transportation noise. J Acoust Soc Am 105: 3336-3344.

Mital A, Ramakrishnan AS (1997). Effectiveness of noise barriers on an interstate highway: a subjective and objective evaluation. J Hum Ergol 26: 31-38.

Moehler U, Hegner R, Schuemer R. et al. (1997). Effects of railway noise reduction on annoyance after rail grinding. In: Proceedings of Inter-Noise 1997, Budapest.

Nilsson ME, Berglund B (2006). Noise annoyance and activity disturbance before and after the erection of a roadside noise barrier. J Acoust Soc Am 119: 2178-2188.

Ohrstrom E (2004). Longitudinal surveys on effects of changes in road traffic noise—annoyance, activity disturbances, and psycho-social well-being. J Acoust Soc Am 115: 719-729.

Ohrstrom E, Bjorkman M (1983). Sleep disturbance before and after traffic noise attenuation in an apartment building. J Acoust Soc Am 73: 877-879.

Ohrstrom E, Skanberg A, Svensson H et al. (2006). Effects of road traffic noise and the benefit of access to quietness. J Sound Vibr 295: 40-59.

Schreckenberg D, Meis M (2007). Noise annoyance around an international airport planned to be extended. In: Proceedings of the 36th International Congress and Exhibition on Noise Control Engineering, Turkey.

Schreckenberg D, Schuemer R, Moehler U (2001). Railway-noise annoyance and "misfeasance" under conditions of change. In: Proceedings of the 2001 International Congress and Exhibition on Noise Control Engineering, The Hague.

Stansfeld SA, Haines MM, Berry B et al. (2009). Reduction of road traffic noise and mental health: an intervention study. Noise & Health 11(44): 169-175.

Vallet M (1996). Annoyance after changes in airport noise environment. In: Proceedings of Inter-noise 1996, Liverpool.

Weinstein N (1982). Community noise problems: evidence against adaptation. J Environ Psychol 2: 87-97.

Aircraft noise indexes - recent developments and current applications*

M. Brink[1], B. Schaeffer[2], D. Schreckenberg[3], M. Basner[4]

[1] ETH Zürich, Public and Organizational Health, WEP H17, CH-8092 Zurich, brink@ethz.ch

[2] Empa Swiss Federal Laboratories for Materials Science and Technology, Laboratory of Acoustics, CH-8600 Duebendorf, reto.pieren@empa.ch

[3] ZEUS GmbH, Center for Applied Psychology, Social and Environmental Research, D-58093 Hagen

[4] University of Pennsylvania, Department of Psychiatry, Unit for Experimental Psychiatry, Division of Sleep and Chronobiology, Philadelphia, PA, USA, and German Aerospace Center (DLR), Institute of Aerospace Medicine, D-51170 Cologne, basner@mail.med.upenn.edu

ABSTRACT

In this paper, we briefly report about recent developments and current applications of aircraft noise indexes at the airports of Zurich where, since a few years, the ZFI (Zürcher Fluglärm Index) is in force, and Frankfurt with its FFI/FNI (Frankfurter Fluglärm Index).

INTRODUCTION

Aircraft noise indexes are integral noise monitoring instruments that express the overall effects of aircraft noise, created by a particular airport as one or two rating figures. By accounting for the most important effect measures (such as annoyance or awakening reactions) and by weighting these measures according to the population density at each grid point within a defined geographic perimeter, noise effect indexes provide residents and authorities with an integral picture of the total noise effect.

Usually, noise protection and abatement concepts are based on predicting annoyance from time-integrated levels of acoustic energy (such as the L_{eq}, L_{dn}, or L_{den}) and setting exposure limits below which it is generally assumed that the well-being of the majority of the population is not seriously affected. In contrast to roads or railway lines, airports can more easily be understood as clearly circumscribable noise emitting installations, similar to industry complexes. The air traffic they 'produce' is responsible for the aircraft noise exposure of the population living in the vicinity of the airport. The overall noise effect from one particular airport can thus be expressed in a single figure, e.g. as the number of people living within a particular exposure contour. In this paper, we propose a more elaborate and effect-oriented approach to aircraft noise assessment with – as they will be called – noise effect indexes. Noise effect indexes are an effective measure to evaluate different operation modes of an airport as a whole, or to survey the effectiveness of previously installed noise abatement measures as well as to monitor changes of the distribution of the noise burden around an airport's vicinity. By expressing noise effect as number of people affected, they can also be used as a basis for (financial) compensation schemes between different municipalities.

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