AIRCRAFT AND ROAD TRAFFIC NOISE AND CHILDREN'S COGNITION AND HEALTH: PRELIMINARY RESULTS ON DOSE-RESPONSE RELATIONSHIPS FROM THE RANCH STUDY

S.A. Stansfeld[1], B. Berglund[2], I. Lopez-Barrio[3], P. Fischer[4], E.Öhrström[5], M.M. Haines[1], B. Berry[6] on behalf of the RANCH Study Team
[1]Queen Mary, University of London, UK, [2]Karolinska Institute, Sweden, [3]CSIC, Madrid, Spain, [4]RIVM, Bilthoven, The Netherlands, [5]Göteborg University, Sweden, [6]BEL, London

Introduction Many studies have found associations between exposure to aircraft noise and children's cognition in terms of reading comprehension, long-term memory and motivation (Cohen et al, 1980; Evans et al, 1995; Haines et al, 2001a,b; Haines et al, 2002; Hygge et al, 2002). Associations have also been found between aircraft noise exposure and psychophysiological indices of arousal such as levels of catecholamines and elevated blood pressure. With a few exceptions (Green et. al, 1982; Haines et. al, 2002), most studies have compared high and low noise exposed groups and have not examined dose-response relationships. Moreover, most studies in children have focussed on aircraft noise rather than traffic noise and have not examined the effects of the combination of aircraft and road traffic noise.

The RANCH Study (Road traffic and aircraft noise exposure and children's cognition and health: exposure-effect relationships and combined effects) was set up to extend the current research to examine dose-effect relationships between aircraft and road traffic noise exposure and annoyance, reading comprehension, long-term memory, working memory, prospective memory, psychosocial distress and sustained attention in 9-10 year old children living around major airports in three European countries: the Netherlands, Spain and the United Kingdom.

In addition, the study has included studies of road traffic noise at home and both sleep and cognition in Sweden and studies of soundscapes embedded within the airport study in the UK and the road traffic noise studies in Sweden. The aims of the study include the development of tools and models for the evaluation of children's cognition and health, the assessment of dose-effect associations between aircraft and road traffic noise and the combinations of aircraft and road traffic noise and children's cognition and health across Europe.

Method

Design Children were selected to take part in this cross sectional field study on the basis of school noise exposure around each of the three airports. Schools were selected from a four by four grid of increasing aircraft and road traffic noise exposure so as to examine a) dose-response relationships for increasing aircraft noise exposure within low road traffic noise and dose-response relationships for increasing road traffic noise exposure within low aircraft noise and b) dose-response relationships for a combination of aircraft and road traffic noise (see figure 1).

Figure 1: Selection of schools by noise exposure

	Aircraft 1	Aircraft 2	Aircraft 3	Aircraft 4
Road 4	X	X		X
Road 3	X		X	
Road 2	X	X		X
Road 1	X	X	X	X

X denotes two schools selected

School selection In each selected noise exposure cell two schools were selected according to a carefully designed protocol (SNAP) agreed across all participating countries. From the pool of primary schools in the areas surrounding the 3 major airports the first step was to exclude all non-state schools. The remaining schools were then matched according to socioeconomic position and main language spoken at home beginning with those schools exposed to the highest levels of aircraft noise. These schools were visited and a noise survey was undertaken and schools were excluded if either another dominant noise was present other than aircraft or road traffic noise or the school was highly sound insulated (measured against a protocol developed before the school visits) or schools had only a single form entry. Two schools were then selected in each noise exposure cell. Two classes were selected from primary school children aged 9-10 years old, both girls and boys, in each school. If there were more than two classes in the year then two were randomly selected. No children were excluded from the selected classes.

In the UK, from 118 primary schools in the West London area, 24 schools were included in the project. All but one of these 24 schools agreed to participate. A further six schools were invited to participate due to a shortfall of classes within particular cells of the selection grid. In the Netherlands out of 366 available schools in a radius of 25 km around the airport, 72 schools were selected for data collection and, after some initial reluctance from schools to be involved because of ‘research fatigue’, 33 schools agreed to participate. In Spain a total of 283 schools in the area around Madrid Airport, were initially selected and from these 24 schools were selected. The number of schools selected rose to 27 because of a shortfall of 5th form classes.

Noise measurement In the United Kingdom aircraft noise measurements were based on the 16hr outdoor LAeq contours provided by the Civil Aviation Authority. Road traffic noise was defined by a combination of proximity to motorways, A-roads, B-roads and traffic flow data. External traffic noise levels were confirmed by visits and noise measurements. In the Netherlands noise measurements were provided by modelled data on road and aircraft noise exposure linked to school locations using GIS. In Spain all 96 pre-selected schools were visited and direct measurements of aircraft and road traffic noise were undertaken. Acute measurements of noise exposure were also taken at the time of cognitive performance testing both internally in the classroom and externally to identify any unexpected sources of noise apart from aircraft or road traffic noise that might interfere in the testing situation and to assess acute aircraft and road traffic noise exposure.

Rather than use exactly the same noise thresholds to define the cells from which we chose the schools we decided to use different thresholds appropriate to the distribution of noise within each of the Countries. Nevertheless, there was considerable overlap between these different grids of noise exposure. The range of noise exposure was (UK, RTN 48->61, AN <50->63; Netherlands, RTN <41->61, AN <45->61; Spain RTN<50->63, AN <37->50 dB(A)). In analysis we have been able to pool the data from the three airport noise field studies and analyse the dose response relationships across the total sample.

Covariates and outcome measures

Cognitive tests After extensive consultation, the following battery of normed and standardised non-verbal cognitive tests to measure reading comprehension, memory and attention were developed. Reading comprehension was measured by nationally standardised and normed tests- in the UK, the Suffolk Reading Scale (Hagley, 2002), in the Netherlands the CLIB test developed by CITO and in Spain by the ECL-2. Episodic memory (recognition and recall) was measured by a task from the Child Memory Scale (Cohen, 1997) adapted for group administration. The task measured time delayed cued recall and delayed recognition of two stories presented on audio cassette after a 30 minute delay with an interference task. Answers were scored for correctly recalled specific pieces of information and for conceptual recall assessing children's general memory and understanding. Working memory was assessed by a modified version of a Swedish Search and memory task that involved memorising between a 1 and 7 target letter sequence which was searched for in rows of random letters. Sustained attention (Spiky squares symbol search) was measured by adapting the Toulouse Pieron Test. Prospective memory was assessed by instructing children to write their initials in the margin when they reached 2 or 3 pre-defined points in two of the tests. This was developed by Queen Mary with J. Dockrell from the Institute of Education, UK. The tests were piloted in two ways. First, pilot studies assessed the feasibility of these tests in the Netherlands and Spain and the UK. Secondly, the reliability, validity and psychometric properties of these tests against comparison tests were assessed separately. In addition, in the Netherlands, the NES computerised test battery was reassessed and selected tests chosen for the main study. Tests and instructions were translated from English into Dutch and Spanish and back translated to ensure accurate conceptual translation.

Children’s questionnaire This included perceived health activities at home and at school, possibilities for psychological restoration, sleep quality and coping capabilities, perceptions of noise and annoyance and noise interference with activities both in the school and home settings. Common questions were also used in the Swedish traffic noise study questionnaire for children.

Parent questionnaire This included the perceived health of their children involved in the study, children’s psychological health measured by the Strengths and Difficulties questionnaire, sociodemographic context variables, environmental attitudes and noise annoyance. Common questions were also used in the Swedish traffic noise study for children. A questionnaire for teachers was developed in Spain dealing largely with the effects of noise experienced at school that was used in both Spain and the UK.

Sociodemographic factors Data was collected on potential confounding factors including socioeconomic position (income, occupation, employment status, eligibility for free school meals), parental education, ethnicity and main language spoken at home, attempting to get comparable measures across countries.

Blood pressure Blood pressure was measured in the Netherlands and the UK, following a detailed protocol, using an automated OMRON (model OMRON711) meter with cuff size of 15-22cm or 22-32cm (van Kempen et al 2003). After an initial period of 5 minutes rest 3 consecutive blood pressure measurements were taken over a period of 15 minutes and averaged to produce one reading for each child. Height and weight were measured as potential adjustment factors.

After piloting minor alterations were made to the content of the cognitive tests and environment questionnaires mainly to do with the use of appropriate language and more user friendly formatting. The results of the cognitive tests were normally distributed with no floor or ceiling effects observed. Focus group discussions held with the children following the testing indicated that RANCH testing sessions were enjoyable, if slightly tiring.

Procedure Group testing was carried out under close supervision in the classroom at the schools during a two hour period in the morning largely in the second quarter of the year. Written consent was obtained from the children and passive consent from their parents. Tests were administered in a fixed order. Indoor and outdoor noise measurements were made at the schools under the supervision of local noise measurement specialists working to a standardised noise protocol. Children were given a questionnaire to take home for, preferably, their mother or other carer. Blood pressure measurements took place during the afternoon of the day on which children participated in the RANCH activities session.

Statistics The potential effects of confounding factors were dealt with through the study design (e.g. by exclusion or matching) and by statistical adjustment in analyses. Preliminary analyses of the pooled data from the UK, Netherlands and Spain were carried out using analysis of covariance with noise included as a continuous variable. All analyses were initially adjusted for centre (Netherlands, Spain or UK) and subsequently adjusted for mother's education (measured on a relative inequality index scored between 0-1, (Kunst, 1998)) and for employment status of the highest income holder in the family (measured as a dichotomous variable, employed or not employed).

Results In the UK 1182 children from 47 classes across 29 schools took part. The child response rate was 89%. The response rate for the parent/carer questionnaire was 78%. The participation rate for children and parent/carer across noise exposure bands did not vary to a significant degree. 653 children (55% of the participating sample) had their blood pressure, height and weight measured. In the Netherlands 824 children were invited from 33 schools and 730 participated and blood pressure was measured in 735 children, and 557 children additionally completed the NES. The response rate for the parent/carer questionnaire was 86%. In Spain 1028 children were invited and 920 children participated a response rate of 89.5%. The response rate for the parent/carer questionnaire was 62.8%; 151 teacher questionnaires were returned.

In preliminary analyses of pooled data from the UK, Netherlands and Spain, aircraft noise was associated with a significant impairment in reading comprehension in analysis of covariance adjusting for country, employment status and mother's education (Table) (Clark et al, 2003). This effect was not found for road traffic noise exposure. No effects of either aircraft noise or road traffic noise were found for sustained attention (Spiky squares symbol test). Long term memory was measured in terms of recognition and cued recall, of which the latter was evaluated in terms of information recall and conceptual recall. No effects were found for road traffic noise for recognition, conceptual recall or information recall (Lopez & Martin, 2003). Aircraft noise was, however, associated with a significant impairment in conceptual recall, information recall and recognition adjusting for country, mother's education and employment (Table 1). Aircraft noise was associated with a significant impairment in prospective memory in analysis of covariance adjusting for country, mother's education and employment status. Again, this effect was not found for road traffic noise. In addition, aircraft noise exposure was significantly associated with annoyance responses in children adjusting for mother's education and employment status (van Kamp et al, 2003).

Table 1 Cognitive outcomes and aircraft noise exposure: adjusted for centre, mother's education and employment status[1]

Cognitive Outcome	B	Confidence Interval	p
Reading comprehension			
Centre adjusted	-.166	-.238 to -.093	.0001
Centre, mother's education, employment adjusted	-.143	-.266 to -.060	.0001
Recognition (LTM)			
Centre adjusted	-.026	-.036 to -.015	.0001
Centre, mother's education, employment adjusted	-.022	-.034 to .-010	.0001
Cued recall conceptual (LTM)			
Centre adjusted	-.030	-.041 to -.018	.0001
Centre, mother's education, employment adjusted	-.027	-.041 to -.014	.0001
Prospective memory			
Centre adjusted	-.043	-.073 to -.013	.005
Centre, mother's education, employment adjusted	-.054	-.091 to -.017	.004
Noise annoyance			
Centre adjusted	.031	.027 to .035	.001
Centre, mother's education, employment adjusted	.032	.028 to .037	.001

1 B = change in outcome score associated with 1 dB change in noise

Analysis of psychological restoration suggests that children with high psychological restoration scores have low annoyance scores and opens up the possibility that psychological restoration may protect against annoyance (Gidlöf Gunnarsson et al, 2003). In the preliminary results from the Swedish traffic noise studies (Öhrström & Svensson, 2003) children seem to have better sleep than adults for some parameters but not for others with some indication of poorer sleep among adults in the highest noise areas. Children seemed to have less sleep impairment at higher noise levels and less annoyance than adults (Öhrström et al, 2003).

Discussion These preliminary analyses of pooled data suggest effects of aircraft noise on reading comprehension, conceptual recall, information recall and recognition in longterm memory and prospective memory. These effects were not found for road traffic noise exposure. No effects of either aircraft noise or road traffic noise were found for sustained attention. These are early analyses and require further work, including multilevel modelling before the existence of dose-response effects can be established. There was, however, a high response rate to the studies and the final results from the aircraft and road traffic field studies relying on data from three countries should be robust. An effect of aircraft noise on reading is consistent with previous studies (Evans et al, 1995; Evans & Maxwell, 1997; Haines et al 2001a,b) and the effects on memory show some consistency with the Munich studies (Evans et al, 1995; Hygge et al, 2002). Also sustained attention was not previously related to aircraft noise exposure (Haines et al, 2001b). Why should there be effects of aircraft but not road traffic noise? Aircraft noise, because of its intensity, the location of the source, and its unpredictability is likely to have a greater impact on children's cognition than road traffic noise that may be more

of a constant intensity. In particular, the noise of aircraft flyovers has an unpredictable rise time that may attract attention and distract children from learning tasks. Another possibility is that the levels of road traffic were not high enough to evoke a response. It was also difficult to measure road traffic noise accurately at schools because of masking by buildings and changes in traffic flow through the day. Analysis of the Swedish road traffic noise studies will help in further understanding the impact of road traffic noise at home on sleep and cognition.

The findings of lower annoyance in children with high levels of psychological restoration open up a new area of protective factors against the effects of noise. Restorative situations in places that create feelings of pleasantness and tranquillity are thought to trigger mental processes or states that contribute to restorative processes. This could be important in helping children cope with noise and in designing new ways of intervening against noise effects. The RANCH team has developed a health evaluation model for children based on current stress theory and children's health in specific environments. It is anticipated that this health evaluation model will form a framework for the theoretical evaluation of the effects of noise on children. Further analyses will clarify the effects of aircraft noise and road traffic noise on children's school performance and health and will provide evidence for policies on noise and health for children across Europe.

Keywords: noise, children, reading, memory attention, blood pressure, annoyance

Acknowledgements The RANCH Study was funded by the European Community (QLRT-2000-00197) in the Vth framework programme under Key Action 1999:/C 361/06 'Quality of life and management of living resources' In the UK co-funding was provided by the Department of Environment, Food and Rural Affairs.

References

Clark, C., Stansfeld, S.A., Haines, M.M., et al. (2003), ICBEN 2003. Rotterdam, The Netherlands.
Cohen, S., Evans, G. W., Krantz, D. S. & Stokols, D.(1980). *American Psychologist* **35,** 231-243.
Cohen, M.J. (1997). San Antonio: The Psychological Corporation Harcourt Brace and Company.
Evans, G. W., Hygge, S. & Bullinger, M. (1995) *Psychological Science* **6,** 333-338.
Evans, G. W., & Maxwell, L. (1997). *Environment and Behavior* **29**, 638-656.
Gidlöf Gunnarsson, A., Berglund, B., Haines, M., Nilsson, M.E., Stansfeld, S.A. (2003). ICBEN 2003, Rotterdam, The Netherlands.
Green, K. B., Pasternack, B. S. & Shore R. E. (1982). *Archives of Environmental Health* **37**, 24-31.
Hagley, F. (2002). Windsor: NFER-NELSON.
Haines, M. M., Stansfeld, S. A., Job, R. F. S., Berglund, B. & Head. J. (2001a). *Psychological Medicine* **31,** 265-277.
Haines, M. M., Stansfeld, S. A., Brentnall, S., Head, J., Berry, B., Jiggins, M. & Hygge S. (2001b). *Psychological Medicine* **31**, 1385-96.
Haines, M. M., Stansfeld, S. A., Head, J. & Job, R. F. S (2002). *Journal of Epidemiology Community Health* **561,** 139-144.
Hygge, S., Evans, G. W. & Bullinger, M. (2002). *Psychological Science* **13**, 469-74.
Kunst, A.E., Groenhof, F., Mackenbach, J.P. (1998). *BMJ* **316**, 1636-8.
Lopez, I., Martin, R., Jiminez, F. et al (2003). ICBEN 2003, Rotterdam, The Netherlands.
Öhrström, E., Svensson, H. (2003). ICBEN 2003, Rotterdam, The Netherlands.
Öhrström, E., Holmes, M., Svennson, H., Hadzibajramovic, E. (2003). ICBEN 2003, Rotterdam, The Netherlands.
Van Kamp, I., van Kempen, E., Stellato, R.K. et al (2003). ICBEN 2003, Rotterdam, The Netherlands.
Van Kempen, E., Van Kamp, I., Stellato et al. (2003). ICBEN 2003, Rotterdam, The Netherlands.