

## Effects of Aircraft Noise and Sleep Disturbance on Children.

This paper reviews national and international research on the effects of aircraft noise on children with a focus on sleep disturbance. Evidence for the following hypotheses was reviewed:

- Aircraft noise causes sleep disturbance in children
- Sleep disturbance leads to negative consequences for children exposed to aircraft noise.

This review was conducted in the light of evidence of general effects of noise on children which is described briefly below. The review will then outline evidence for effects of noise, and in particular, aircraft noise, on sleep and the possible consequences associated with such sleep disturbance. Recommendations for practice and future research are then highlighted.

### Effects of noise on children

Noise can be defined as any sound which produces an undesired effect or is unwanted (Bistrup, 2001). Children have been identified as a particularly vulnerable group to noise disturbance, having less well developed coping strategies and being in the process of developing both cognitively and physically (Stansfeld & Matheson, 2003). In a review of literature in this area, commissioned by a number of European countries, a number of possible effects of noise on children's health (including mental health and wellbeing) were identified (Bistrup, 2001). This included increased stress responses as indicated by higher blood pressure and increased hormone responses (Evans, Bullinger & Hygge, 1998), disruption of sleep and negative effects on learning, language development, memory (Hygge, 2003), concentration and motivation. It should be noted that the majority of research has only indicated an association between such effects and the presence of noise, rather than implying a definite causal relationship.

### Effects of Aircraft noise

A number of studies have demonstrated associations between aircraft noise and poorer performance on cognitive tasks, especially reading and memory. A large-scale study comparing children living around major airports in the UK with children who did not live near an airport, found that those living near airports performed more poorly on tests of reading comprehension (Haines et al, 2001). These effects appear to be greatest for more complex tasks (Stansfeld & Matheson, 2003). Aircraft noise was not associated with mental health outcomes of depression or anxiety (Haines et al, 2001) but was weakly associated with hyperactivity (Haines et al 2001a). These findings are consistent with a hypothesis that aircraft noise leads to increased levels of arousal which interferes with the performance of complex tasks and causes more hyperactive type behaviour. Another recent study measured cognitive effects on children living near three major European airports (including schools in the UK) and also found associations with poorer reading comprehension (Stansfeld et al, 2005).

Another commonly found effect of airport noise is impairment of memory (Stansfeld & Matheson, 2003; Hygge, 2003). This was found in the European study (Stansfeld et al, 2005); but not in the UK study (Haines et al, 2001). Neither study indicated effects

on attention. Children living near airports do, however, give higher ratings of annoyance by aircraft noise than those who do not live near an airport.

It should be noted that cross-sectional studies such as these cannot prove conclusively that airport noise is responsible for these effects. For example, in a comparison of SATs scores, Haines et al (2002) found that the lower scores of those children living near an airport could be explained by differences in socio-economic status as families living near airports tended to be less affluent than those who did not live near an airport.

In a study of children in Munich, children who lived near to the site of a new airport experienced a drop in reading and long-term memory scores following the opening of the airport, whereas children living near the site of the old airport experienced an increase in scores following its closure (Hygge, Evans and Bullinger, 2002). These findings lend weight to the hypothesis that aircraft noise is responsible for these cognitive effects although it should be noted that increases in aircraft noise were probably not the only changes experienced by these children and a range of other factors associated with the new airport, such as land development or increases in road traffic may also have had an effect.

As mentioned above, increased arousal due to noise has been hypothesised as a potential cause of these effects. Other possible explanations include overgeneralization of a strategy designed to 'tune-out' unwanted noise, increased teacher frustration, interruption of teacher-child interactions and teaching, as well as 'learned helplessness' whereby a child feels a lack of control of their environment leading to a general reduction in motivation. Rabinowitz (2005) also suggests that disturbance in sleep patterns caused by living near a flight path may also lead to impairment of learning.

Interestingly, Hygge (2003) found that the effects of aircraft noise on memory, and in particular, recall of text, was greater for aircraft noise than for other types of noise such as train noise or speech. As this study was carried out under artificial conditions (sounds were played to children, rather than experienced naturally in the environment), it is difficult to assess the cause of this difference, and in particular what the differential effects of long-term environmental exposure to these sources of noise may be. Road traffic noise was found to be similarly disruptive. Aircraft noise is characterised by high intensity, variability and unpredictability, which may lead to greater adverse effects (Stansfield et al, 2005). For example, in adults, intermittent noise has been found to be more disturbing to sleep than continuous noise (Carter, 1996).

#### Effects of Aircraft Noise on Sleep.

Sleep is an essential process, which allows recovery of both brain and body to take place. In addition, sleep is often related to perceptions of quality of life and wellbeing (Passchier-Verneer & Passchier, 2000). Disruption of sleep is therefore likely to have negative consequences on a child's health and functioning when awake. Evidence indicates that children may be more sensitive to noise exposure than adults, which may also be true during sleep (Bistrup, 2001).

Research has shown that noise of a sufficient intensity can cause changes in EEG measurements during sleep in laboratory studies, however associations between outdoor noise levels in natural settings and sleep disturbance are generally low (Stansfeld & Matheson, 2003). Evidence is mixed, however, it appears that habituation to outdoor noise may occur (Passchier-Verneer & Passchier, 2000; Bistrup, 2001; Stansfeld & Matheson, 2003). UK studies have recorded increased levels of sleep disturbance that are attributed to aircraft noise in people living near airports, but not an increase in the actual amount of sleep disturbance (Civil Aviation Authority, 1980). In contrast, it has been shown that levels of noise annoyance reported do not habituate over time. Changes in heart rate also do not reduce with repeated exposure to noise (Stansfeld & Matheson, 2003)

EEG effects occur most frequently during REM sleep, which occurs most frequently towards the end of the sleep cycle, and is necessary for processes such as consolidation of memory (Passchier-Verneer & Passchier, 2000). Therefore, it is possible that aircraft noise may have some consequences for cognitive processes such as memory, and that this disturbance will be greatest for noise in the early hours of the morning.

#### Consequences of disturbed sleep in children

Studies of sleep deprivation in children have been limited in comparison to those with adults, as noted in a review of the literature in this area (Sadeh, Gruber & Raviv, 2001). Adult literature attests to the adverse effects of sleep deprivation on daytime alertness and cognitive performance.

As many as 20-30% of children have sleep problems, as reported by parents or children themselves (Stores, 1999). Sleep disturbance in children has been associated with a multitude of factors including medical conditions and developmental disorders such as ADHD and Autism. Sadeh, Gruber and Raviv (2002) describe the effects of 'fragmented sleep' on children, a pattern of sleep disturbance characterised by frequent awakening during the night. This pattern appears to closely reflect that hypothesised to occur as a result of aircraft noise, although as noted above, evidence is mixed as to whether this pattern of awakening does in fact occur.

Links have been demonstrated between poor sleep and poor performance on complex cognitive tasks as well as increased behavioural problems as reported by parents (Sadeh et al, 2002). Specifically, poor sleepers showed increased difficulty in sustained attention and behavioural inhibition. This pattern of difficulty corresponds closely to the effects of airport proximity on cognitive performance found in the studies of UK and European airports discussed earlier (Haines et al, 2001, 2001a; Stansfeld et al, 2005). It should be noted that it is not possible to imply that the presence of poor sleep patterns necessarily caused these cognitive difficulties for the children studied. Other causes may include the presence of co-morbid conditions such as ADHD.

#### Children's perceptions of noise

Relatively few studies have gathered children's views on noise in the environment. As part of an international children's conference on environmental issues, Haines,

Brentnall & Stansfeld (2000) carried out qualitative data collection in the form of questionnaires and focus groups to assess children's perceptions of noise pollution. Overall, children rated traffic noise and noise from neighbours as the most perceived noise in their environment. 42% said they heard aircraft noise at home. Overall, children reported very low levels of annoyance regarding any noise, however, they stated that in comparison to noise from people, they felt less able to control noises related to traffic or planes. They were unable to suggest specific strategies for coping with these sources of noise, although some general strategies for coping with noise were identified (e.g. listen to music, think about something else). Children did not perceive noise pollution as something that would adversely affect their health.

When presented with information about research conducted around Heathrow airport (Haines et al 2001, 2001a), the children suggested that the children living close to the airport were likely to be affected in their cognitive performance (reading comprehension and memory) because they felt annoyed or irritated by the noise, which would affect their work, they might be distracted by the noise or visual sight of the plane, they would find it hard to hear their teacher and that teachers would be annoyed by the noise.

This study involved a self-selected sample of children and therefore cannot be assumed to be representative of all children. In particular, these children were not selected as having any particular experience of noise pollution. In fact the low levels of annoyance reported may indicate that these children were not generally exposed to high levels of noise pollution at home. The views expressed by children living near a source of noise such as an airport may be very different. In particular, it may be hypothesised that these children would display more annoyance regarding aircraft noise.

### Conclusions

From this review a number of conclusions can be drawn:

- Noise in general is related to a number of effects in children including stress, sleep disturbance and problems in learning and memory.
- Aircraft noise specifically has been related to a number of effects in children, most notably with decreases in reading ability and in memory. These studies have been cross-sectional and therefore cannot conclusively prove that aircraft noise causes these effects. For example, one confounding factor may be socio-economic status.
- Sleep disturbance has been hypothesised as one of several possible causes of these effects.
- It is likely that children exposed to aircraft noise for extended periods can habituate such that actual awakening does not occur, however, noise of sufficient intensity is likely to disturb the quality of sleep, as well as heart rate and blood pressure, and this occurs at times which are known to be important for the consolidation of memory. The nature of aircraft noise may lead to increased interference of this nature.
- Fragmented sleep is associated with cognitive deficits and behavioural difficulties in children.

It appears that living near an airport could be related to detrimental effects on children's cognitive functioning, as demonstrated by poorer reading and memory scores. What is not clear, however, is the cause of these difficulties. It is plausible that noise from aircraft has the potential to disturb the quality of children's sleep and it is therefore tempting to suggest that one cause of the cognitive effects associated with living near an airport and experiencing aircraft noise is sleep disturbance. However, it should be stressed that this conclusion is not fully addressed by the literature described above. In order to support such a hypothesis it will be necessary for researchers to investigate whether sleep disturbance could indeed act as a mediating factor for these effects. As a starting point, researchers would need to measure sleep disturbance and other possible mediating factors in addition to cognitive effects.

### Recommendations

Many children in the UK are affected by aircraft noise, both in their home and school environments. As such, the findings of this review suggest that the adults on whom these children rely to protect their wellbeing, including both parents and those involved in planning provision such as local authorities, need to consider how to best protect the education and wellbeing of these children to avoid some of the adverse effects described here.

This may involve considerations around the building and sound insulation of homes and schools near a flight path, but also ways in which the ability of families, schools and children to cope with the effects of aircraft noise can be promoted. Further research is needed to identify the causal mechanisms behind these affects, in order to allow effective interventions to be designed. It is clear that children's views should also be taken into account when planning to address these issues. In particular, it would be interesting to gather children's views on noise disturbance in their environment and any coping strategies they may have developed.

Lisa Henson BSc PGCE  
Trainee Educational Psychologist

### References

Bistrup, M.L. (2001) *Health Effects of Noise on Children*. National Institute of Public Health: Denmark.

Carter, N. (1996) Transportation noise, sleep and possible after-effects. *Environment International* 1:105-116

Civil Aviation Authority (1980) *Aircraft Noise and Sleep Disturbance: Final Report*. DORA Report 8008: London.

Evans, G. W., Bullinger, M., & Hygge, S. (1998). Chronic noise exposure and physiological response: a prospective study of children living under environmental stress. *Psychological Science* 9: 75–77.

Haines, M., Brentall, S & Stansfeld, S (2000) Noise and Children Workshop in Bistrup, M.L. (2001) *Health Effects of Noise on Children*. National Institute of Public Health: Denmark

Haines, M., Stansfeld, S., Job, R., Berglund, B. & Head, J (2001) Chronic aircraft noise exposure, stress responses, mental health and cognitive performance in school children. *Psychological Medicine* 31: 265-277.

Haines, M., Stansfeld, A., Brentall, S., Head, J., Berry, B., Jiggins, M & Hygge, S (2001a) The West London Schools Study: The effects of chronic aircraft noise exposure on child health. *Psychological Medicine* 31: 1385-1396.

Haines, M., Stansfeld, S., Head, J & Job, R (2002) Multilevel modelling of aircraft noise on performance tests in schools around Heathrow Airport London. *Journal of Epidemiology and Community Health* 56: 139-144.

Hygge, S (2003) Classroom Experiments on the Effects of Different Noise Sources and Sound Levels on Long-Term Recall and Recognition in Children. *Applied Cognitive Psychology* 17: 895-914

Hygge, S., Evans, G.W. & Bullinger, M. (2002) A prospective study of some effects of aircraft noise on cognitive performance in school children. *Psychological Science* 15(5): 469-474

Passchier-Verneer, W. & Passchier, W (2002) Noise Exposure and Public Health. *Environmental Health Perspectives* 108 (S1): 103-121

Rabinowitz, P (2005) Is noise bad for your health? *The Lancet* 365: 1908-1909

Sadeh, A., Gruber, R & Raviv, A (2002) Sleep, Neuro-Biological Functioning, and Behaviour in School-Age Children. *Child Development* 73(2): 405-417.

Stansfeld, S. & Matheson, P (2003) Noise Pollution: Non-Auditory Effects on Health. *British Medical Bulletin* 68: 243-257

Stansfeld, S., Berglund, B., Clark, C., Lopez-Bario, I., Fisher, P., Christrom, E., Haines, M., Head, J., Hygge, S., Kamp, I. & Berry, B, (2005) Aircraft and road traffic noise and children's cognition and health: a cross-national study. *The Lancet* 365: 1942-49

Stores, G (1999) Children's sleep disorders: modern approaches, developmental effects, and children at special risk. *Developmental Medicine and Child Neurology* 41: 568-573.