ANNOYANCE, DISTURBANCE AND SEVERANCES IN CHILDREN EXPOSED TO TRANSPORTATION NOISE.

P. Lercher
Institute of Hygiene and Social Medicine, Sonnenburgstrasse 16, A-6020 Innsbruck

Introduction The population impact of sources of environmental noise in adults is typically assessed in terms of annoyance with a set of established questions – at least one of it in a standardized, recommended version (Fields et al. 1997; 2001). From many surveys across Europe, North America and Australia standard dose-response curves for aircraft, road traffic and rail noise were derived from archival data (Fidell et al. 1991, Miedema & Vos 1998, Miedema & Oudshoorn 2001). Furthermore, meta-analyses have extracted the major moderating factors responsible for the substantially varying annoyance reactions in the different noise surveys (Job, 1991; Fields, 1993; Miedema & Vos 1999).
In the early 21st Century we have to admit that we do not have either an agreed, suitable methodology (first gap) nor sufficient representative data to answer the questions on dose-response (second gap) and important moderators of the annoyance response (third gap) in children. We do, however, have a certain body of evidence on the effects of environmental noise on performance, cognition, motivation, sleep and physiologic changes of blood pressure and stress hormones in children (Babisch, 2003; Evans & Hygge, 2003). It may have been that both the inconsistency of the results and the difficulty to interpret effects seen in these research areas up into the early nineties have discouraged community annoyance researchers. Particularly, sleep studies have suggested that children are less affected by noise during night – based on encephalographic recordings only – without parallel assessment of the cardiovascular response.
It is the intention of this paper to review the currently limited knowledge on the annoyance response of children as evidenced in community surveys. We exclude from the review here the more specialized investigations in and around school settings and other institutional environments (such as day care centers) which are more concerned with indoor noise levels or the extent of interference between outdoor and indoor levels. We follow herein the above outlined three gaps.

First gap: survey methodology Currently, we have only single, patchy information about annoyance, other attitudes or affective responses of noise exposed children in residential settings. You can screen through the older reviews on noise and children – no paragraph is devoted to this question. In their rationale to study annoyance, Evans et al. (1995) concluded "Very little is known about children's affective responses to noise".
Currently, there are only three sufficiently large studies available, which have applied *a systematic, quantitative approach* towards the assessment of noise annoyance of children *in residential settings*. The majority of studies cover the same age range (8-12 years). Investigators agree on the need to use different questionnaire design and administration when assessing child annoyance. The applied techniques, however, varied and therefore are shortly outlined.
The Munich airport study Two approaches were applied (Evans et al., 1995, 1998). The specific annoyance ratings in the first cross-section of this study (135 children) were conducted in a climate controlled, sound-attenuated trailer. The child was exposed to three sets (broadband, aircraft, road traffic noise) of randomly presented, standardized noise sequences of

short duration, covering a range from 42 to 90 dB,A. After a careful training phase, children provided magnitude estimates of noise annoyance for each standard noise and the community noise on a vertical, visual analogue scale. Nine uncalibrated annoyance ratings were summed to provide the community noise rating for each child ("raw scores"). Calibrated individual scores were derived by the slope of the regression line fitting each child's broadband noise standard stimuli to their community noise rating. "Raw" and "calibrated" score results did not differ.

The general rating of environmental annoyance was based on the so-called "environmental list", a child adapted questionnaire with 21 Likert-scaled items ("completely disagree - disagree - agree - completely agree"). The assessment covers different degrees of perception (quiet – hear – disturbing) of noise (aircraft, road, industry, neighbours), air quality (good quality, exhaust smell, smells from industry), other residential qualities (traffic safety, green space, housing) and opportunities (playgrounds, nature).

The "environmental list" was used as a self-administered questionnaire in the Munich studies. The details of the reliability and validity is described in a dissertation (Meis 1998). A modified list (22 items) was utilized in a sidearm of this study (N=530) with older children (13-15 yrs) where the focus was on overall environmental annoyance (Bullinger & Bahner, 1997. See also below).

Heathrow studies At Internoise 2000, the approach used in the Schools Environment and Health Study around Heathrow airport were described in more detail (Haines & Stansfeld, 2000). This article gives a very useful description of the general aspects of the survey methodology, necessary to ensure reliable and valid data are collected from children (introductory debriefing, reading questionnaires aloud, preventing 'expected answers', preparing necessary assistance, etc.). The questionnaires were group-administered in the classroom.

First study (Haines et al. 2001a, N= 340): Noise annoyance was measured with seven child adapted standard questions according to Fields et al. (1997). These questions assessed the level of annoyance (very much, quite a bit, a little, not at all) felt by the child when they heard four sources of environmental noise (aircraft noise, train noise, road traffic and neighbours' noise without a timeframe).

In addition, self-reported perceived noise was measured by a simple yes/no question 'Do you hear plane noise around your school ?' or 'Do you hear plane noise around your school ?'

Other questions (concerning air quality, safety, friendliness of the area) – similar to the ones of the environmental list in the Munich study were used with a different grading. Example: 'How clean do you think the air is around your school ? (very clean, clean, not very clean).

Second study (Haines et al. 2001b, N= 451): Here, noise annoyance was measured with four child adapted standard questions with the newly recommended 5-point Likert scale (Fields et al. 1998). The assessment targeted two noise sources (aircraft noise and road traffic noise at home and school) and now included a timeframe (the last 12 months).***Tyrol studies*** Within the framework of an Environmental Health Impact Assessment two comple-mentary study designs were used. For a complete description of the study designs consult Lercher et al. (2002). A slightly adapted methodology from the Munich study was applied.

Field study (N=1280): At Internoise 2000, a short description of the procedure was given (Lercher et al., 2000). A slightly modified environmental list (19 items, including rail noise) assessed perception (hear) and annoyance/disturbance with the same Likert-type verbal scale from the Munich study (see above). The assessment took place after a careful debriefing with a similar emphasis on the aspects of administration mentioned by Haines & Stansfeld (2000).

A developmental psychologist supervised the design and testing of the questionnaires. She also trained the research group to develop standardized, but flexible support behaviour during the group-administered assessment procedure in the classroom.

Experimental study (N=123): An extreme sub-sample (50dB,Ldn<noise >60dB,Ldn) of children from the field study (N=1280), stratified by noise and educational level. All the testing took place in a sound attenuated laboratory trailer in the community where the child lived (Evans et al., 2001).
Two different annoyance assessment approaches were used.
In the first approach, children were asked to assess the annoyance of eight sounds (four motorway and four rail traffic sounds, binaurally recorded in the area and standardized to a range from 50 to 80 dB,A) presented via headphones. A horizontal, visual Analogous Scale (VAS), similar to a graphic ruler (with numbers from 0 to 100) was used for the assessment. The words 'not annoying' and 'very annoying' marked the two poles of the ruler. Each child was given a detailed standardized instruction and enough time to get used to the procedure. Each of the eight sounds was presented for 30 seconds with an inter-stimulus interval of 10 seconds. To minimize order-effects, two tapes with different orders of the eight sounds had been arranged.
In the second approach children assessed the annoyance of imagined motorway or rail traffic sounds in two different imagined situations (playing around the home, doing homework). A more detailed description is given in Sukowski et al. (2000).
Results: For both sound sources (highway, rail) children from the quiet area scored consistently higher at each sound level (50 to 80 dB,A). Nearly the same result were observed with the imagined procedure. Surprisingly, rail noise was rated more annoying at 60 and 70 dB,A, but equally annoying at the two outer poles of the exposure (50 and 80 dB,A).
Furthermore, the children felt significantly less annoyed by traffic noise when they imagined they were playing than when they imagined doing their homework
Summary: All approaches sound methodologically appropriate. The variety indicates the experimental stage of development in this field. It is difficult to judge how large the effects of the variations in the assessment designs are.

Second gap: lack of representative and dose-response data This gap concerns the usability of the data from the viewpoint of a public health administrator.
First limitation: The main information on noise annoyance in children comes from high impact areas around major airports. Other studies focused on small, highly impacted school areas (Bronzaft & McCarthy, 1975; Lukas et al., 1981).
There is common agreement in science and policy that 65 dB,A is a noise level that should be phased out in residential settings (CEC, 1996; Berglund et al., 2000). We are less certain about what happens to life quality, performance and health through chronic exposure between 55 and 65 dB,A, to which the largest fraction of the population (also children) are exposed (Stanners & Bordieu 1995). Only one study (Tyrol) provides data for this exposure range with "high exposure" starting at 50 dBA,Ldn, and the low exposure group going down to quiet places (30 dB,A,Ldn). The cut-off definitions for the low exposure group in the airport studies were 59.2 dB,A (Munich) and 57 dB,A (Heathrow I and II). This means, the airport comparison groups show exposure levels already not considered compatible with the recommendations for residential areas (Berglund et al., 2000). Thus, assuming potential health effects occur in these midrange or most prevalent exposure levels – this "high level" reference group could have obscured the true effect size in the very high level exposure group in these studies. In addition, the current annoyance data base lacks sufficient information on road traffic noise: around 80 % of the noise exposure in Europe above 55 dBA,Leq is caused by it.
Second limitation: Restrictions in level and/or quality of the noise data in these studies did not allow to generate dose-response curves in most studies. Field dose-response data were reported only from the Tyrol-study for road and rail noise (Lercher et al. 2000).

The dose-response for road noise shows a linear increase with a relatively high starting point at lower levels (10% highly annoyed) and only a shallow slope to 15% highly annoyed at 60 dBA,Ldn. The rail response was near zero up to 50 dBA,Ldn, where the curve levels off exponentially with nearly 40 % highly annoyed at 70 dBA,Ldn. Due to the very specific exposure situation (alpine valley topography, complex meteorology ("sensitive area"), low background levels versus high rail noise levels during night) – a generalization would not be advisable.

All other available annoyance data were presented in a dichotomous way as means for high or low noise exposure. Analyses with dichotomized exposure variables are highly susceptible to bias (Zhao & Kolonel, 1992; Taylor & Yu, 2002). The often dictated cut-off (e.g. by the size of the group) of the exposure range makes comparisons across studies extremely difficult. Furthermore, it does not only reduce the general statistical power to detect differences in any effect marker – it often leads also to data descriptions with a poor information content: "Children living in the noisier areas were significantly more annoyed by the noise in their communities" or "Chronic exposure to high levels of aircraft noise was associated with higher levels of annoyance in the analyses". Such sentences describe correctly the data but may be considered as trivial by decision makers.

Third limitation: Currently, we have not sufficient information to relate the existing information on noise annoyance to other annoyances or severances the child experiences around its residential environment (relative importance of annoyance).

From a sidearm of the Munich airport study (Bullinger & Bahner, 1997) where the "environmental list" was used with 13-15 year old children (N=530, response = 48%), we know that these children overall report lower mean annoyance levels than their mothers. However, the levels and the topics of annoyance vary considerably between urban to rural areas. The highest mean annoyance ratings were observed in the aircraft exposed rural area while road traffic noise annoyance ratings were of equal size to air pollution, odorous pollution from farming and mobility related items such as poor traffic connections or shopping opportunities.

In the Tyrol study with younger children, the main concern (% highly annoyed) was traffic safety (14.7 %), road traffic noise 11.6 %), truck noise (8.5 %), rail noise (5.4 %) and car exhaust (5.1 %). The overall, equivalent prevalences for road and rail noise and car exhaust were about 50 % lower in the responses of their mothers.

Third gap: lack of moderator information Noisy environments are frequently associated with other environmental (e.g. air pollution, vibration, lack of green areas) and social stressors (e.g. poverty, crowding, safety). The co-variation of noise with these other adverse ambient stressors makes it often difficult to isolate the adverse effects of noise on child development (Evans & Lepore, 1993). We need therefore to understand the context in which the relationship between noise and annoyance is embedded (Lercher, 2001). If we lack this piece of information we miss the opportunity to assess the relative contribution environmental and social factors make to the annoyance response in children and which part of it may be amenable to intervention. Moreover, from a health promotion point of view ("supportive environments") we need to know about the necessary qualities an environment must have to support children in their development and daily tasks (Berglund et al., 2000). The main reason why this has not been accomplished was either the sample size of the studies was too small for analysis or the information has not been collected or not yet reported.

The results of the Tyrol-study (Lercher et al., 2000) showed a substantial variability of the annoyance response with various environmental, social and personal factors. Among the tested set of modifiers the largest moderation comes from satisfaction with the living area, opportunities to act out and have fun.

Furthermore, the importance of these factors differed between road and rail noise. For instance, density (persons/room) had only an impact on reported road noise but not on rail noise annoyance. This differential effect of density on road noise annoyance was equally observable in the mother's response.
This first information shows substantial moderation of the children's response due to environmental, situational and personal variables and should be followed up in other studies.

Conclusions and future research From the limited, existing data base neither general nor firm conclusions can be drawn. The only available community studies used different noise indices (16 hrs leq, 24 hrs Leq, 24 hrs Ldn) which are difficult to compare without further data on night levels.
The noise exposure information was only used in a dichotomized way in the airport studies and the cut-off point for the reference groups was rather high. Potential misclassification errors caused by differences between school and home noise levels cannot be estimated from the current data base. Future studies need to consider this relationship between school and home exposure more carefully, because there is evidence from earlier studies of school x home interactions (Cohen et al., 1980; Hambrick-Dixon, 1986) in other effect markers.
The annoyance information was gathered by different scaling procedures and wording. Currently, it is not possible to draw conclusions whether the "adapted standard format" is advantageous over more "child oriented environmental list formats". The same can be said about "self" versus "group" administration. Probably, all formats provide a certain information. The child orientation of the instruments should be tested in larger and more representative focus groups and surveys before a final judgement and recommendations can be proposed.
It seems that the annoyance response differs among children of different age and also differs somewhat from the response of their mothers. Greater safety concerns with road traffic may be responsible for the stronger reaction of children already at lower noise levels.
Although the major studies are confident about the validity of the annoyance reports of the children a formal reassessment and validation of these procedures is lacking.
A better picture can be drawn of the reliability of the response scales. The repeated assessment in the Heathrow study one year apart (Haines et al., 2001c) and the reliability data from the Munich "environmental list" showed good agreement over three time points (Meis, 1998).
The best evidence for the usability of the items comes from the prospective Munich data (Bullinger et al., 1999) over three time points (6 month before the airport moved, 6 and 18 months after the move of the airport): The annoyance from the new airport increased from wave one to wave three in the noise impacted communities while the mean annoyance in the children around the closed airport dropped from a high score before the move in wave one to a very low score in wave three. Both changes were significant against the two control groups. Because, these changes in annoyance were accompanied also by small changes in reported life quality, motivation, and attribution of failure, this adds indirect evidence for the validity of the annoyance measurement procedure.
Moreover, we learned from the Munich study that the change in annoyance appeared within a short time frame while the changes in the other effect markers need a certain latency time to occur (24 months).
In future studies it seems therefore useful to include also other markers of effect such as quality of life and environmental stress questionnaires to better understand the complex relationships between noise, annoyance, cognition, emotion, motivation, performance and health.
Future research on annoyance in children would probably profit from the inclusion of the eco-psychological concept of "affordances" (Heft, 1988; Kyttä, 2002). By measuring "the significant properties of the environment that are perceived by the acting individual" we may

be better able to distinguish the effects of "background" stressors from the effects of noise and to assess the potential interaction effects.

A more integrative approach to study noise annoyance in children seems necessary for three main reasons: firstly, children are considered to be more dependent on the overall environmental outfit than adults. Secondly, the relative importance of noise exposure and noise annoyance can directly be judged against the rest of the environmental stressors, which helps administrators and policy makers. Thirdly, if we understand the context in which adverse effects occur architects and land use experts are supported in planning the environment to better fit the needs of children in development.

References

Babisch W. Stress hormones in the research on cardiovascular effects of noise. Noise & Health 2003; (in press)

Berglund, B., Lindvall, Th, Schwela, D.H. (eds), Guidelines for community noise. WHO. Geneva 2000, http://www.who.int./peh/noise/noiseindex.html

Bullinger M, Hygge S, Evans GW, Meis M, Von Mackensen S. The psychological cost of aircraft noise for children. Zentralblatt für Hygiene und Umweltmedizin 1999; 202 (2-4): 127-138

Bullinger M, Bahner U. Erlebte Umwelt und subjektive Gesundheit: Eine Untersuchung an Müttern und Kindern aus unterschiedlich lärmbelasteten Gebieten Zeitschrift für Gesundheitswissenschaften 1997; 3. Beiheft: 89-108.

CEC. Future Noise Policy. European Commission Green Paper. COM(96) 540 Final, Office for Official Publications of the European Communities, Luxembourg, 1996.

Cohen S, Krantz DS, Evans GW, Stokols D. Physiological, motivational, and cognitive effects of aircraft noise on children. American Psychologist 1980; 35: 231-243.

Evans GW and Lepore SJ. Non-auditory effects of noise on children: A critical review. Children's Environments 1993; 10: 31-51.

Evans GW, Hygge S, Bullinger M. Chronic noise and psychological stress. Psychological Science 1995; 6: 333-338.

Evans GW, Maxwell L. Chronic noise exposure and reading deficits. Environment and Behavior 1997; 29: 638-656.

Evans GW, Bullinger M, Hygge S. Chronic noise exposure and physiological response: A prospective study of children living under environmental stress. Psychological Science 1998; 9:75-77.

Evans GW, Lercher P, Meis M, Ising H, Kofler W. Typical community noise exposure and stress in children. Journal of the Acoustical Society of America 2001; 107: 1023-1027.

Evans GW & Hygge S. Noise and performance in children and adults. In. L. Luxon & D. Prasher (Eds.). Noise and its effects. London: Whurr. (2003 in press).

Fidell S, Barber DS, Schultz TJ. Updating a dosage-effect relationship for the prevalence of annoyance due to general transportation noise. The Journal of Acoustical Society of America 199189:221-233.

Fields JM. Effect of personal and situational variables on noise annoyance in residential areas. The Journal of the Acoustical Society of America 1993; 93: 2753-2763.

Fields JM, de Jong RG, Brown AL, Flindell IH, Gjestland T, Job RFS, Kurra S, Lercher P, Schuemer-Kohrs A, Vallet M, Yano M Guidelines for reporting core information from community noise reaction surveys. Journal of Sound and Vibration 1997; 206: 685-695.

Fields, JM, de Jong RG, Gjestland T, Flindell IH, Job RFS, Kurra S, Lercher P, Vallet M, Yano T, Guski R, Felscher-Suhr U, Schumer R. Standardized general-purpose noise reaction

questions for community noise surveys: research and a recommendation. Journal of Sound and Vibration 2001; 242: 641-679.
Hambrick-Dixon PJ. Effects of experimentally imposed noise on task performance of Black children attending day care center near elevated subway trains. Dev Psych 1985; 22:259-264.
Haines MM, Stansfeld SA. Measuring annoyance and health in child social surveys. In: Cassereau D, ed. Proceedings of Internoise 2000, Nice, France: Société Française d'Acoustique, 2000, Vol 3: 1609-1614.
Haines MM, Stansfeld SA, Job RFS, Berglund B, & Head J. Chronic airport noise exposure, stress responses, mental health, and cognitive performance in school children. Psychological Medicine 2001a; 31: 265-277.
Haines MM, Stansfeld SA., Brentnall S, Head J, Berry B, Jiggins M, Hygge S. The West London Schools Study: the effects of chronic aircraft noise exposure on child health. Psychological Medicine 2001b; 31: 1385-1396
Haines MM, Stansfeld SA, Job RFS, Berglund B, Head J. A follow-up study of effects of chronic aircraft noise exposure on child stress responses and cognition. International Journal of Epidemiology 2001c;30 (4): 839-845.
Heft H. Affordances of children's environments: a functional approach to environmental description. Children's Environments Quarterly 1988; 5:29-37.
Job RFS. Impact and potential use of attitude and other modifying variables in reducing community stress from noise. Transportation Research Record, 1991; 1312: 109-115.
Kyttä M. Affordances of children's environments in the context of cities, small towns, suburbs and rural villages in Finland and Belarus. Journal of Environmental Psychology 2002; 22:109-123.
Lercher P, Brauchle G, Kofler W, Widmann U, Meis M. The assessment of noise annoyance in schoolchildren and their mothers. In: Cassereau D, ed. Proceedings of Internoise 2000, Nice, France: Société Française d'Acoustique, 2000, Vol 4: 2318-2322.
Lercher, P. Contextual and non-contextual perspectives in research and management of noise annoyance: an environmental health perspective. Proceedings Internoise 2001, The Hague, NL.
Lercher P, Evans GW, Meis M, Kofler WW. Ambient neighbourhood noise and children's mental health. Occupational and Environmental Medicine 2002; 59: 380-386.
Lukas J, DuPree R, Swing J. Report of a study on the effects of freeway noise on academic achievement of elementary school children and a recommendation for a criterion level for a school noise abatement program. Sacramento, CA: California Department of Health Services, 1981.
Meis, M., Zur Wirkung von Lärm auf das Gedächtnis: Explizite und implizite Erinnerungsleistungen fluglärmexponierter Kinder im Rahmen einer medizinpsychologischen Längsschnittstudie. Dissertation, Hamburg: Verlag Dr. Kovac, 1998.
Miedema HME, Vos H. Exposure response functions for transportation noise. Journal of the Acoustical Society of America 1998; 104: 3432-3445.
Miedema HME, Vos H. Demographic and attitudinal factors that modify annoyance from transportation noise. Journal of the Acoustical Society of America 1999; 105: 3336-3344.
Miedema HME, Oudshoorn CG. Annoyance from transportation noise: relationships with exposure metrics DNL and DENL and their confidence intervals. Environmental Health Perspectives 2001; 109: 409-416.
Stanners D, Bordeau P (Eds). Europe's Environment. Copenhagen: European Environment Agency, 1995.
Sukowski H, Meis M, Lercher P, Heydinger D, Schick A. Noise annoyance of children exposed to chronic traffic noise: results from the Tyrol School Study II. In: Contribution to

psychological acoustics. Results of the 8th Oldenburg Symposium on psychological acoustics. Bibliotheks- und Informationssystem der Universität Oldenburg: 571-580. Oldenburg 2000.

Taylor JMG, Yu M. Bias and efficiency loss due to categorizing an explanatory variable. Journal of Multivariate Analysis 2002; 83: 248–263.

Zhao LP, Kolonel LN. Efficiency loss from categorizing quantitative exposures into qualitative exposures in case-control studies. American Journal of Epidemiology 1992; 136: 464–474.