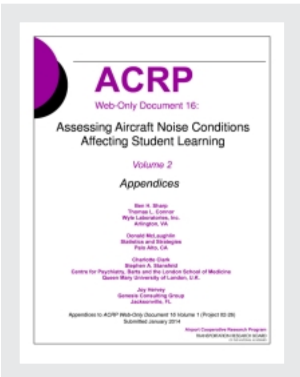

Assessing Aircraft Noise Conditions Affecting Student Learning, Volume 2: Appendices

DETAILS

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Citation	Abstract
Anderson, K. (2004). The problem of classroom acoustics: The typical classroom soundscape is a barrier to learning. **Semin. Hear.** 25, 117–129.	The typical classroom acoustic environment or soundscape often is a significant barrier to listening and learning for children with normal hearing and is a barrier especially to children with hearing impairments. How these barriers affect speech perception, attention, task persistence, and reading achievement are overviewed. In addition, acoustic environments are discussed in terms of acoustic access for children with hearing impairment and how acoustics can be viewed as an impediment to teaching.
Ando, Y., Y. Nakane, and J. Egawa. (1975) Effects of aircraft noise on the mental work of pupils. **Journal of sound and vibration**. (43) 683-691.	In order to examine the effects of aircraft noise on the mentality of growing children, a simple search task and an adding task were applied to 1144 elementary school pupils who live around an airport, and in a quiet area, under the conditions of no stimulus sound, and jet noise stimulus 90 ± 5 dB(A) respectively. The result was that children from relatively noisy living areas tended, when performing tasks, to show occasional short periods in which they produced substantially less than their own average rate of work. A similar difference did not appear when working in noise rather than quiet conditions, and it was considered to something chronic about the children themselves. These results were independent of the sex of the subjects and the feelings of the subjects to aircraft noise.
Astolfi, A. and F. Pellerey. (2008). Subjective and objective assessment of acoustical and overall environmental quality in secondary school classrooms. **J. Acoust. Soc. Am.** Vol. 123 No. 1, January 2008:163-173.	A subjective survey on perceived environmental quality has been carried out on fifty-one secondary-school classrooms, some of which have been acoustically renovated, and acoustical measurements were carried out in eight of the fifty-one classrooms, these eight being representative of the different types of classrooms that are the subject of the survey. A questionnaire, which included items on overall quality and its single aspects such as acoustical, thermal, indoor air and visual quality, has been administered to 1006 students. The students perceived that acoustical and visual quality had the most influence on their school performance and, with the same dissatisfaction for acoustical, thermal and indoor air quality, they attributed more relevance, in the overall quality judgment, to the acoustical condition. Acoustical quality was correlated to speech comprehension, which was correlated to the speech transmission index, even though the index does not reflect all the aspects by which speech comprehension can be influenced. Acoustical satisfaction was lower in non-renovated classrooms, and one of the most important consequences of poor acoustics was a decrease in concentration. The stronger correlation between average noise disturbance scores and LA max levels, more than LAeq and LA90, showed that students were more disturbed by intermittent than constant noise.
Babisch, W. (2005). Guest Editorial, Noise and Health. Environmental Health Perspectives Vol. 113, No. 1, January 2005: A14-A15.	Even ear-safe sound levels can cause non-auditory health effects if they chronically interfere with recreational activities such as sleep and relaxation, if they disturb communication and speech intelligibility, or if they interfere with mental tasks that require a high degree of attention and concentration (Evans and Lepore 1993). The signal–noise ratio (in terms of signal processing) should be at least 10 dB(A) to ensure undisturbed communication. High levels of classroom noise have been shown to affect cognitive performance (Bistrup et al. 2001). Reading and memory have been reported to be impaired in schoolchildren who were exposed to high levels of aircraft noise (Hygge et al. 2002). Some studies have shown higher stress hormone levels and higher mean blood pressure readings in children exposed to high levels of community noise (Babisch 2000; Passchier-Vermeer 2000).
Banbury, S., W. Macken, S. Tremblay S, and	Irrelevant sound tends to break through selective attention and impair cognitive performance. This

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D. Jones. (2001). Auditory distraction and short-term memory: phenomena and practical implications. **Human Factors** Vol. 43: 19–29.	observation has been brought under systematic scrutiny by laboratory studies measuring interference with memory performance during exposure to irrelevant sound. These studies established that the degree of interference depends on the properties of the irrelevant sound as well as those of the cognitive task. The way in which this interference increases or diminishes as characteristics of the sound and of the cognitive task are changed reveals key functional characteristics of auditory distraction. A number of important practical implications that arise from these studies are discussed, including the finding that relatively quiet background sound will have a marked effect on efficiency in performing cognitive tasks.
Berg, F., J. Blair, and P. Benson. (1996). Classroom acoustic: The problem, impact and solution. **Language, Speech, and Hearing in Schools**, Vol. 27:16-20.	Classroom acoustics are generally overlooked in American education. Noise, echoes, reverberation, and room modes typically interfere with the ability of listeners to understand speech. The effect of all of these acoustical parameters on teaching and learning in school needs to be researched more fully. Research has shown that these acoustical problems are commonplace in new as well as older schools, and when carried to an extreme, can greatly affect a child's ability to understand what is said (Barton, 1989; Blair, 1990; Crandell, 1991; Finitzo, 1988). The precise reason for overlooking these principles needs to be studied more fully. Recently, however, acoustic principles have been clarified, and technologies for measuring room acoustics and providing sound systems have become available to solve many of the acoustical problem in classrooms (Berg, 1993; Brook, 1991; D'Antonio, 1989; Davis & Davis, 1991; Davis & Jones, 1989; Eargle, 1989; Egan, 1988; Everest, 1987, 1989; Foreman, 1991; Hedeen, 1980). This article describes parameters of the problem, its impact on students and teachers, and four possible solutions to the problem. These solutions are noise control, signal control without amplification, individual amplification systems, and sound field amplification systems.
Bistafa, S. and J. S. Bradley. (2000) Reverberation time and maximum background-noise level for classrooms from a comparative study of speech intelligibility metrics**. J. Acoust. Soc. Am.**, Vol. 107, No. 2, February 2000.	Speech intelligibility metrics that take into account sound reflections in the room and the background noise have been compared, assuming diffuse sound field. Under this assumption, sound decays exponentially with a decay constant inversely proportional to reverberation time. Analytical formulas were obtained for each speech intelligibility metric providing a common basis for comparison. These formulas were applied to three sizes of rectangular classrooms. The sound source was the human voice without amplification, and background noise was taken into account by a noise-to-signal ratio. Correlations between the metrics and speech intelligibility are presented and applied to the classrooms under study. Relationships between some speech intelligibility metrics were also established. For each noise-to-signal ratio, the value of each speech intelligibility metric is maximized for a specific reverberation time. For quiet classrooms, the reverberation time that maximizes these speech intelligibility metrics is between 0.1 and 0.3 s. Speech intelligibility of 100% is possible with reverberation times up to 0.4–0.5 s and this is the recommended range. The study suggests ''ideal'' and ''acceptable'' maximum background-noise level for classrooms of 25 and 20 dB, respectively, below the voice level at 1 m in front of the talker.
Bistafa, S. and J. Bradley. (2001) Predicting speech metrics in a simulated classroom with varied sound absorption. **J Acoust Soc Am.** 2001 Apr;109(4):1474-82.	By systematically varying the amount of sound absorption, and the location of the sound-absorbing material in a simulated classroom, it was possible to assess the accuracy of the prediction of speech metrics in quite simple acoustical environments. Predictions of speech level, early-to-late sound ratios (C50) and speech transmission index (STI) values were obtained analytically and with two hybrid ray-based computer programs, RAYNOISE 3.0 and ODEON 4.1. The RAYNOISE predictions were accomplished with a purely specular reflection model and also with a calibrated diffuse reflection model. ODEON uses a parameter

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	called transition order, TO, to change the reflection procedure from purely specular to diffuse for reflections that have orders higher than TO. A parametric study was conducted to determine the best transition order for the ODEON prediction of speech metrics. It was found that the analytical predictions of speech level and C50 were on average accurate to about one just-noticeable difference (jnd), whereas the analytical predictions of STI were on average within 2 jnd's. ODEON predictions of speech level, C50 and STI were on average within 2 jnd's. RAYNOISE predictions of C50 and STI with the specular model were on average within 2 jnd's. However, the RAYNOISE predictions of speech level, with both types of reflection models, and the RAYNOISE predictions of C50 and STI with the diffuse model had average errors greater than 2 jnd's. The effects of the sound-absorption treatments on the measured speech metric values are also discussed.
Bistrup, M. L., S. Hygge, L. Keiding, and W. Passchier-Vermeer. (2001) *Health effects of noise on children and perception of the risk of noise*. National Institute of Public Health. Copenhagen, 2001.	This project focuses on the effects of noise on children and on perceptions of the risk of noise from a public health perspective. Children have been chosen as the focal point because children may be more vulnerable to noise than adults, because children have less control over their environments and daily situations than adults have and because legislation and policy have not traditionally focused on the special needs of children. Noise is any sound – independent of loudness – that may produce an undesired physiological or psychological effect in an individual and that may interfere with the social ends of an individual or group. Children's daily lives are full of noise, and children make noise themselves. It is as if children are being brought up in noise and learn to regard noise as a normal situation. But noise can adversely affect children. The most well-known and most serious consequences of noise are hearing damage and tinnitus. Noise can also provoke a stress response in children that includes increased heart rate and increased hormone response. Noise can disrupt sleep and thus hinder needed restoration of the body and brain. Noise can negatively affect children's learning and language development, can disturb children's motivation and concentration and can result in reduced memory and in reduced ability to carry out more or less complex tasks.
Boman, E., I. Enmarker, and S. Hygge. (2003). Strength of Noise Effects on Memory as a Function of Noise Source and Age. **Noise & Health** 2003. Vol. 7:11-26.	The objectives in this paper were to analyze noise effects on episodic and semantic memory performance in different age groups, and to see whether age interacted with noise in their effects on memory. Data were taken from threes separate previous experiments, that were performed with the same design, procedure and dependent measures with participants from four age groups (13-14, 18-20, 35-45, and 55-65). Participants were randomly assigned to one of three conditions: (a) meaningful irrelevant speech, (b) road traffic noise, and (c) quiet. The results showed effects of both noise sources on a majority of the dependent measures, both when taken alone and aggregated according to the nature of the material to be memorized. However, the noise effects of episodic memory tasks were stronger than for semantic memory tasks. Further, in the reading comprehension task, cued-recall and recognition were more impaired by meaningful irrelevant speech than by road traffic noise. Contrary to predictions, there was no interaction between noise and age group, indicating that the obtained noise effects were not related to the capacity to perform the task. The results from the three experiments taken together throw more light on the relative effects of road traffic noise and meaningful irrelevant speech on memory performance in different age groups.
Boman, E. and I. Enmarker. (2004). *Noise in the School Environment – Memory and*	The general objectives of this dissertation were to examine the effects of acute exposure to meaningful relevant speech and road traffic noise on memory performance, and to explore annoyance response to noise

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Annoyance. (Doctoral thesis, University of Galve, Sweden).	exposure in school environment for pupils and teachers in different age groups. 288 pupils and teachers participated in the age groups: 13-14 years, 18-20 years, 35-45 years, and 55-65 years. The subjects were randomly assigned to one of three conditions: (a) meaningful irrelevant speech, (b) road traffic noise, and (c) silence. The overall findings showed that both noise sources affected episodic and semantic memory to the same degree for all age groups. The results indicated that the similarity of semantic content between noise and the task at hand was not the only suitable explanation model, since a non-speech noise impaired memory as much as speech. Results also indicated that attention effects did not mediate the obtained noise effects and that the noise effects did not differ between age groups.
Boman, E. and I. Enmarker. (2004). Factors affecting pupils' noise annoyance in schools: The building and testing of models. **Environment and Behavior**, Vol. 36, No. 2:207-228.	This article reports two studies intended to develop and assess conceptual models of how different factors mediate and moderate the annoyance reaction in school environments. In the first, a survey of 207 pupils was conducted where assumptions about mediators and moderators were formulated and tested. In the best model, general sensitivity and adaptation led to a higher degree of annoyance causing stress symptoms. In the second study, focus group interviews with sixteen pupils were performed to set up a model of mediating and moderating factors from pupils' statements in the formation of annoyance. The objective was also to get their opinions about ways to improve the sound environment in school. The interviews indicated a serial arrangement in which stress symptoms and distraction mediated between chatter and disturbance. Thus, the two studies suggested different models for the prediction of the annoyance reaction. The pupils' views about how to improve the school sound environment are discussed in the framework of an empowerment model.
Boman, E. (2004). The effects of noise and gender on pupils' episodic and semantic memory. **Scandinavian Journal of Psychology**, Vol. 45 issue 5: 407-416.	The main objectives in the present study were to examine meaningful irrelevant speech and road traffic noise effects on episodic and semantic memory, and to evaluate whether gender differences in memory performance interact with noise. A total of ninety-six subjects, aged 13–14 years (n= 16 boys and 16 girls in each of three groups), were randomly assigned to a silent or two noise conditions. Noise effects found were restricted to impairments from meaningful irrelevant speech on recognition and cued-recall of a text in episodic memory and of word comprehension in semantic memory. The obtained noise effect suggests that the meaning of the speech were processed semantically by the pupils, which reduced their ability to comprehend a text that also involved processing of meaning. Meaningful irrelevant speech was also assumed to cause a poorer access to the knowledge base in semantic memory. Girls outperformed boys in episodic and semantic memory materials, but these differences did not interact with noise.
Bradley, J. (1986a). Predictors of speech intelligibility in rooms. **J. Acoust. Soc. Am.** 80, 837–845.	Three different types of acoustical measures were compared as predictors of speech intelligibility in rooms of varied size and acoustical conditions. These included signal-to-noise measures, the speech transmission index derived from modulation transfer functions, and useful/detrimental sound ratios obtained from early/late sound ratios, speech, and background levels. The most successful forms of each type of measure were of similar prediction accuracy, but the useful/detrimental ratios based on a 0.08-s early time interval were most accurate. Several physical measures, although based on very different calculation procedures, were quite strongly related to each other.
Bradley, J. (1986b). Speech intelligibility studies in classrooms. **J. Acoust. Soc. Am.** Vol. 80, No. 3:846–854.	Speech intelligibility tests and acoustical measurements were made in ten occupied classrooms. Octave-band measurements of background-noise levels, early decay times, and reverberation times, as well as various early/late sound ratios, and the center time were obtained. Various octave-band useful/detrimental

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	ratios were calculated along with the speech transmission index. The interrelationships of these measures were considered to evaluate which were most appropriate in classrooms, and the best predictors of speech intelligibility scores were identified. From these results ideal design goals for acoustical conditions for classrooms were determined either in terms of the 50-ms useful/detrimental ratios or from combinations of the reverberation time and background noise level.
Bradley, J. and H. Sato. (2004). Speech intelligibility results for grade 1, 3 and 6 children in real classrooms. *Proceedings of the 18th International Congress on Acoustics*, Kyoto, Japan, 2004, paper ID: Tu4.B1.2, pp. II-1191–1194.	The WIPI (Word Intelligibility by Picture Identification) test was used in classrooms to assess the word recognition performance of 1st, 3rd and 6th Grade schoolchildren for varied speech-to-noise ratios (S/N). The effects of age from the classroom tests were compared with baseline data obtained using young adults in simulated sound fields. The young adults completed the WIPI test, a Rhyme test, and a Listening Difficulty test in the simulated sound fields to make it possible to compare the results of these three test procedures and to act as baseline data for comparison with the classroom results of the children. There were highly significant effects of age and S/N. The results will help to more accurately define the needs of young listeners in actual classroom conditions.
Bradley, J. and H. Sato. (2008). The intelligibility of speech in elementary school classrooms. **Acoust. Soc. Am.** Volume 123, Issue 4, pp. 2078-2086 (April 2008)	This is the second of two papers describing the results of acoustical measurements and speech intelligibility tests in elementary school classrooms. The intelligibility tests were performed in 41 classrooms in 12 different schools evenly divided among Grades 1, 3, and 6 students (nominally 6, 8, and 11 year olds). Speech intelligibility tests were carried out on classes of students seated at their own desks in their regular classrooms. Mean intelligibility scores were significantly related to signal-to-noise ratios and to the grade of the students. While the results are different than those from some previous laboratory studies that included less realistic conditions, they agree with previous in-classroom experiments. The results indicate that +15 dB signal-to-noise ratio is not adequate for the youngest children. By combining the speech intelligibility test results with measurements of speech and noise levels during actual teaching situations, estimates of the fraction of students experiencing near ideal acoustical conditions were made. The results are used as a basis for estimating ideal acoustical criteria for elementary school classrooms.
Bronzaft, A. and D. P. McCarthy. (1975). The effect of elevated train noise on reading ability. **Environ. Behav.** 7, 517–528.	This study investigated the hypothesis that low reading achievement may be related to noise interference. Reading scores of children in classrooms near train tracks were lower than scores of children whose classrooms were quieter. Score differences may be due to children's blockage of all sounds in a noisy environment.
Bronzaft, A. (1981). The Effect of a Noise Abatement Program on Reading Ability. **Journal of Environmental Psychology** (1981), Vol. 1: 215-222.	A school was selected for the testing of the effects of resilient rubber pads as noise control devices on a nearby elevated rail track. In addition three school classrooms received acoustical treatment to the ceilings. Teachers and students reported a quieter atmosphere after the installation of the pads. Reading scores in the year prior to installation were lower on the noisy side of the building, but after installation of the rubber pads and the noise-absorbing ceiling there were no differences in reading achievement between children on the noisy side and those on the quiet side. Possible explanations of these findings and implications for social policy decisions are discussed.
Bronzaft, A. A Quieter School: An Enriched Learning Environment. Found at http://www.quietclassrooms.org/ library/library.htm on 8/11/2010.	It is common knowledge to anyone administering a school that lunchrooms, gymnasia, and schoolyards are noisy and, in some cases, actions have been taken to lower the decibel levels in these facilities. However, are administrators aware of the noises to which children are exposed within their classrooms - from the hallways, nearby classes, heating and ventilation systems, adjacent highways, overhead jets, holes cut in

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	walls for electrical wiring or sprinklers, appliances, or over crowdedness? Even if aware, have they done enough to quiet these classrooms? The aim of this article is to alert school administrators to the effects of noise on children's cognition, reading skills, and learning ability and to suggest ways they can participate in the growing worldwide effort to lessen the din - not only in the school but in children's homes and wherever else children our exposed to noises. Noises are not only hazardous to our children's mental abilities but to their overall well-being as well.
Bronzaft, A. (1997). Beware: Noise Is Hazardous to Our Children's Development. **Hearing Rehabilitation Quarterly** - Volume 22, Number 1 (1997). Found at http://www.chchearing.org/noise-center-home/noise-archives/noise-hazardous-our-children%E2%80%99s-development].	In the Time magazine's special report on "How a Child's Brain Develops" (February 3, 1997), one of the articles, "The Day-Care Dilemma" (Collins, February 3, 1997) began simply with the following statement: "Environment matters." Collins goes on to say that what the baby "sees, hears and touches..." is critical to development. It is equally true that what the child doesn't hear is also important, but how often do we think about or discuss the impact of those unnecessary intrusive sounds on the child's development (other than effects of noise on hearing), or for that matter the crucial role quiet and solitude play in the child's maturation process? The non-auditory effects of noise on a child's overall development, the focus of this paper, has received too little attention.
Bronzaft, A. (2000). Noise: Combating a ubiquitous and hazardous pollutant. Noise & Health 2000; 2:1-8.	With a growing body of data suggesting a link between noise and adverse mental and physical health and with noise pollution becoming even more pervasive, especially from the rapid increase in air travel and highway traffic, individuals worldwide are forging alliances to combat this hazardous pollutant. Especially active are the anti-aircraft noise groups. In the United States, the Federal government has limited its responsibilities with respect to noise control after an initial interest in the 1970s when legislation was passed promising to protect the American people against the harmful effects of noise. These past years anti-noise activists in the United States have been working arduously to urge the Federal government to once again take an active role in abating and controlling noise. They have also been enlisting more citizens to their cause as they educate them to the hazards of noise.
Bronzaft, A. (2003). United States aviation transportation policies ignore the hazards of airport-related noise. World Transport Policy & Practice, Volume 9, Number 1, (2003) 37–40.	By relying on methods that underestimate the numbers of people affected by airport-related noises and dismissing the growing evidence that aviation noise is harmful to health, quality of life and children's development, United States aviation transportation policies largely ignore the impacts of airport-related noises on residents. Anti-aviation noise community groups continue to demand the refunding of the Office of Noise Abatement and Control which once had the responsibility of protecting citizens from the dangers of noise.
Christie, D. J. and C. Glickman. (1980). The effects of classroom noise on children: evidence for sex differences. **Psychology in Schools**, Vol. 17, 405-408.	To clarify the relationship between classroom noise and children's intellectual performance, 156 first-, third-, and fifth-grade children worked on a matrix task in either a noisy environment (70dbA) or in a quiet environment (40dbA). Children's performance on the intellectual task increased with age. Moreover, in the environment with classroom noise, boys consistently solved more complex matrix problems than did girls.
Clark, Charlotte, R. Martin, E. van Kempen, T. Alfred1, J. Head, H. W. Davies, M. M. Haines, I. Lopez Barrio, M. Matheson and S. A. Stansfeld. (2006). Exposure-Effect Relations between Aircraft and Road Traffic Noise Exposure at School and Reading	Transport noise is an increasingly prominent feature of the urban environment, making noise pollution an important environmental public health issue. This paper reports on the 2001–2003 RANCH project, the first cross-national epidemiologic study known to examine exposure-effect relations between aircraft and road traffic noise exposure and reading comprehension. Participants were 2,010 children aged 9–10 years from eighty-nine schools around Amsterdam Schiphol, Madrid Barajas, and London Heathrow airports. Data from the Netherlands, Spain, and the United Kingdom were pooled and analyzed using multi-level

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Comprehension. **American Journal of Epidemiology** Volume 163, Number 1 Pp. 27-37.	modeling. Aircraft noise exposure at school was linearly associated with impaired reading comprehension; the association was maintained after adjustment for socio-economic variables (ß = –0.008, p = 0.012), aircraft noise annoyance, and other cognitive abilities (episodic memory, working memory, and sustained attention). Aircraft noise exposure at home was highly correlated with aircraft noise exposure at school and demonstrated a similar linear association with impaired reading comprehension. Road traffic noise exposure at school was not associated with reading comprehension in either the absence or the presence of aircraft noise (ß = 0.003, p = 0.509; ß = 0.002, p = 0.540, respectively). Findings were consistent across the three countries, which varied with respect to a range of socio-economic and environmental variables, thus offering robust evidence of a direct exposure-effect relation between aircraft noise and reading comprehension.
Clark, C and Sa A. Stansfeld. (2007). The Effect of Transportation Noise on Health and Cognitive Development: A Review of Recent Evidence. **International Journal of Comparative Psychology**, 2007, Vol. 20, 145-158.	Noise from transport is an increasingly prominent feature of the urban environment. While the auditory effects of noise on humans are established, non-auditory effects - the effects of noise exposure on human health, well-being and cognitive development - are less well established. This narrative review evaluates recent studies of aircraft and road traffic noise that have advanced or synthesized knowledge about several aspects of adult and child health and cognition. Studies have demonstrated a moderate effect of transport noise on hypertension, cardiovascular disease and catecholamine secretion: there is also evidence for an effect on psychological symptoms but not for the onset of more serious clinically defined psychiatric disorder. One way noise may affect health is through annoyance: noise causes annoyance responses in both children and adults and annoyance may cause stress responses and subsequent illness. Another possible mechanism is sleep disturbance: transport noise has been found to disturb sleep in laboratory and field studies, although there is evidence for adaptation to noise exposure. For children effects of aircraft and road traffic noise have been observed for impaired reading comprehension and memory skills: there is equivocal evidence for an association with blood pressure. To date most health effects have been very little researched and studies have yet to examine in detail how noise exposure interacts with other environmental stressors. In conclusion, noise is a main cause of environmental annoyance and it negatively affects the quality of life of a large proportion of the population. In addition, health and cognitive effects, although modest, may be of importance given the number of people increasingly exposed to environmental noise and the chronic nature of exposure.
Clark, C., S. Stansfeld, and J. Head. (2009). The long-term effects of aircraft noise exposure on children's cognition: findings from the UK RANCH follow-up study. EURONOISE 2009, October 26-28, 2009.	Exposure to transport noise is an increasing and prominent feature of the urban environment. The RANCH project (Road Traffic Noise and Aircraft Noise Exposure and Children's Cognition and Health), the largest study of noise and children's cognition undertaken to date, examined the effects of aircraft noise and road traffic noise exposure at primary school on the cognitive performance of 2844 9-10-year-old children attending 89 schools around Heathrow (London), Schiphol (Amsterdam), and Barajas (Madrid) airports. The study found linear exposure-effect relationships between aircraft noise exposure at school and children's reading comprehension and recognition memory. While previous studies had demonstrated effects of chronic aircraft noise exposure on primary school children's reading comprehension and long-term memory, comparing children with high noise exposure with those with low noise exposure, the RANCH study was the first to examine the shape of exposure-effect relations and to compare the effect of noise exposure on children's cognition across countries. The

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	development of cognitive abilities such as reading is important not only in terms of educational achievement but also for subsequent life chances and adult health. To understand the causal pathways between noise exposure and cognition, and design preventive interventions, there is a need to study these associations longitudinally. Few longitudinal studies have examined the effects of persistent exposure throughout the child's education: a study over only a one-year period found that deficits in reading comprehension persisted and that children did not adapt to their noise exposure. Studies of noise abatement suggest that a reduction of noise exposure eliminates previously observed reading deficits but studies of the long-term consequences of noise exposure during primary school for later cognitive development have not been conducted. This research followed-up the UK sample of the RANCH cohort to examine the long-term effects of aircraft noise exposure at primary school on children's reading comprehension. The following hypotheses were examined: • Do children who attend aircraft noise exposed primary schools experience impaired reading comprehension during secondary school, compared with peers who were not exposed to aircraft noise at primary school? • Does secondary school aircraft noise exposure influence later reading comprehension, over and above the effect of aircraft noise exposure at primary school on later reading comprehension?
Cohen, S., G. Evans, and D. Stokol. (1980). Physiological, motivational, and cognitive effects of aircraft noise on children. **American Psychologist**, 35, 231-243.	A combination of laboratory and filed methodologies is suggested as a strategy to increase the influence of psychological research in the formation of public policy. A naturalistic study of the effects of aircraft noise on elementary school children is presented as evidence for the effects of community noise on behavior and as an example of a study that examines the generality of laboratory effects in a naturalistic setting. The study is concerned with the impact of noise on attentional strategies, feelings of personal control, and physiological processes related to health. In general, the results are consistent with laboratory work on physiological response to noise and on uncontrollable noise as a factor of helplessness. Thus children from noisy schools have higher blood pressure than those from matched control (quiet) schools. Noise school children are also more likely to give up before the time to complete the task has elapsed. The development of attentional strategies predicted from laboratory and previous filed research was, on the whole, not found. The implications of the study both for understanding of the relationship between noise and behavior and for the influencing of public policy are discussed.
Cohen, S., G. Evans, D. Krantz, D. Stokols, and S. Kelly. (1981). Aircraft noise and children: Longitudinal and cross-sectional evidence on adaptation to noise and the effectiveness of noise abatement. J. Pers Soc. Psychol. Vol.40, No. 2:331–345.	Longitudinal and cross-sectional data on effects of aircraft noise on elementary school children are presented as evidence for the effects of community noise on behavior. To examine the generality of previous laboratory findings in a naturalistic setting, the study assesses the impact of noise on attentional strategies, learned helplessness, performance of cognitive tasks, and blood pressure. Children were tested on the same measures twice, with a 1-year interval between sessions. A previous article reported cross-sectional findings from the first testing session. In the present article, longitudinal data are used to determine whether the children adapt to aircraft noise over the 1-year period and to assess the effectiveness of noise abatement intervention introduced in a number of noise-impacted classrooms. Additional cross-sectional data from the original testing session are also presented to provide further information on the utility of noise abatement. In general, there was little evidence for adaption to noise over the 1-year period.

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	Noise abatement had small ameliorative effects on congnitive performance, children's ability to hear their teachers, and school achievement. The implications of the study for understanding the relationship between noise and behavior and resulting policy implications are discussed.
Crook, M. and F. Langdon. (1974). The Effects of Aircraft Noise In Schools around London Airport. **Journal of Sound and Vibration** (1974) Vol. 34, No. 2:221-232.	The effects of aircraft noise on teaching and classroom activity were studied in a number of schools close to Heathrow Airport, both by direct observation and by a small sample survey of teachers' opinions. The principal changes in observed behavior result from interference with speech and this finding corresponds with the survey of teachers' opinions. The study was unable to identify any other consistent or systematic changes in class activities directly related to aircraft noise. Teachers speaking to whole classes pause more frequently with increasing peak levels over a wide range of flyover levels. Since they pause during at least one flyover in four of those which peak at or above 70 dB(A) one may assume such flyovers cause appreciable discomfort. When talking to individuals or small groups teaching is less vulnerable to interference and is not seriously affected during flyovers which peak above 75 dB(A). Above this level there is a rapid increase in pausing and in the masking of teacher's speech when addressing the+ whole class. The nuisance caused by flyovers peaking above 70 dB(A) depends on the nature of the activities and the level of background noise in the classrooms which was observed to vary between 55 and 70 dB(A).
de Oliveira Nunes, M. F. & Sattler, M. A. (2006) Aircraft noise perception and annoyance at schools near Salgado Filho International Airport, **Brazil Journal of Building Acoustics** 13, 159:172.	This article presents results of an evaluation of aircraft noise perception and annoyance in schools located in the vicinity of Salgado Filho International Airport, in the city of Porto Alegre, RS, Brazil. This research is based on indoor and outdoor acoustic measurements, in addition to questionnaires in three schools. The results indicate problems in school performance, resulting from frequent interruption of classroom communication associated with high noise levels. The research also indicates that children aged between 11 and 13 years form the most vulnerable group.
Dockrell, J. and B. Shield. (2004). Children's perceptions of their acoustic environment at school and at home. **J. Acoust. Soc. Am.**, Vol. 115, No. 6, June 2004	This paper describes the results of a large-scale questionnaire survey that ascertained children's perceptions of their noise environment and the relationships of the children's perceptions to objective measures of noise. Precision, specificity, and consistency of responding was established through the use of convergent measures. Two thousand and thirty-six children completed a questionnaire designed to tap (a) their ability to discriminate different classroom listening conditions; (b) the noise sources heard at home and at school; and (c) their annoyance by these noise sources. Teachers completed a questionnaire about the classroom noise sources. Children were able to discriminate between situations with varying amounts and types of noise. A hierarchy of annoying sound sources for the children was established. External LAmax levels were a significant factor in reported annoyance, whereas external LA90 and LA99 levels were a significant factor in determining whether or not children hear sound sources. Objective noise measures (LA90 and LA99) accounted for 45% of the variance in children's reporting of sounds in their school environment. The current study demonstrates that children can be sensitive judges of their noise environments and that the impact of different aspects of noise needs to be considered. Future work will need to specify the factors underlying the developmental changes and the physical and location dimensions that determine the school effects.
Dockrell, J. and B. Shield. (2006). Acoustical Barriers in Classrooms: The Impact of Noise on Performance in the Classroom. **British**	There is general concern about the levels of noise that children are exposed to in classroom situations. The article reports the results of a study that explores the effects of typical classroom noise on the performance of primary school children on a series of literacy and speed tasks. One hundred and fifty-eight children in

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Educational Research Journal, v32 n3 p509-525.	six Year 3 classes participated in the study. Classes were randomly assigned to one of three noise conditions. Two noise conditions were chosen to reflect levels of exposure experienced in urban classrooms: noise by children alone, that is classroom-"babble", and "babble" plus environmental noise, "babble and environmental". Performance in these conditions were compared with performance under typical quiet classroom conditions or "base". All analyses controlled for ability. A differential negative effect of noise source on type of task was observed. Children in the "babble and environmental" noise condition performed significantly worse than those in the "base" and "babble" conditions on speed of processing tasks. In contrast, performance on the verbal tasks was significantly worse only in the "babble" condition. Children with special educational needs were differentially negatively affected in the "babble" condition. The processes underlying these effects are considered and the implications of the results for children's attainments and classroom noise levels are explored.
DNWG [Department of Defense Noise Working Group]. (2009). *Improving Aviation Noise Planning, Analysis and Public Communication with Supplemental Metrics: Guide to Using Supplemental Metrics*. Found at https://www.denix. osd.mil/portal/page/portal/DNWG/Documents.	The intent of this guidelines document is to guide the Military Services in providing more useful information on the noise environment than is available through solely using the long-term, cumulative metrics such as DNL. (All references to DNL throughout this Guidelines document also apply to CNEL when applied to noise analysis for facilities located in California). Supplemental analysis with additional metrics is not intended to replace the DNL metric as the primary descriptor of cumulative noise exposure in an Environmental Assessment (EA) or Environmental Impact Statement (EIS) performed under the National Environmental Policy Act (NEPA). Furthermore, this guideline document is not intended to replace the minimum federal land use/noise compatibility guidelines that are produced during the Navy, Marine Corps, and Air Force Air Installation Compatible Use Zones (AICUZ) studies, Army Installation Operational Noise Management Plan (IONMP) studies, and Joint Land Use Studies (JLUS). Further research is needed to determine if there a causal relationship between metrics other than DNL and long-term community effects such as annoyance.
Emmen, H.,B. Staatsen, P. Fischer, and I. Kamp, IV. (2001). Neurobehavioral Measurements in Children Living Around Schiphol Airport; Further Methodological Considerations. *Proceedings of the International Congress and Exhibition on Noise Control Engineering*. Vol. 2001.	Within the framework of the Health Impact Assessment Schiphol Airport, a feasibility study was conducted in primary school children (1,2). The purpose of the study was to examine the feasibility of using computerized performance tests and questionnaires to examine the behavioral effects of exposure to aircraft noise in children. The study involved 159 children aged 8-12 years, 86 attending school in Zwanenburg, a town located 8 kilometres from the airport and seventy-three children attending school in Uitgeest, a town located approximately 23 kilometres from the airport. Methods used to assess behavioral functioning included selected tests from the Neurobehavioral Evaluation System designed to assess attention, psycho-motor performance, perceptual coding, learning and memory as well as two behavioral questionnaires. Subjective ratings of sleep quality and annoyance were also examined. Children were tested twice during school hours in the period May-June 1995 with a 4-6 week interval between testing. The results of this study indicated a high level of acceptance of computerized testing procedures by the children, teachers and parents and a high level of test-retest reliability for most tests and rating scales. In conclusion, the results of this study demonstrate the feasibility of applying computerized behavioral testing methods in a school setting. Based on these results, it is recommended that future research designed to examine the effects of aircraft noise using these methods employ study designs involving the testing of at least 500 children from locations with known exposure levels. Further, these locations should be chosen to maximize the contrast in

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	environmental noise exposure and estimates of individual aircraft exposure for each child should be obtained. In the design of a new study around Schiphol (RANCH), the recommendations of the pilot study are accounted for. Hereby a combination of sensitive computerized tests and paper-and-pencil tests will be used.
Evans, G. and R. Stecker. (2004). Motivational consequences of environmental stress. **Journal of Environmental Psychology** 24 (2004) 143–165.	Exposure to uncontrollable stimuli produces deficits in task performance linked to learned helplessness. It is not widely appreciated, however, that many of these stimuli are environmental stressors. Both acute and chronic exposure to noise, crowding, traffic congestion, and pollution are capable of causing learned helplessness in adults and children. Pre-exposure to brief, acute environmental stressors that are uncontrollable produces learned helplessness wherein participants manifest difficulties in learning a new task because of their mistaken belief that they are incapable of influencing their environment. Another index of learned helplessness, less persistence in the face of challenge also follows acute exposure to uncontrollable environmental stressors. Finally depressed affect may co-occur with learned helplessness under certain circumstances. Field studies of chronic environmental stressors reveal parallel trends. Chronic environmental stressors also heighten vulnerability to the induction of learned helplessness by acute, uncontrollable stimuli. The potential pathway linking chronic environmental stressor exposure to helplessness and then, in turn, to mental health is an important area for future research. Furthermore, the generalizability of environmental stressor-induced motivational deficits, as well as their longevity, particularly among children, remains to be investigated.
Evans, G. (2006) Child Development and the Physical Environment. **Annual Review of Psychology**. 2006. 57:423–51.	Characteristics of the physical environment that influence child development are discussed. Topics include behavioral toxicology, noise, crowding, housing and neighborhood quality, natural settings, schools, and day care settings. Socioemotional, cognitive, motivation, and psychophysiological outcomes in children and youths are reviewed. Necessary methodological and conceptual advances are introduced as well.
Evans, G. and S. Lepore. (1993). Non-auditory Effects of Noise on Children: A Critical Review. *Children's Environments* 10(1): 42-72. Retrieved from http://www.colorado.edu/journals/cye/.	Large numbers of children both in the United States and throughout the economically developing world are chronically exposed to high levels of ambient noise. Although a great deal is known about chronic noise exposures and hearing damage, much less is known about the non-auditory effects of chronic ambient noise exposure on children. To estimate the risk of ambient noise exposure to healthy human development, more information about and attention to non-auditory effects such as psychophysiological functioning, motivation, and cognitive processes is needed. This article critically reviews existing research on the non-auditory effects of noise on children; develops several preliminary models of how noise may adversely affect children; and advocates an ecological perspective for a future research agenda.
Evans, G., S. Hygge and M. Bullinger. (1995). Chronic Noise and Psychological Stress. **Psychological Science**. Vol. 6 No. 6, Nov. 1995.	This article illustrates the value of incorporating psychological principles into the environmental sciences. Psychophysiological, cognitive, motivational, and affective indices of stress were monitored among elementary school children chronically exposed to aircraft noise. The study demonstrates for the first time that chronic noise exposure is associated with elevated neuroendocrine and cardiovascular measures, muted cardiovascular reactivity to a task presented under acute noise; deficits in a standardized reading test administered under quiet conditions, poorer long-term memory, and diminished quality of life on a standardized index. Children in high-noise areas also showed evidence of poor persistence on challenging tasks and habituation to auditory distraction on a signal-to-noise task. They reported considerable annoyance with community noise levels, as measured utilizing a calibration procedure that adjusts

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	individual difference in rating criteria for annoyance judgments.
Evans, G. and L. Maxwell. (1997). Chronic noise exposure and reading deficits: the mediating effects of language acquisition. **Environ. Behav.** 29, 638–656.	First- and second-grade schoolchildren chronically exposed to aircraft noise have significant deficits in reading as indexed by a standardized reading test administered under quiet conditions. These findings indicate that the harmful effects of noise are related to chronic exposure rather than interference effects during the testing session itself. We also provide evidence that the adverse correlation of chronic noise with reading is partially attributable to deficits in language acquisition. Children chronically exposed to noise also suffer from impaired speech perception, which, in turn, partially mediates the noise-exposure-reading deficit link. All of these findings statistically controlled for mother's education. Furthermore, the children in this study were prescreened for normal hearing by a standard audiometric examination.
Evans, G., M. Bullinger, and S. Hygge. (1998). Chronic Noise Exposure and Physiological Response: A Prospective Study of Children Living Under Environmental Stress. **Psychological Science**. Vol. 9 No. 1, Jan. 1998.	Chronic exposure to aircraft noise elevated psychophysiological stress (resting blood pressure and overnight epinephrine and norepinephrine) and depressed quality-of-life indicators over a 2-year period among 9- to 10-year-old children. Data collected before and after the inauguration of a major new international airport in noise-impacted and comparison communities show that noise significantly elevates stress among children at ambient levels far below those necessary to produce hearing damage.
Evans G., P. Lercher, M. Meis, H. Ising, W. Kofler. (2001). Community noise exposure and stress in children. **J Acoust Soc Am.** 2001.Vol. 109(3):1023-7.	Although accumulating evidence over the past two decades points towards noise as an ambient stressor for children, all of the data emanate from studies in high-intensity, noise impact zones around airports or major roads. Extremely little is known about the non-auditory consequences of typical, day-to-day noise exposure among young children. The present study examined multimethodological indices of stress among children living under 50 dB or above 60 dB (A-weighted, day-night average sound levels) in small towns and villages in Austria. The major noise sources were local road and rail traffic. The two samples were comparable in parental education, housing characteristics, family size, marital status, and body mass index, and index of body fat. All of the children were prescreened for normal hearing acuity. Children in the noisier areas had elevated resting systolic blood pressure and 8-h, overnight urinary cortisol. The children from noisier neighborhoods also evidenced elevated heart rate reactivity to a discrete stressor (reading test) in the laboratory and rated themselves higher in perceived stress symptoms on a standardized index. Furthermore girls, but not boys, evidenced diminished motivation in a standardized behavioral protocol. All data except for the overnight urinary neuroendocrine indices were collected in the laboratory. The results are discussed in the context of prior airport noise and non-auditory health studies. More behavioral and health research is needed on children with typical, day-to-day noise exposure.
FICAN. (2000). FICAN Position on Research into Effects of Aircraft Noise on Classroom Learning.	Research on the effects of aircraft noise on children's learning suggests that aircraft noise can interfere with learning in the following areas: reading, motivation, language and speech acquisition, and memory. The strongest findings to date are in the area of reading, where more than twenty studies have shown that children in noise impact zones are negatively affected by aircraft. Recent research confirms conclusions from studies in the 1970s showing a decrement of reading when outdoor noise levels are at Leq of 65 dB or higher. It is also possible that, for a given level of Leq, the effects of aircraft noise on classroom learning may be greater than the effects of road and railroad traffic. Members of FICAN are in agreement on the following: (1) Further work should be done to establish whether school day Leq is the appropriate measure for determining the effect of aircraft noise on classroom learning. (2) In the absence of appropriations for

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	specific research, FICAN encourages "before" and "after" evaluations of the effectiveness of noise mitigation in schools. (3) FICAN will undertake a pilot study to evaluate the effectiveness of school sound insulation programs. (4) FICAN supports the work of the American National Standards Institute in its efforts to develop a standard for classroom noise.
FICAN. (2007). Findings of the FICAN Pilot Study on the Relationship between Aircraft Noise Reduction and Changes in Standardized Test Scores. Found at http://www.fican.org/pages/ findings.html.	Research on the effects of aircraft noise on children's learning suggests that aircraft noise can interfere with learning in the following areas: reading, motivation, language and speech acquisition, and memory. The strongest findings to date are in the area of reading, where more than twenty studies have shown that children in noise impact zones are negatively affected by aircraft. In September 2000, FICAN undertook a pilot study to evaluate the effectiveness of school sound insulation programs. This finding reports on the results of that study. The study was designed to answer the following: Is abrupt aircraft noise reduction within classrooms related to mandatory, standardized test score improvement, after controlling for demographics? Does this relationship vary by age group, by student group, and/or by test type? The study included thirty-five public schools nearby three airports in the U.S. Abrupt noise reduction at these schools was caused by either airport closure or newly implemented sound insulation. In the analysis, the noise-reduction group (each school, before-to-after the summer of noise reduction) was compared to the control group (same school, but for years prior to noise reduction). Analysis consisted of multi-level regression with "change in test scores" regressed against a range of variables such as "change in cumulative noise exposure".
Green, K.B., B. Pasternak, and R. Shore. (1982). Effects of aircraft noise on reading ability of school age children. **Archives of Environmental Health**, 37, 24-31.	The percent of students reading below grade level from 1972 to 1976 was regressed on racial, socio-economic, educational, and noise level variables for all elementary schools in Brooklyn and Queens, New York. Schools were assigned noise exposure scores based on Noise Exposure Forecast contours for New York City airports. The correlations between these noise scores and a variety of noise level metrics ranged from 0.74 to 0.97. The regression coefficients adjusted for confounding factors, indicated that an additional 3.6% of the students in the noisiest schools read at least 1 yr below grade level with 95% confidence limits from 1.5 to 5.8%. The dose-response relationship indicated that the percent reading below grade level increased as noise level increased.
Green, Rochelle, S. Smorodinsky,J. Kim, R. McLaughlin, and B. Ostro1. (2004). Proximity of California Public Schools to Busy Roads. **Environmental Health Perspectives**. Volume 112, No. 1, January 2004.	Residential proximity to busy roads has been associated with adverse health outcomes, and school location may also be an important determinant of children's exposure to traffic-related pollutants. The goal of this study was to examine the characteristics of public schools (Grades K–12) in California (n = 7,460) by proximity to major roads. We determined maximum daily traffic counts for all roads within 150 m of the school using a statewide road network and a geographic information system. Statewide, 173 schools (2.3%) with a total enrollment of 150,323 students were located within 150 m of high-traffic roads (≥ 50,000 vehicles/day); 536 schools (7.2%) were within 150 m of medium-traffic roads (25,000–49,999 vehicles/day). Traffic exposure was related to race/ethnicity. For example, the overall percentage of non-white students was 78% at the schools located near high-traffic roads versus 60% at the schools with very low exposure (no streets with counted traffic data within 150 m). As the traffic exposure of schools increased, the percentage of both non-Hispanic black and Hispanic students attending the schools increased substantially. Traffic exposure was also related to school-based and census-tract–based socio-economic indicators, including English language learners. The median percentage of children enrolled in free or

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	reduced price meal programs increased from 40.7% in the group with very low exposure to 60.5% in the highest exposure group. In summary, a substantial number of children in California attend schools close to major roads with very high traffic counts, and a disproportionate number of those students are economically disadvantaged and non-white.
Haines, M, S. Stansfeld, R. Job, B. Berglund, and J. Head. (2001a). Chronic aircraft noise exposure, stress responses, mental health and cognitive performance in school children. **Psychological Medicine**, 2001, Vol. 31: 265-277.	Previous research suggests that children are a high-risk group vulnerable to the effects of chronic noise exposure. However, questions remain about the nature of the noise effects and the underlying causal mechanisms. This study addresses the effects of aircraft noise exposure on children around London Heathrow airport, in terms of stress responses, mental health and cognitive performance. The research also focuses on the underlying causal mechanisms contributing to the cognitive effects and potential confounding factors. The cognitive performance and health of 340 children aged 8-11 years attending four schools in high aircraft noise areas (16 h outdoor Leq>66 dBA) was compared with children attending four matched control schools exposed to lower levels of aircraft noise (16 h outdoor Leq<57 dBA). Mental health and cognitive tests were group administered to the children in the schools. Salivary cortisol was measured in a subsample of children. Chronic aircraft noise exposure was associated with higher levels of noise annoyance and poorer reading comprehension measured by standardized scales with adjustments for age, deprivation and main language spoken. Chronic aircraft noise was not associated with mental health problems and raised cortisol secretion. The association between aircraft noise exposure and reading comprehension could not be accounted for by the mediating role of annoyance, confounding by social class, deprivation, main language or acute noise exposure. These results suggest that chronic aircraft noise exposure is associated with impaired reading comprehension and high levels of noise annoyance but not mental health problems in children.
Haines, M, S. Stansfeld, S. Brentnall, J. Head, B. Berry, M. Jiggins, and S. Hygge. (2001b). The West London Schools Study: the effects of chronic aircraft noise exposure on child health. **Psychological Medicine**, 2001, Vol. 31: 1385-1396.	Background. Previous field studies have indicated that children's cognitive performance is impaired by chronic aircraft noise exposure. However, these studies have not been of sufficient size to account adequately for the role of confounding factors. The objective of this study was to test whether cognitive impairments and stress responses (catecholamines, cortisol and perceived stress) are attributable to aircraft noise exposure after adjustment for school and individual level confounding factors and to examine whether children exposed to high levels of social disadvantage are at greater risk of noise effects. Methods. The cognitive performance and health of 451 children aged 8-11 years, attending 10 schools in high aircraft noise areas (16 h outdoor Leq>63 dBA) was compared with children attending 10 matched control schools exposed to lower levels of aircraft noise (16 h outdoor Leq<57 dBA). Results. Noise exposure was associated with impaired reading on difficult items and raised annoyance, after adjustment for age, main language spoken and household deprivation. There was no variation in the size of the noise effects in vulnerable subgroups of children. High levels of noise exposure were not associated with impairments in mean reading score, memory and attention or stress responses. Aircraft noise was weakly associated with hyperactivity and psychological morbidity. Conclusions. Chronic noise exposure is associated with raised noise annoyance in children. The cognitive results indicate that chronic aircraft noise exposure does not always lead to generalized cognitive effects but, rather, more selective cognitive impairments on difficult cognitive tests in children.
Haines, M., S. Stansfeld, R. Job, B. Berglund,	Children are a high-risk group vulnerable to the effects of chronic aircraft noise exposure. This study

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and J. Head. (2001c). A follow-up study of effects of chronic aircraft noise exposure on child stress responses and cognition. **International Journal of Epidemiology** 2001. Vol. 30: 839-845.	examines the effects of aircraft noise exposure on children health and cognition around London Heathrow airport and tests sustained attention as an underlying mechanism of effects of noise on reading and examines the way children adapt to continued exposure to aircraft noise. In this repeated measures epidemiological filed study, the cognitive performance and health of 275 children aged 8-11 years attending four schools in high noise areas (16-h outdoor Leq>66 dBA) was compared with children attending four matched control schools exposures to lower levels of aircraft noise 916-h outdoor Leq<57 dBA). The children first examined at baseline were examined again after a period of one year at follow up. Health questionnaires and cognitive tests were group administered to the children in the schools. At follow up chronic aircraft noise exposure was associated with higher levels of annoyance and perceived stress, poorer reading comprehension and sustained attention, measured by standardized scales after adjustment for age, social deprivation and main language spoken. These results do not support the sustained attention hypothesis previously used to account for the effects of noise on cognition in children. The reading and annoyance effects do not habituate over a one-year period and do not provide strong evidence of adaptation.
Haines, M., S. Stansfeld, J. Head and R. F. S. Job. (2002). Multilevel modeling of aircraft noise on performance tests in schools around Heathrow Airport London. **Journal of Epidemiology and Community Health** 2002; Vol. 56:139–144.	To examine the effects of chronic exposure to aircraft noise on children's school performance taking into account social class and school characteristics. This is a cross-sectional study using the National Standardized Scores (SATs) in mathematics, science, and English (11,000 scores from children aged 11 years). The analyses used multi-level modeling to determine the effects of chronic aircraft noise exposure on children's school performance adjusting for demographic, socio-economic and school factors in 123 primary schools around Heathrow Airport. Schools were assigned aircraft noise exposure level from the 1994 Civil Aviation Authority aircraft noise contour maps. The sample were approximately 11,000 children in year 6 (approximately 11 years old) from 123 schools in the three boroughs surrounding Heathrow Airport. Chronic exposure to aircraft noise was significantly related to poorer reading and mathematics performance. After adjustment for the average socio-economic status of the school intake (measured by percentage of pupils eligible for free school meals) these associations were no longer statistically significant. Chronic exposure to aircraft noise is associated with school performance in reading and mathematics in a dose-response function but this association is confounded by socio-economic factors.
Haines, M., S. L. Brentnall, S. A. Stansfeld, and E. Klineberg. (2003). Quantitative Responses of Children to Environmental Noise. **Noise & Health** 2003. Vol. 5:19-30.	Results from recent quantitative research consistently demonstrate that children are a high-risk group, vulnerable to the adverse effects of noise exposure, especially effects on cognitive performance, motivation, and annoyance. The aims of two qualitative studies reported in this paper are to explore children's a) perception of noise exposure; b) perceived risk of and attitudes towards noise pollution; c) coping strategies; and d) the annoyance response. The Millennium Conference Study involved focus group interviews with an international sample (n=36) unselected by exposure. The West London Schools Study involved individual interviews, conducted with purposively selected sample (n=18) exposed to aircraft noise. The children in the focus groups reported being affected by neighbors' noise and road traffic noise, whereas children exposed to aircraft noise were most affected by aircraft noise. As expected, the impact of noise pollution on everyday activities (e.g. schoolwork, homework and playing) was larger for the children exposed to high levels of aircraft noise compared with the low noise exposed children and focus group samples. The range of coping strategies that children employed to combat noise exposure in their lives was dependent upon the amount of control they had over the noise source. The emotional response of children

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	describing the annoyance reaction to noise was consistent with adult reactions and it would seem that child noise annoyance is the same construct. Future research should employ qualitative methods to supplement quantitative investigations.
Hiramatsu K., T. Tokuyama, T. Matsui, T. Miyakita, Y. Osada, T. Yamamoto. (2004). The Okinawa Study: effect of chronic aircraft noise exposure on memory of school children. *Proc. Noise Public Health Probl. Int. Congr.*, 8th, pp. 179–180. Schiadam, The Netherlands.	Impact of chronic aircraft noise exposure on school-aged children's memory was investigated around two military airfields in Okinawa, Japan.
Hodgson M, E. Nosal. (2002). Effect of noise and occupancy on optimal reverberation times for speech intelligibility in classrooms. **J Acoust Soc Am.** 2002. Vol. 111(2):931-9.	The question of what is the optimal reverberation time for speech intelligibility in an occupied classroom has been studied recently in two different ways, with contradictory results. Experiments have been performed under various conditions of speech-signal to background-noise level difference and reverberation time, finding an optimal reverberation time of zero. Theoretical predictions of appropriate speech intelligibility metrics, based on diffuse-field theory, found nonzero optimal reverberation times. These two contradictory results are explained by the different ways in which the two methods account for background noise, both of which are unrealistic. To obtain more realistic and accurate predictions, noise sources inside the classroom are considered. A more realistic treatment of noise is incorporated into diffuse-field theory by considering both speech and noise sources and the effects of reverberation on their steady-state levels. The model shows that the optimal reverberation time is zero when the speech source is closer to the listener than the noise source, and nonzero when the noise source is closer than the speech source. Diffuse-field theory is used to determine optimal reverberation times in unoccupied classrooms given optimal values for the occupied classroom. Resulting times can be as high as several seconds in large classrooms; in some cases, optimal values are unachievable, because the occupants contribute too much absorption.
Houtgast, T. (1981) The effect of ambient noise on speech intelligibility in classrooms. **Appl. Acoust.** 14, 15–25 (1981).	Intelligibility tests were performed by teachers and pupils in classrooms under a variety of (road traffic) noise conditions. The intelligibility scores are found to deteriorate at (indoor) noise levels exceeding a critical value of — 15 dB with regard to a teacher's long-term (reverberant) speech level. The implications for external noise levels are discussed: typically, an external noise level of 50 dB(A) would imply that the critical indoor level is exceeded for about 20 per cent of teachers.
Hygge, S. and I. Knez. (2001). Effects of Noise, heat, and Indoor Lighting on Cognitive Performance and Self-Reported Effect. **Journal of Environmental Psychology** (2001) 21, 291-299.	Theoretical and practical concerns guided the design of an experiment on how ventilation noise (38 and 58 dBA), air temperature (21 and 278C), and illuminance (300 and 1500 lx) combine or interact in their effects on cognitive performance. Self-reports of affective states were taken with an affect circumplex measure (Larsen & Diener, 1992; Knez & Hygge, in press) to study the mediation from the environmental variables over affect to cognitive performance. Arousal models (e.g., Broadbent, 1971) would predict that increased levels of noise and illuminance increase activation and/or affect levels and that mild heat decreases it. The inverted-U-hypothesis would further predict that intermediate levels of perceived arousal improve attention, memory and problem solving performance. A distinction was made between synergetic and antagonistic interactions in order to differentiate arousal and non-arousal mediated effects on cognitive performance. The results showed that attention worked faster in noise but at the cost of lesser accuracy, which supports the Speed-Accuracy-Trade-Off hypothesis (Hockey, 1984). Interactions were found between noise and heat

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	on the long-term recall of a text, and between noise and light on the free-recall of emotionally toned words. These effects on cognitive performance could not be explained as mediated by the affective states, and were not consistent with an arousal model and the inverted-U hypothesis.
Hygge, S., G. Evans, and M. Bullinger. (2002) A prospective Study of Some Effects of Aircraft on cognitive Performance in Schoolchildren. **Psychological Science**. Vol. 13, No. 2: 469-474.	Before the opening of the new Munich International Airport and the termination of the old airport, children near both sites were recruited into aircraft noise groups (aircraft noise at present or pending) and control groups with no aircraft noise (closely matched for socio-economic status). A total of 326 children (mean age= 10.4 years). Took part in three data-collection waves, one before and two after the switch-over of the airports. After the switch, long-term memory and reading were impaired in the noise group at the new airport, and improved in the formerly noise-exposed group at the old airport. Short-term memory also improved in the latter group after the old airport was closed. At the new airport, speech perception was impaired in the newly noise-exposed group. Mediational analyses suggest that poorer reading was not mediated by speech perception, and that impaired recall was in part mediated by reading.
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 (2003)	A total of 1358 children aged 12–14 years participated in ten noise experiments in their ordinary classrooms and were tested for recall and recognition of a text exactly one week later. Single and combined noise sources were presented for 15 min at 66 dBA Leq (equivalent noise level). Single-source presentations of aircraft and road traffic noise were also presented at 55 dBA Leq. Data were analyzed between subjects since the first within-subjects analysis revealed a noise after-effect or a asymmetric transfer effect. Overall, there was a strong noise effect on recall, and a smaller, but significant effect on recognition. In the single-source studies, aircraft and road traffic noise impaired recall at both noise levels. Train noise and verbal noise did not affect recognition or recall. Some of the pair wise combinations of aircraft noise with train or road traffic, with one or the other as the dominant source, interfered with recall and recognition. Item difficulty, item position and ability did not interact with the noise effect. Arousal, distraction, perceived effort, and perceived difficulty in reading and learning did not mediate the effects on recall and recognition.
Hygge, S., E. Boman, and I. Enmarker. (2003). The effects of road traffic noise and meaningful irrelevant speech on different memory systems. **Scandinavian Journal of Psychology**, Vol. 44:13-21.	To explore why noise has reliable effects on delayed recall in a certain text-reading task, this episodic memory task was employed with other memory tests in a study of road traffic noise and meaningful but irrelevant speech. Context-dependent memory was tested and self-reports of affect were taken. Participants were ninety-six high school students. The results showed that both road traffic noise and meaningful irrelevant speech impaired recall of the text. Retrieval in noise from semantic memory was also impaired. Attention was impaired by both noise sources, but attention did not mediate the noise effects on episodic memory. Recognition was not affected by noise. Context-dependent memory was not shown. The lack of mediation by attention, and road traffic noise being as harmful as meaningful irrelevant speech, are discussed in relation to where in the input/storing/output sequence noise has its effect and what the distinctive feature of the disturbing noise is.
Jamieson, D., G. Kranjc, K. Yu, W. Hodgetts. (2004). Speech intelligibility of young school-aged children in the presence of real-life classroom noise. **J Am Acad Audiol.** 2004 Jul-Aug;15(7):508-17.	We examined the ability of forty young children (aged five to eight) to understand speech (monosyllables, spondees, trochees, and trisyllables) when listening in a background of real-life classroom noise. All children had some difficulty understanding speech when the noise was at levels found in many classrooms (i.e., 65 dBA). However, at an intermediate (-6 dB SNR) level, kindergarten and grade 1 children had much more difficulty than did older children. All children performed well in quiet, with results being comparable to or slightly better than those reported in previous studies, suggesting that the task was age appropriate and

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	well understood. These results suggest that the youngest children in the school system, whose classrooms also tend to be among the noisiest, are the most susceptible to the effects of noise.
Jones, K. (2010). Aircraft Noise and Children's Learning. Environmental Research and Consultancy Department, UK CAA, ERCD Report 0908. Feb. 2010.	This report is a literature review of the research into the effects of aircraft noise on children's learning and cognition. The primary cognitive processes that are examined in relation to aircraft noise are episodic memory, semantic memory, sustained attention and reading comprehension. The review includes early work in this area from the 1970s, to the most recent studies. Key studies are described, along with suggestions for future research.
Kaltenbach, M., C. Maschke, R. Klinke. (2008). Health Consequences of Aircraft Noise. **Deutsches Ärzteblatt International**; 105(31–32): 548–56.	Introduction: The ever-increasing level of air traffic means that any medical evaluation of its effects must be based on recent data. Methods: Selective literature review of epidemiological studies from 2000 to 2007 regarding the illnesses, annoyance, and learning disorders resulting from aircraft noise. Results: In residential areas, outdoor aircraft noise-induced equivalent noise levels of 60 dB(A) in the daytime and 45 dB(A) at night are associated with an increased incidence of hypertension. There is a dose-response relationship between aircraft noise and the occurrence of arterial hypertension. The prescription frequency of blood pressure lowering medications is associated dose-dependently with aircraft noise from a level of about 45 dB(A). Around 25% of the population are greatly annoyed by exposure to noise of 55 dB(A) during the daytime. Exposure to 50 dB(A) in the daytime (outside) is associated with relevant learning difficulties in schoolchildren. Discussion: Based on recent epidemiological studies, outdoor noise limits of 60 dB(A) in the daytime and 50 dB(A) at night can be recommended on grounds of health protection. Hence, maximum values of 55 dB(A) for the day and 45 dB(A) for the night should be aimed for in order to protect the more sensitive segments of the population such as children, the elderly, and the chronically ill. These values are 5 to10 dB(A) lower than those specified by the German federal law on aircraft noise and in the report "synopsis" commissioned by the company that runs Frankfurt airport (Fraport).
Kawada, T. (2004). The Effect of Noise on the Health of Children. **Journal of Nippon Medical School** 2004; 71 (1).	The effects of noise on health especially that of children were reviewed. (1) From the point of view of disturbance of daily living, subjective recognition of "noisiness" is an important issue in relation to the study of noise. Concerning the effects of airplane noise on school children, while no effects on the hearing level were detected, a significant increase in the complaint of "noisiness" was observed. (2) Exposure of pregnant women to airplane noise was found to be associated with a decrease in the body weight of newborn babies. Moreover, the height of 3-year-old boys and girls was found to be significantly decreased in association with increase in the environmental noise. (3) Noise levels that seemed to have some influence on the sleep of adults did not affect the sleep of children. (4) In a group of children living in noisy districts exhibiting poor academic performance, the academic performance seemed to become progressively worse as the school grade advanced. (5) No consensus has been arrived at in regard to headphone-induced hearing impairment. Researches and studies effective enough to influence policy decisions must be continually conducted in the future, with appropriate control for related factors.
van Kempen, E., I. Van Kamp, .P Fischer, H. Davies, D. Houthuijs, R. Stellato, C. Clark, S.	Background: Conclusions that can be drawn from earlier studies on noise and children's blood pressure are limited due to inconsistent results, methodological problems, and the focus on school noise exposure.

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Stansfeld. (2006). Noise exposure and children's blood pressure and heart rate: the RANCH project. **Occupational and Environmental Medicine** 2006; Vol. 63:632–639.	Objectives: To investigate the effects of aircraft and road traffic noise exposure on children's blood pressure and heart rate. Methods: Participants were 1283 children (age 9–11 years) attending 62 primary schools around two European airports. Data were pooled and analyzed using multi-level modeling. Adjustments were made for a range of socio-economic and lifestyle factors. Results: After pooling the data, aircraft noise exposure at school was related to a statistically non-significant increase in blood pressure and heart rate. Aircraft noise exposure at home was related to a statistically significant increase in blood pressure. Aircraft noise exposure during the night at home was positively and significantly associated with blood pressure. The findings differed between the Dutch and British samples. Negative associations were found between road traffic noise exposure and blood pressure, which cannot be explained. Conclusion: On the basis of this study and previous scientific literature, no unequivocal conclusions can be drawn about the relationship between community noise and children's blood pressure.
van Kempen, E. (2008). *Transportation noise exposure and children's health and cognition*. (Doctoral thesis, University of Utrecht, The Netherlands).	This thesis focuses on the effects of transportation noise exposure on children [cognition, annoyance, perceived health and blood pressure]. Children's exposure may differ from adults' exposure to noise, since children spend their time in different settings to adults and because they behave differently. Furthermore, children are suspected of being more susceptible to noise exposure for different reasons: (i) their organs are not fully developed; (ii) children are not always aware of the dangers; and (iii) children have not (fully) developed coping mechanisms and cannot change their situation, where as adults may have the power and/or resources to do so. In addition, results from observational studies have shown that many adult diseases may originate in childhood. Understanding the way the environment affects children's health and development could therefore be important for the prevention of adult illness.
van Kempen, E., I. van Kamp, E. Lebret, J. Lammers, H. Emmen and S. Stansfeld. (2010). Neurobehavioral effects of transportation noise in primary schoolchildren: a cross-sectional study. Environmental Health 2010, Vol. 9:25.	Background: Due to shortcomings in the design, no source-specific exposure-effect relations are as yet available describing the effects of noise on children's cognitive performance. This paper reports on a study investigating the effects of aircraft and road traffic noise exposure on the cognitive performance of primary schoolchildren in both the home and the school setting. Methods: Participants were 553 children (age 9-11 years) attending 24 primary schools around Schiphol Amsterdam Airport. Cognitive performance was measured by the Neurobehavioral Evaluation System (NES), and a set of paper and- pencil tests. Multi-level regression analyses were applied to estimate the association between noise exposure and cognitive performance, accounting for demographic and school related confounders. Results: Effects of school noise exposure were observed in the more difficult parts of the Switching Attention Test (SAT): children attending schools with higher road or aircraft noise levels made significantly more errors. The correlational pattern and factor structure of the data indicate that the coherence between the neurobehavioral tests and paper-and-pencil tests is high. Conclusions: Based on this study and previous scientific literature it can be concluded that performance on simple tasks is less susceptible to the effects of noise than performance on more complex tasks.
Klatte, M., M. Wegner and J. Hellbruk. (2005). Noise in the School Environment and cognitive performance in Elementary School Children,	International studies indicate that noise exposure in schools and kindergartens are often above reasonable limits for children, caregivers, and teachers. Learning in loud, reverberating rooms is especially impeded by poor speech intelligibility. Children are highly impaired by such disturbances than adults. However,

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Part B – Cognitive Psychological Studies. *Proceedings of ForumAcusticum 2005*, 2071-2074.	research in this field has concentrated on laboratory studies researching the effects of acute noise cognitive performance. The long-term effects caused by the hearing environment on children's cognitive development will be investigated in a field study. Testing will be conducted in elementary schools varying in noise exposure. According to current knowledge, language functions are more sensitive to negative effects of noise. Therefore, a test battery was constructed which comprises speech perception as well as reading and writing and the underlying phonological processing functions. In addition to the group texts in classrooms, a sample of poor readers and controls will be tested alone. It is assumed that in the noise-exposed group, reading deficits will often co-occur with deficits in central auditory processing. At the time of the conference, data collection will have just finisher. The design and procedure will be presented and discussed.
Klatte, M., M. Meis, H. Sukowski, and A. Schick. (2007). Effects of irrelevant speech and traffic noise on speech perception and cognitive performance in elementary school children. **Noise & Health** July-September 2007, Vol. 9: 64-74.	The effects of background noise of moderate intensity on short-term storage and processing of verbal information were analyzed in 6- to 8-year-old children. In line with adult studies on "irrelevant sound effect" (ISE), serial recall of visually presented digits was severely disrupted by background speech that the children did not understand. Train noises of equal intensity however, had no effect. Similar results were demonstrated with tasks requiring storage and processing of heard information. Memory for non-words, execution of oral instructions and categorizing speech sounds were significantly disrupted by irrelevant speech. The affected functions play a fundamental role in the acquisition of spoken and written language. Implications concerning current models of the ISE and the acoustic conditions in schools and kindergartens are discussed.
Knecht H., P. Nelson, G. Whitelaw, L. Feth. (2002). Background noise levels and reverberation times in unoccupied classrooms: predictions and measurements. **Am J Audiol.** 2002 Dec;11(2):65-71.	Classrooms are often filled with deterrents that hamper a child's ability to listen and learn. It is evident that the acoustical environment in classrooms can be one such deterrent. Excessive background noise and reverberation can affect the achievement and educational performance of children with sensorineural hearing loss (SNHL) and children with normal hearing sensitivity who have other auditory learning difficulties, as well as elementary school children with no verbal or hearing disabilities. The purpose of this study was to evaluate the extent of the problem of noise and reverberation in schools. To that end, we measured reverberation times and background-noise levels in 32 different unoccupied elementary classrooms in eight public school buildings in central Ohio. The results were compared with the limits recommended in the American National Standards Institute standard for acoustical characteristics of classrooms in the United States (ANSI S12.60-2002). These measurements were also compared to the external and internal criteria variables developed by Crandell, Smaldino, & Flexer (1995) to determine if a simple checklist can accurately predict unwanted classroom background-noise levels and reverberation. Results indicated that most classrooms were not in compliance with ANSI noise and reverberation standards. Further, our results suggested that a checklist was not a good predictor of the noisier and more reverberant rooms.
Ko, N.W.M. (1979). Responses of Teachers to Aircraft Noise. **Journal of Sound and Vibration** 62: 277-292.	Acoustic measurements of aircraft noise in 139 schools in Hong Kong have been carried out. The schools are located under and very near the flight paths of aircraft coming in and leaving the international airport, Kai Tak. Coupled with the acoustic measurements, measurements of the subjective responses to this aircraft noise of 2100 Chinese teachers in these schools have been made. It is found that the subjective responses of the teachers correlate well with the Noise and Number Index. Besides the effect of annoyance, it is further

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	found that the more serious effect of aircraft noise is the disruption of verbal communication, resulting in speech and teaching interference during lessons.
Kyzar, B.L. (1977). Noise Pollution and Schools: How Much Is Too Much? **CEFP Journal** 4: 10-11.	Undesirable noise is one of the products of an advanced technology and population density. Air and land transportation constitute a major source of this form of pollution. Government units, in applying the "Public Good" doctrine to determine priorities in locating traffic arteries, can create intolerable problems. Schools are occasionally the victims. But how much is too much? At what point and to what degree dose loud noise interrupt or hamper the process of education. This article attempts to answer these questions by presenting data relative to a school affected by the placement of a traffic artery. The reader must decide if the cost of progress meets the test of reason. School was approximately 10 years old when a new bridge necessitated a traffic approach. The route selected bordered school property for approximately 4 hundred feet, with the outside northbound lane coming within 20 feet of the building. Air conditioning permitted closing of the building and newly planted shrubbery served as a shield; nevertheless, noise permeated the building. The effect was disturbing but its precise impact was undetermined. An investigation was undertaken to: 1. Decibel levels of noise in classroom on the street and off-street sides of the building. 2. The effects of traffic noises on patterns of verbal communication and on time used for instruction. 3. The effects of noise on the instructional program as perceived by the principal and teachers; and 4. The impact of noise pollution on the ability of students to maintain periods of sustained attention to detail.
Lercher, P., G. Brauchle, W. Kofler, U. Widmann, and M. Meis. (2000). The assessment of noise annoyance in schoolchildren and their mothers. *InterNoise 2000, the 29th International Congress and Exhibition on Noise Control Engineering*, 27–30 August, 2000, Nice.	Children and young persons differ substantially in their environmental needs and behavior (development, learning, playing). Nevertheless, the assessment of the effects on this population segment of a noisy environment is based on results from adult surveys. Currently, no dose-response curve is available for noise annoyance of children. Only recently (Bullinger 1995, Evans et al 1995, Evans et al 1998) a standardized methodology was developed to survey schoolchildren about their perception of the environment. In June 1998 we surveyed one thousand 2 hundred and eighty children in Grades 3 - 4 (M=9.44 years) from twenty-six local schools in their classrooms. Furthermore, the mothers of these children completed a standardized questionnaire. The response rate was 79.5%. Noise exposure (dB, A, Ldn) was assessed by modeling and calibration through measurements from thirty-one sites. Data were linked via GIS. The extensive data base allowed the assessment of various dose-response curves for road and rail noise. Moreover a comparison is made with the mother's responses to the same noise sources. In addition the differences in the perception of the soundscape and the environmental, situational and personal modifying factors are reported.
Lercher, P. G. W. Evans, M. Meis, W. W. Kofler. (2002). Ambient neighborhood noise and children's mental health. **Occupational and Environmental Medicine** 2002;Vol. 59:380–386.	To investigate the relation between typical ambient noise levels (highway, rail, road) and multiple mental health indices of school children considering psychosocial and biological risk factors as potential moderators. With a two stage design strategy (representative sample and extreme sample) two cross-sectional samples (n=1280; n=123) of primary school children (age 8–11) were studied. Individual exposure to noise at home was linked with two indices of mental health (self-reporting by the child on a standard scale and rating by the teacher of classroom adjustment on a standard scale). Noise exposure was modeled

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	firstly according to Austrian guidelines with the aid of a geographical information system and then calibrated and corrected against measurements from thirty-one locations. Information on potential confounders and risk factors was collected by mothers and controlled in regression modeling through a hierarchical forward stepping procedure. Interaction terms were also analyzed to examine subgroups of children at risk—for example, low birth weight and preterm birth. Noise exposure was significantly associated in both samples with classroom adjustment ratings. Child self-reported mental health was significantly linked to ambient noise only in children with a history of early biological risk (low birth weight and preterm birth). Exposure to ambient noise was associated with small decrements in children's mental health and poorer classroom behavior. The correlation between mental health and ambient noise is larger in children with early biological risk.
Lubman, D. and L. Sutherland. (2004). Education Stakeholders and the ANSI Standard for School Acoustics. **Sound and Vibration** June 2004. pp. 12-14.	The new standard for classroom acoustics (ANSI S12.60-2002) has generated much interest - and some anxiety in the school planning and design community. The standard is not mandatory but can be adopted voluntarily by schools or school districts. The standard specifies maximum noise levels and reverberation times in unoccupied classrooms, and minimum values of sound isolation between classrooms and adjacent spaces. ANSI-compliant classrooms are inclusive: the vast majority of teachers and students will find such spaces comfortable and effective for teaching and learning. This article addresses some questions asked by stakeholders in the education and school building process, and looks at the historical role of acoustics in school planning.
Lukas, J.S., DuPree, R.B and Swing, J.W, (1981) "Effects of noise on academic achievement and classroom behavior", Office of Noise Control, Cal. Dept. of Health Services, FHWA/CA/DOHS-81/01, Sept 1981.	There is a significant acoustical difference between State and Federal rules governing implementation of noise abatement programs in schools impacted by freeway noise. The magnitude of that difference suggests the rules may have been based upon empirically weak grounds. This study of third and sixth grades of fifteen elementary schools in the Los Angeles Unified School District indicates that California's rule is more accurate than is the Federal rule in predicting effects of noise on reading achievement. Based upon this study and another independent study, a revision of the existing rule is recommended. The design criterion for traffic noise levels inside classrooms should be Leq=58 dB C-weighted. This criterion level is approximately 7 dB less than the current Federal standard and about 6 dB higher than the California standard. Because of the apparent synergistic effects of community and classroom noise levels on academic achievement, in order for the above classroom noise level to be effective in preventing degradation of achievement from noise, efforts will be required to contain community noise levels so as not to exceed L_1=65 dBA.
Lundquist, P., K. Holmberg, and U. Landstrom. (2000). Annoyance and effects on work from environmental noise at school. **Noise & Health 2000**; 8, 39-46.	The aim of this study is to investigate how students rate the annoyance and effects of noise in their working environment. 216 students between ages 13-15 years, and twelve teachers took part in this study. Sound level measurements were made for 20 minutes in the middle of a lesson of each class. On the measurement occasion the students were seated in a class room working on mathematics. Immediately after the sound measurement, the students and the teacher filled in a questionnaire. The correlation between sound level and perceived annoyance and rated effect of noise on the students' schoolwork was poor. The correlation between the annoyance and rated effect of noise on the students' schoolwork was significant. Equivalent sound levels during mathematics lessons were 58-69 dB(A). Even though the sound levels were relatively high the students claimed that there just moderately annoyed. More than 1/3 of the students claimed that

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	the existing sound environment obstructed their work. No difference was found between boys and girls in rated annoyance and rated effect on their work. The younger students were more annoyed than the older ones. The participants claimed that chatter in the classroom and scraping sounds from tables and chairs were the most annoying sound sources. The teachers shared this opinion. The concurrency between the students' rating of their annoyance and the teachers' rating of the students' annoyance was remarkably low.
Matheson, M.P., S. Stansfeld, and M. Haines. (2003) The effects of chronic aircraft noise exposure on children's cognition and health: 3 field studies. **Noise and health**. (5) 31-40.	This article provides a review of three of the most important field studies to have examined the non-auditory effects of chronic aircraft noise exposure on children's cognition and health. The design of each of the studies is outlined, relevant methodological issues are highlighted and the findings from the studies are reported. Effects are reported on annoyance and quality of life, motivation and helplessness, stress responses as indexed by neuroendocrine tests and blood pressure measurements. In terms of cognitive performance, effects are reported on reading, attention and long-term and working memory.
Maxwell, L., and G. (2000). The effects of noise on preschool children's prereading skills. **Journal of Environmental Psycholog**y, Vol. 20:91–97.	Previous research has shown a link between chronic noise exposure and reading skills. Elementary school-age children are thought to be negatively affected by such exposure. A limited amount of work has been done on the effects of chronic noise on preschool children, and such work has primarily focused on attentional skills. A cohort model was used in this study to examine the effects of chronic noise on preschool children's pre-reading skills. All of the children attended the same child care center. Ninety 4 and 5-year-old children were tested on cognitive measures of pre-reading skills and were rated by classroom teachers on their understanding and use of language. Children were tested in year one, before sound attenuation work in the classrooms, and in year two, after the installation of sound absorbent panels. In the quieter condition, children scored higher than their noisier cohort on the letter–number–word recognition measure and were rated higher by their teachers on the language scale. In addition, children in the quieter classrooms were less susceptible than those in the noisy classrooms to induced helplessness.
Meis, M., S. Hygge, G. Evans, and M. Bullinger. (1998). Disassociative effects of traffic noise on implicit and explicit memory: results from field and laboratory studies. *In Proceedings of the 7th International Conference on Noise as a Public Health Problem*, Vol. 1 (ed. N. Carter and R. F. S. Job), pp. 389-394.	An overview of the literature regarding the effects of noise on performance shows that the concept of noise covers an abundance of different types of auditory stimulations and measurements of performance. Noise leads to decreasing memory performance, if the tasks are complex, if items are presented peripherally, and if the tasks are strongly dependent on semantic processing. These studies of memory under the influence of noise have traditionally relied on tests such as free-recall, cued-recall, and recognition. A common feature of these memory tests is that they make explicit reference to a specific learning episode. Since the early seventies, however, greater attention has been paid to experimental situations in which information that was encoded during a learning phase is subsequent expressed without conscious recollection. These memory procedures are termed 'implicit memory'. Typical instructions of implicit memory are to complete graphemic fragments or word stems, and to produce examples of categories of previously read words. The 'implicit' or 'priming factor' is the facilitation of previously read or performed items ('old') in relation to 'new' items. In several studies dissociative effects of implicit and explicit memory were observed. In a recent experiment, it was demonstrated that mild divisions of attention reduce category cued-recall (explicit memory task) but not conceptual priming (implicit memory task). Strong divisions of attention, on the other hand, reduce the performance on both tests and eliminating priming. The present study explored these assumptions in two experiments. The first was embedded in the Munich

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	Airport Noise Study to test memory effects with children in the presence of chronic and acute aircraft noise. …
Meis, M. (2000). Habituation to suboptimal environments: the effects of transportation noise on children's task performance. In A. Schick, M. Meis & C. Reckhardt (2000): 'Contributions to Psychological Acoustics: Results of the 8th Oldenburg Symposium on Psychological Acoustics', pp. 509-531.	In this paper essential studies regarding the effects of chronic transportation noise from cars, trains and planes on children are summarized; especially the effects of 'chronic traffic noise by acute laboratory noise' on cognitive performance and school achievement as important outcome variables for school children. Most of the reported findings can be classified in terms of habituation: children from areas exposed to traffic noise were not or were less affected when they were confronted with laboratory traffic noise although this form of habituation was not found regarding the main effects of chronic noise. Another prevailing habituation type of task performance under transportation noise can be described in terms of 'environmental stimulation congruence', indicating that children from noisy areas performed best under noisy laboratory conditions, whereas children from quiet areas performed best under quiet conditions. In the future the detailed underlying cognitive models and coping processes have to be clarified. Furthermore, it should be an aim for noise effect researchers to provide, within the framework of Environmental and Health Impact Assessments, guidelines and advice for policy makers when changes are planned in the traffic infrastructure.
Mills, J. H. (1975). Noise and Children: A Review of Literature. **Journal of the Acoustical Society of America** 58: 767-779.	There is a large body of knowledge that is concerned with the auditory and the extra-auditory effects of noise on adults•. It is well established that exposure to noise of sufficient levels for sufficient periods can produce temporary, .chronic temporary, and permanent hearing losses. Such hearing losses are accompanied by temporary and permanent injuries of the inner ear. Exposure to noise can interfere with speech communication, the perception of non-speech signals, as well as performance on auditory and non-auditory tasks. Noise can interfere with sleep, can be a source of annoyance, and can act as a stressing agent. Other effects of noise, such as peripheral vascular constriction, hypertrophy of the adrenal glands, decreasing resistance to disease, to name a few, are less well understood and continue to be the subject of much debate and controversy. Most of the information available on the effects of noise on people comes from studies on young adults. It is possible that some of the information obtained from adults does not apply to children, and that there could be situations which affect children uniquely or differentially, and for which no data are available. The present report, therefore, focuses on those effects of noise that may be more deleterious to infants and children than to adolescents and adults; that may have possible health, social, and/or educational implications that may have a high incidence; and that are amenable to investigation. In accordance with these criteria and in light of available information, the topic of noise and hearing loss and the topic of noise and speech communication emerge as being especially noteworthy. Other effects of noise are also discussed along with gaps in basic knowledge.
Muller F., E. Pfeiffer, M. Jilg, R. Paulsen, and U. Ranft. (1998). Effects of acute and chronic traffic noise on attention and concentration of primary school children. *Proc. Int. Congr. Noise Public Health Probl.*, 7th, Sydney.	There are some indications that children who grow up in noisy environments compared to quiet areas might be disadvantaged; especially if the acquisition of language and reading are concerned. Some studies have shown that in the presence of acute noise cognitive performance, like memory functions, are restricted. The aim of this study is to explore whether chronic noise exposure will influence the reactions in acute noise as it should be expected if the children tackling with the noisy environments develop coping strategies. This is the reason why children who take part in the study were tested in quiet as well as in noise. Tests were

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	chosen which reflect upon attention and concentration serving as a basis for appropriate execution of cognitive operations. 76 children aged between 8 and 10 years, half of them living for at least 2 years in the busy city centre (CC) and the other half living for the same time in a quiet suburb (QS) of Dusseldorf, were tested. The two groups were matched for age, sex, number of siblings, and level of education of their parents.
Nelson, P.B., Soli, S.D., and Seltz, A. (2002). *Classroom Acoustics II. Acoustical Barriers to Learning*. Melville, NY: Acoustical Society of America.	"Speech produced in one place in a room should be clear and intelligible everywhere in the room." (Nabelek and Nabelek, 1985) This simple statement defines a classroom with no acoustic barriers: a well-designed learning space with low noise levels and minimal reverberation or reflections. Many U.S. classrooms are not free of acoustic barriers to learning. It is not possible to provide an appropriate education in excessively noisy and reverberant rooms. Students and teachers need rooms with good acoustics so that acoustic barriers to learning are removed. To this end, the American National Standards Institute (ANSI) has approved a standard for maximum levels of classroom noise and reverberation (ANSI S12.60-2002. Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools).
Nelson. P., K. Kohnert, S. Sabur, D. Shaw. (2005). Classroom noise and children learning through a second language: double jeopardy? **Lang Speech Hear Serv Sch**. 2005 Jul;36(3):219-29.	Two studies were conducted to investigate the effects of classroom noise on attention and speech perception in native Spanish-speaking second graders learning English as their second language (L2) as compared to English-only-speaking (EO) peers. Study 1 measured children's on-task behavior during instructional activities with and without sound field amplification. Study 2 measured the effects of noise (+10 dB signal-to-noise ratio) using an experimental English word recognition task. Findings from Study 1 revealed no significant condition (pre/postamplification) or group differences in observations in on-task performance. Main findings from Study 2 were that word recognition performance declined significantly for both L2 and EO groups in the noise condition; however, the impact was disproportionately greater for the L2 group. Children learning in their L2 appear to be at a distinct disadvantage when listening in rooms with typical noise and reverberation. Speech-language pathologists and audiologists should collaborate to inform teachers, help reduce classroom noise, increase signal levels, and improve access to spoken language for L2 learners.
Neuman A., M. Wroblewski, J. Hajicek, A. Rubinstein. (2010). Combined effects of noise and reverberation on speech recognition performance of normal-hearing children and adults. **Ear and Hearing** 2010 Jun; Vol. 31(3):336-44.	The purpose of this study is to determine how combinations of noise levels and reverberation typical of ranges found in current classrooms will affect speech recognition performance of typically developing children with normal speech, language, and hearing and to compare their performance with that of adults with normal hearing. Speech recognition performance was measured using the Bamford-Kowal-Bench Speech in Noise test. A virtual test paradigm represented the signal reaching a student seated in the back of a classroom with a volume of 228 m and with varied reverberation time (0.3, 0.6, and 0.8 sec). The signal-to-noise ratios required for 50% performance (SNR-50) and for 95% performance were determined for groups of children aged 6 to 12 yrs and a group of young adults with normal hearing. This is a cross-sectional developmental study incorporating a repeated measures design. Experimental variables included age and reverberation time. A total of sixty-three children with normal hearing and typically developing speech and language and nine adults with normal hearing were tested. Nine children were included in each age group (6, 7, 8, 9, 10, 11, and 12 yrs). The SNR-50 increased significantly with increased reverberation and decreased significantly with increasing age. On average, children required positive SNRs for 50% performance, whereas thresholds for adults were close to 0 dB or <0 dB for the conditions tested. When

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	reverberant SNR-50 was compared with adult SNR-50 without reverberation, adults did not exhibit an SNR loss, but children aged 6 to 8 yrs exhibited a moderate SNR loss and children aged 9 to 12 yrs exhibited a mild SNR loss. To obtain average speech recognition scores of 95% at the back of the classroom, an SNR > or = 10 dB is required for all children at the lowest reverberation time, of > or = 12 dB for children up to age 11 yrs at the 0.6-sec reverberant condition, and of > or = 15 dB for children aged 7 to 11 yrs at the 0.8-sec condition. The youngest children require even higher SNRs in the 0.8-sec condition. Results highlight changes in speech recognition performance with age in elementary school children listening to speech in noisy, reverberant classrooms. The more reverberant the environment, the better the SNR required. The younger the child, the better the SNR required. Results support the importance of attention to classroom acoustics and emphasize the need for maximizing SNR in classrooms, especially in classrooms designed for early childhood grades.
Ohrstrom, E., Hadzibajramovic, E., Holmes, M., et al (2006) Effects of road traffic noise on sleep: studies on children and adults. **Journal of Environmental Psychology**, 26, 116:126.	Socio-acoustic studies were conducted in residential areas in Sweden exposed to different levels of road traffic noise. The objectives were to evaluate exposure–effect relationships between road traffic noise and sleep quality and to compare sleep assessed by sleep logs and wrist-actigraphy for children and parents. The main study involved interviews with 160 children (9–12 years old) and 160 parents. Half of the families also participated in an in-depth study in which their sleep was registered with sleep logs and wrist-actigraphy. For parents the results demonstrate a significant exposure–effect relationship between noise levels from road traffic and the following sleep parameters: sleep quality, awakenings, the habit of keeping windows closed at night and perceived interference with road traffic noise. For children a significant exposure–effect relationship was found between road traffic noise and sleep quality as well as problems with daytime sleepiness. Results from the in-depth study showed that children had better perceived sleep quality and fewer awakenings than parents, although sleep assessed by wrist-actigraphy indicated a better sleep for parents.
Picard M. and J. Bradley. (2001). Revisiting speech interference in classrooms**. Audiology**. 2001 Sep-Oct;40(5):221-44.	A review of the effects of ambient noise and reverberation on speech intelligibility in classrooms has been completed because of the long-standing lack of agreement on preferred acoustical criteria for unconstrained speech accessibility and communication in educational facilities. An overwhelming body of evidence has been collected to suggest that noise levels in particular are usually far in excess of any reasonable prescription for optimal conditions for understanding speech in classrooms. Quite surprisingly, poor classroom acoustics seem to be the prevailing condition for both normally-hearing and hearing-impaired students with reported A-weighted ambient noise levels 4-37 dB above values currently agreed upon to provide optimal understanding. Revision of currently proposed room acoustic performance criteria to ensure speech accessibility for all students indicates the need for a guideline weighted for age and one for more vulnerable groups. For teens (12-year-olds and older) and young adults having normal speech processing in noise, ambient noise levels not exceeding 40 dBA are suggested as acceptable, and reverberation times of about 0.5 s are concluded to be optimum. Younger students, having normal speech processing in noise for their age, would require noise levels ranging from 39 dBA for 10-11-year-olds to only 28.5 dBA for 6-7-year-olds. By contrast, groups suspected of delayed speech processing in noise may require levels as low as only 21.5 dBA at age 6-7. As one would expect, these more vulnerable students would include the hearing-impaired in the course of language development and non-native listeners.

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Ristovska, G., D. Gjorgjev, and N. Pop Jordanova. (2004). Psychosocial Effects of Community Noise: Cross Sectional Study of School Children in Urban Center of Skopje, Macedonia. **Croatian Medical Journal** 2004. Vol. 45: 473-476.	To assess noise exposure in school children in urban center in different residential areas and to examine psychosocial effects of chronic noise exposure in school children, taking into account their socio-economic status. We measured community noise on specific measurement points in residential-administrative-market area and suburban residential area. We determined the average energy-equivalent sound level for 8 hours (LAeq, 8 h) or 16 hours (LAeq, 16 h) and compared measured noise levels with World Health Organization (WHO) guidelines. Psychological effects were examined in two groups of children: children exposed to noise level LAeq, 8 h >55 dBA (n=266) and children exposed to noise level LAeq, 8 h<55 dBA (n=263). The examinees were schoolchildren of 10-11 years of age. We used a self-reported questionnaire for each child – Anxiety test (General Anxiety Scale) and Attention Deficit Disorder Questionnaire intended for teachers to rate children's behavior. We used Mann-Whitney U test and multiple regressions for identifying the significance of differences between the two study groups. School children who lived and studied in the residential-administrative-market area were exposed to noise levels above WHO guidelines (55 dBA), and school children who lived and studied in the suburban residential area were exposed to noise levels below WHO guidelines. Children exposed to LAeq, 8 h>55 dBA had significantly decreased attention (Z=-2.16; p=0.031), decreased social adaptability (Z =-2.16; p=0.029), and increased opposing behavior in their relations to other people (Z=-3; p=0.001).We did not find any correlation between socio-economic characteristics and development of psychosocial effects. School children exposed to elevated noise level had significantly decreased attention, and social adaptability, and increased opposing behavior in comparison with school children who were not exposed to elevated noise levels. Chronic noise exposure is associated with psychosocial effects in school children and should be taken as an important factor in assessing the psychological welfare of the children.
Sanz S., A. M. Garcia, and A. Garcia. (1993) Road traffic noise around schools: a risk for pupil's performance? **Int Arch Environ Health**, Vol. 65:205-207.	Noise levels around educational centers can negatively affect the performance of both teachers and pupils. Two public schools in Valencia, Spain, were selected for study. One of these schools was exposed to excessively high road traffic noise levels while the other was located in a relatively quiet area. The socio-economic level of those attending the schools was very similar. A set of external and internal noise measurements were carried out, along with two different attention tests among the children. Test results were consistently better (both for tests and for children from different classrooms in each school) in the quiet school. Exposure to high traffic noise levels in the noisy school over the whole school year is a plausible determinant of these results.
Sargent, J.W., M.I. Gidman, M.A. Humphreys and W.A. Utley (1980). The Disturbance Caused to School Teachers by Noise. **Journal of Sound and Vibration** 70: 557-572.	A survey to investigate the disturbance caused to secondary school teachers by noise is described. Although the survey sample was selected on the basis of road traffic noise exposure it has also been possible to draw conclusions about the disturbance by aircraft noise. Quantitative relationships have been established between the proportions of teachers bothered by noise and the noise level to which they are exposed. The results of this school survey are compared with dwelling noise surveys.
Sato, H. and J. Bradley. (2008). Evaluation of acoustical conditions for speech communication in working elementary school classrooms. **Journal of the Acoustical Society of America**, 123, (4), pp. 2064-2077.	Detailed acoustical measurements were made in 41 active elementary school classrooms near Ottawa, Canada to obtain more representative and more accurate indications of the acoustical quality of conditions for speech communication during actual teaching activities. This paper describes the room acoustics characteristics and noise environment of twenty-seven traditional rectangular classrooms from the forty-one measured rooms. The purpose of the work was to better understand how to improve speech communication

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	between teachers and students. The study found that on average the students experienced: teacher speech levels of 60.4 dBA, noise levels of 49.1 dB and a mean speech-to-noise ratio of 11dBA during teaching activities. The mean reverberation time in the occupied classrooms was 0.41 s, which was 10% less than in the unoccupied rooms. The reverberation time measurements were used to determine the average absorption added by each student. Detailed analyses of early and late-arriving speech sounds showed these sound levels could be predicted quite accurately and suggest improved approaches to room acoustics design.
Schick, A. M. Klatte, M. Meis. (2000). Noise Stress in Classrooms. In A. Schick, M. Meis & C. Reckhardt (2000): 'Contributions to Psychological Acoustics: Results of the 8th Oldenburg Symposium on Psychological Acoustics', pp. 533-569.	An analysis of German and international reference works shows that classroom acoustics have been sadly neglected worldwide. This is just as true for German as for other countries. In the United States, however, classroom acoustics has become increasingly important. From all parts of the world, values for noise levels are being reported which are no longer permissible in industrial and commercial places of work. That means: while parents are protected at their places of work, their children are expected to endure such conditions for years. The investigations also show that children suffer from learning difficulties under such stressful conditions. On occasions these can even lead to children doing significantly worse in tests in their noisy classrooms than under quiet conditions. Our report summarizes the verifiable difficulties children have when learning to read and speak in noisy surroundings. Today there appears to be justification for the assumption that poor performance at school has, to a great extent, to be put down to the inadequate ergonomic conditions found in schools. Noise caused in schools themselves together with the dreadful acoustics are mainly responsible for that.
Sharp, B. and K. Plotkin. (1984). Selection of Noise Criteria for School classrooms. Prepared by the PONYNJ, Wyle TN 84-2, October 1984.	The Port Authority of New York and New Jersey were engaged in a noise abatement program that involved the soundproofing of schools exposed to noise from aircraft operating out of the three New York airports. The purpose of this technical note is to review alternative measures of noise, select the measure most suitable for school activities and recommend a numerical value of the measure that can be specified as a noise criterion in the soundproofing program.
Shield B., J. Dockrell, R. Jeffery, and I. Tachmatzidis. (2001). The Effects of Noise on the Attainments and Cognitive Performance of Primary School Children – Executive Summary. London: South Bank University and Institute of Education, University of London.	Summary The present series of studies indicate that • Children in London primary schools are exposed to higher levels of noise at school than recommended by current guidelines • External and internal noise levels show negative associations with results of standard assessment tests • Children judgments of their own noise exposure proved to be a valid indicator • Children were aware of external noise and annoyed by specific sound sources, although for many activities classroom noise levels are dominated by the noise of these classroom activities • Children's reported levels of noise occurrences are related to objective external noise measures • Acute exposure to noise affected performance on academic tasks • The noise levels most closely related to SATS results were the maximum level LAmax in the case of external noise and background level LA90 for internal noise. Conclusion Data from noise surveys, analysis of SATs results, children's reports and experimental studies provide converging evidence that noise levels influence children's performance and can negatively impact on their attainments.

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Shield. B. and J. E. Dockrell. (2003). The effects of noise on children at school: A review. **Build. Acoust.** 10(2), 97–116 (2003).	This paper reviews research on issues relating to the effects of noise on children at school. Areas covered include factors affecting speech intelligibility in the classroom; the effects of environmental and classroom noise on children's academic performance; children's annoyance due to noise; and surveys of classroom noise levels. Consistencies and discrepancies between the results of various studies are highlighted. The paper concludes by outlining some current acoustic standards for classrooms.
Shield, B. and J. Dockrell. (2004). External and internal noise surveys of London primary schools. **J. Acoust. Soc. Am**. 115 (2), February 2004.	Internal and external noise surveys have been carried out around schools in London, UK, to provide information on typical levels and sources to which children are exposed while at school. Noise levels were measured outside 142 schools, in areas away from flight paths into major airports. Here 86% of the schools surveyed were exposed to noise from road traffic, the average external noise level outside a school being 57 dB LAeq. Detailed internal noise surveys have been carried out in 140 classrooms in 16 schools, together with classroom observations. It was found that noise levels inside classrooms depend upon the activities in which the children are engaged, with a difference of 20 dB LAeq between the ''quietest'' and ''noisiest'' activities. The average background-noise level in classrooms exceeds the level recommended in current standards. The number of children in the classroom was found to affect noise levels. External noise influenced internal noise levels only when children were engaged in the quietest classroom activities. The effects of the age of the school buildings and types of window upon internal noise were examined but results were inconclusive.
Shield, B. and J.Dockrell. (2008). The effects of environmental and classroom noise on the academic attainments of primary school children. **J Acoust Soc Am.** 2008 Jan;123(1):133-44.	While at school children are exposed to various types of noise including external, environmental noise and noise generated within the classroom. Previous research has shown that noise has detrimental effects upon children's performance at school, including reduced memory, motivation, and reading ability. In England and Wales, children's academic performance is assessed using standardized tests of literacy, mathematics, and science. A study has been conducted to examine the impact, if any, of chronic exposure to external and internal noise on the test results of children aged 7 and 11 in London (UK) primary schools. External noise was found to have a significant negative impact upon performance, the effect being greater for the older children. The analysis suggested that children are particularly affected by the noise of individual external events. Test scores were also affected by internal classroom noise, background levels being significantly related to test results. Negative relationships between performance and noise levels were maintained when the data were corrected for socio-economic factors relating to social deprivation, language, and special educational needs. Linear regression analysis has been used to estimate the maximum levels of external and internal noise which allow the schools surveyed to achieve required standards of literacy and numeracy.
Stansfeld, S. A., Haines, M. M. & Brown, B. (2000) Noise and health in the urban environment. *Reviews of Environmental Health*, 15, 43:82.	Noise, including noise from transport, industry, and neighbors, is a prominent feature of the urban environment. This paper reviews the effects of environmental noise on the non-auditory aspects of health in urban settings. Exposure to transport noise disturbs sleep in laboratories, but generally not in field studies, where adaptation occurs. Noise interferes with complex task performance, modifies social behavior, and causes annoyance. Studies of occupational noise exposure suggest an association with hypertension, whereas community studies show only weal relations between noise and cardiovascular disease. Aircraft and road traffic noise exposure are associated with psychological symptoms and with the use of psychotropic medication, but not with the onset of clinically defined psychiatric disorders. In carefully controlled studies, noise exposure does not seem to be related to low birth weight or to congenital birth

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	defects. In both industrial and community studies, noise exposure is related to increased catecholamine secretion. In children, chronic aircraft noise exposure impairs reading comprehension and long-term memory and may be associated with increased blood pressure. Noise from neighbors causes annoyance and sleep and activity interference health effects have been little studies. Further research is needed for examining coping strategies and the possible health consequences of adaptation to noise.
Stansfeld, S. A. and M .P. Matheson. (2003). Noise pollution: non-auditory effects on health. **British Medical Bulletin** 2003; 68: 243–257	Noise is a prominent feature of the environment including noise from transport, industry and neighbors. Exposure to transport noise disturbs sleep in the laboratory, but not generally in field studies where adaptation occurs. Noise interferes in complex task performance, modifies social behavior and causes annoyance. Studies of occupational and environmental noise exposure suggest an association with hypertension, whereas community studies show only weak relationships between noise and cardiovascular disease. Aircraft and road traffic noise exposure are associated with psychological symptoms but not with clinically defined psychiatric disorder. In both industrial studies and community studies, noise exposure is related to raised catecholamine secretion. In children, chronic aircraft noise exposure impairs reading comprehension and long-term memory and may be associated with raised blood pressure. Further research is needed examining coping strategies and the possible health consequences of adaptation to noise.
Stansfeld, S. A. B. Berglund, C. Clark, I. Lopez-Barrio, P. Fischer, E. Öhrström, M. M. Haines, J. Head, S. Hygge, I. van Kamp, B. F. Berry, on behalf of the RANCH study team. (2005) Aircraft and road traffic noise and children's cognition and health: a cross-national study. **The Lancet** Vol. 365 June 4, 2005	Background - Exposure to environmental stressors can impair children's health and their cognitive development. The effects of air pollution, lead, and chemicals have been studied, but there has been less emphasis on the effects of noise. Our aim, therefore, was to assess the effect of exposure to aircraft and road traffic noise on cognitive performance and health in children. Methods - We did a cross-national, cross-sectional study in which we assessed 2844 of 3207 children aged 9–10 years who were attending 89 schools of seventy-seven approached in the Netherlands, 27 in Spain, and thirty in the UK located in local authority areas around three major airports. We selected children by extent of exposure to external aircraft and road traffic noise at school as predicted from noise contour maps, modeling, and on-site measurements, and matched schools within countries for socio-economic status. We measured cognitive and health outcomes with standardized tests and questionnaires administered in the classroom. We also used a questionnaire to obtain information from parents about socio-economic status, their education, and ethnic origin. Findings - We identified linear exposure-effect associations between exposure to chronic aircraft noise and impairment of reading comprehension (p=0·0097) and recognition memory (p=0·0141), and a non-linear association with annoyance (p0·0001) maintained after adjustment for mother's education, socio-economic status, long-standing illness, and extent of classroom insulation against noise. Exposure to road traffic noise was linearly associated with increases in episodic memory (conceptual recall: p=0·0066; information recall: p=0·0489), but also with annoyance (p=0·0047). Neither aircraft noise nor traffic noise affected sustained attention, self-reported health, or overall mental health. Interpretation - Our findings indicate that a chronic environmental stressor—aircraft noise—could impair cognitive development in children, specifically reading comprehension. Schools exposed to high levels of aircraft noise are not healthy educational environments.
Stansfeld, S.A. J. Head, C. Clark, I. van Kemp, and I. L. Barrio. (2005) Aircraft noise and	"Andy Smith makes two important points about our study of aircraft and road traffic noise and children's cognition. First, that our results might be explained by the different geographical distribution of children's

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children's cognition: Reply. **Lancet**. (366) 716-716	intelligence by noise exposure level. We included a brief measure of intelligence—the figure analogies subtest from the nonverbal battery of the Cognitive Abilities Test1—in Spain and the UK. After discussion, we were reluctant to include this as a covariate because of the colinearity of intelligence with our other cognitive measures and because we expected that our school-matching procedure might partly control for intelligence as well as socio-economic status. Reading comprehension and intelligence were correlated (r=0·37), as were recognition memory and intelligence (r=0·19)."
Stansfeld, S. A., C. Clark, , R. Cameron, T. Alfred, J. Head, M. Haines, I. van Kamp,E. van Kempen, & I. Lopez-Barrio. (2009). Aircraft and road traffic noise exposure and children's mental health. **Journal of Environmental Psychology** 29, 203-207.	There have been few studies examining noise and psychological disorders in children and the results are equivocal. The objective of this study was to examine exposure–effect relationships between aircraft and road traffic noise exposure and children's mental health. We conducted a cross-national, cross-sectional study assessing 2844 pupils, aged 9–10, from eighty-nine schools around three major airports in the Netherlands, Spain and United Kingdom matched within country for socio-economic position. We selected children on the basis of exposure to external aircraft and road traffic noise exposure. The Strengths and Difficulties Questionnaire (SDQ) assessed child mental health, including emotional problems, conduct disorder, hyperactivity, peer problems and prosocial behavior. Aircraft noise exposure was significantly associated with an increased score on the hyperactivity subscale (pooled B estimate 0.013 CI 0.007–0.019) after full adjustment. Road traffic noise was significantly associated with lower scores on the conduct problems subscale maintained after full adjustment (pooled B estimate 0.010 95%CI −0.020 to −0.001). There was no association between either aircraft or road traffic noise exposure and the SDQ total score. The hyperactivity results have been found in a previous UK study and may indicate that high aircraft noise exposure exacerbates hyperactivity symptoms in children although this finding requires further replication.
Sutherland, L. and D. Lubman. (2001). *The Impact of Classroom Acoustics on Scholastic Achievement*. Presented at the 17th Meeting of the International Commission for Acoustics, Rome, Italy, Sept. 2-7, 2001	What are the relationships between scholastic achievement and acoustics in learning spaces? Answers to this difficult question are needed to support setting objective limits for noise and reverberation. Good acoustics is necessary in classrooms and learning spaces whenever speech communication is important to the learning process. It is clear that excessive noise and reverberation interfere with speech communication and thus present acoustical barriers to learning. Acoustical allowances are needed to accommodate differences in student abilities, health, and scholastic preparation. This paper reviews speech communication criteria and studies that have linked scholastic performance with acoustical noise or reverberation. Some studies link aircraft noise with delayed language acquisition, reading deficiencies, reduced motivation, and long-term recall of learned material. Others link ground transportation noise with reduced academic achievement. Aside from reduced speech intelligibility, little data were found to gauge the impact on learning achievement from heating, ventilating, and air conditioning noise; from the noises of students interacting in cooperative learning environments; or from reverberation. Despite their incomplete nature, some useful inferences can be drawn from these studies. For example, evidence for cumulative impact of poor acoustics on scholastic achievement suggests that good acoustics be made a high priority for children in lower grades.
Wålinder. R., K.Gunnarsson, R. Runeson, G. Smedje. (2007). Physiological and psychological stress reactions in relation to classroom noise. **Scand J Work Environ**	This study tested the hypothesis that classroom noise is related to stress reactions among primary school children. Stress was monitored via symptoms of fatigue and headache, systolic blood pressure, reduced diurnal cortisol variation, and indicators of emotional distress. In three classrooms of pupils in the fourth grade (10 years of age), daily measurements of equivalent sound levels (Leq) were made during 4 weeks,

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Health. 2007 Aug;33(4):260-6.	evenly distributed from September to December. One day each week of the study, the pupils answered a questionnaire about disturbance and symptoms, and blood pressure and salivary cortisol were measured. In the first and fourth week, the children also performed a standardized drawing test concerning emotional indicators. Daily measurements of equivalent sound levels in the classes (Leq during school day) ranged from 59 to 87 dB(A). Equivalent sound levels were significantly related to an increased prevalence of symptoms of fatigue and headache and a reduced diurnal cortisol variability. Blood pressure and emotional indicators were not significantly related to sound levels. Current sound levels in Swedish classrooms may have a negative health impact, being directly or indirectly related to stress reactions among children. This finding indicates that noise should be focused on as a risk factor in the school environment.
Wesler, J. (1986). Priority Selection of Schools for Soundproofing. Prepared for the PONYNJ, Wyle TN 86-8. October 1986.	As part of its overall aviation noise abatement program, the Port Authority of New York and New Jersey considered a continuing project to soundproof schools which are exposed to aircraft noise near its three airports. This technical note will briefly review the factors which should be considered in selecting candidate schools for soundproofing, and recommend a procedure for ranking those schools for priority attention.
Yang, W. and J. Bradley. (2009). Effects of room acoustics on the intelligibility of speech in classrooms for young children**. J Acoust Soc Am.** 2009 Feb;125(2):922-33.	This paper reports new measurements of the intelligibility of speech in conditions representative of elementary school classrooms. The speech test material was binaurally recorded in simulated classroom conditions and played back to subjects over headphones. Subjects included Grade 1, 3, and 6 students (6, 8, and 11 year olds) as well as adults. Recognizing that reverberation time is not a complete descriptor of room acoustics conditions, simulated conditions included realistic early-to-late arriving sound ratios as well as varied reverberation time. For conditions of constant signal-to-noise ratio, intelligibility scores increased with decreasing reverberation time. However, for conditions including realistic increases in speech level with varied reverberation time for constant noise level, intelligibility scores were near maximum for a range of reverberation times. Young children's intelligibility scores benefited from added early reflections of speech sounds similar to adult listeners. The effect of varied reverberation time on the intelligibility of speech for young children was much less than the effect of varied signal-to-noise ratio. The results can be used to help to determine ideal conditions for speech communication in classrooms for younger listeners.
Zuurbier, M., C. Lundqvist, G. Salines, S. Stansfelds, W. Hanke, W. Babisch, M. L. Bistrup, P. van den Hazel, and H. Moshammer. (2007). The Environmental Health of Children: Priorities in Europe. **International Journal of Occupational Medicine and Environmental Health** 2007;20(3):291 – 308	Objectives: To evaluate existing research on the environmental health of children and provide a prioritized list of risk factors and policy recommendations for action, the Policy Interpretation Network on Children's Health and Environment (PINCHE) was set up within EU FP5 (QLK4-2002-02395). The project focused on air pollutants, carcinogens, neurotoxicants and noise. PINCHE was a multidisciplinary and multinational network of representatives from science, industry, NGOs, and consumer and patient organizations in Europe. Materials and methods: A literature search was performed using the Pubmed, Embase and Toxline databases. The quality of the gathered articles was assessed and their information and relevance was interpreted within a systematic framework. Information related to exposure, epidemiology, and toxicology was analyzed separately and then a risk evaluation of particular environmental factors was made. Socio-economic factors were specifically taken into account. The results were compiled, and considering the present regulatory situation, policy recommendations for action were made. Finally, the risk factors and policy recommendations were prioritized through a process of discussion between all the partners. Results and conclusions: PINCHE concluded that outdoor air pollutants (especially traffic-related), environmental

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	tobacco smoke, allergens, and mercury were high priorities with an urgent need for action. Brominated flame retardants, lead, PCBs and dioxins, ionizing and solar radiation, and some noise sources were classified as being of medium priority. Some toxins were given low priority, based on few exposed children, relatively mild health effects or an improving situation due to past policy measures. We recognize the shortcomings of such a prioritization and, though some measures are more urgent than others, emphasize that ideally all policy measures should be carried out without delay for all toxins. This priority list must be continuously revised, the precautionary principle should be central to all decisions, and the focus should be on safe exposure levels for children.

APPENDIX B. Catalog of Research Studies—Subjects

Authors (Pub. Year)	Country	Location	Noise Source	# Schools	# Students	School Grades
Ando, Y., Y. Nakane, and J. Egawa (1975)	Japan	Itami City near Osaka Airport Kawanishi City - quiet area	Aircraft	4	1144	Elementary (2nd and 4th Grades)
Astolfi, A. and F. Pellerey (2008)	Italy	Secondary school in Turin	Classroom noise	1	1006	Secondary
Bistafa, S. and J. Bradley (2001)	NA	NA	NA	NA	NA	NA
Boman, E., I. Enmarker, and S. Hygge (2005)	Sweden	Lab at University of Gavle	Road traffic noise recordings	NA	32	Primary and secondary (with other age groups)
Boman, E. and I. Enmarker (2004) - Study 3	Sweden	Lab at University of Gavle	Road traffic noise recordings	1	96	Secondary

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Authors (Pub. Year)	Country	Location	Noise Source	# Schools	# Students	School Grades
Boman, E. and I. Enmarker (2004) - Study 5	Sweden	Medium-sized city	Classroom noise	2	207	Secondary
Boman, E. and I. Enmarker (2004) - Study 1	Sweden	Medium-sized city	Classroom noise	2	207	Secondary
Boman, E (2004)	Sweden	Lab at University of Gavle	Meaningful irrelevant speech Road traffic noise recordings	1	96	Secondary
Bradley, J (1986a	Canada	Ottawa	Pulse recordings	NA	NA	Secondary (along with older adults)
Bradley, J (1986b	Canada	Ottawa	Omni directional pulse response (blank pistol)	various	NA	Secondary
Bradley, J. and H. Sato (2004)	Canada	Small towns and rural areas of Eastern Ontario	Classroom noise	12	840	Primary
Bradley, J. and H. Sato (2008)	Canada	Small towns and rural areas of Eastern Ontario	Classroom noise	12	840	Primary

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Authors (Pub. Year)	Country	Location	Noise Source	# Schools	# Students	School Grades
Bronzaft, A. and D. P. McCarthy (1975)	US	PS 98 in NYC	Elevated train	1	161	Primary
Bronzaft, A (1981)	US	PS 98 in NYC	Elevated train	1	350 in 1978 605 in 1980-81	Primary
Christie, D. J. and C. Glickman (1980)	US	Central Ohio	Classroom noise recordings	1	156	Primary
Clark, C., R. Martin, E. van Kempen, T. Alfred1, J. Head, H. W. Davies, et. al. (2005)	UK	Heathrow	Aircraft and road noise	29	1174	Primary

APPENDIX B. Catalog of Research Studies—Subjects

Authors (Pub. Year)	Country	Location	Noise Source	# Schools	# Students	School Grades
Clark, C., R. Martin, E. van Kempen, T. Alfred1, J. Head, H. W. Davies, et. al. (2005)	The Netherlands	Schiphol	Aircraft and road noise	33	762	Primary
Clark, C., R. Martin, E. van Kempen, T. Alfred1, J. Head, H. W. Davies, et. al. (2005)	Spain	Barajas	Aircraft and road noise	27	908	Primary
Clark, C., S. Stansfeld, and J. Head. (2009)	UK	London Boroughs of Hillingdon, Hounslow, Slough, Windsor & Maidenhead, Surrey, and Richmond	Aircraft noise	58	1015	Secondary
Cohen, S., G. Evans, and D. Stokol (1980)	US	near LAX	Aircraft noise	4 affected 3 control	142 affected 120 control	Primary

APPENDIX B. Catalog of Research Studies—Subjects

Authors (Pub. Year)	Country	Location	Noise Source	# Schools	# Students	School Grades
Cohen, S., G. Evans, D. Krantz, D. Stokols, and S. Kelly (1981)	US	near LAX	Aircraft noise	4 affected 3 control	97 noisy 45 abated 120 control	Primary
Crook, M. and F. Langdon (1974)	UK	Near Heathrow	Aircraft noise	3 2		Primary Secondary
de Oliveira Nunes, M. F. & Sattler, M. A. (2006)	Brazil	Salgado Filho International Airport	Aircraft noise	3	1097	Primary
Dockrell, J. and B. Shield (2004)	UK	London	External including aircraft, road, and rail	43	2036	Primary
Dockrell, J. and B. Shield (2006)	UK	north London	Classroom and environmental noise	4	158	Primary
Emmen, H.,B. Staatsen, P. Fischer, and I. Kamp, IV (2001)	NTH	Zwanenburg (8 km from Schiphol) Uitgeest (23 km away)	Aircraft noise	2	86 73	Primary (8-12 years)

APPENDIX B. Catalog of Research Studies—Subjects

Authors (Pub. Year)	Country	Location	Noise Source	# Schools	# Students	School Grades
Evans, G., S. Hygge and M. Bullinger (1995)	Germany	New Munich International Airport	Aircraft noise		135	Primary (3rd and 4th Grades)
Evans, G. and L. Maxwell (1997)	US	Major NY airport: impacted and control schools	Aircraft noise	2	116	Primary (1st and 2nd Grades)
Evans, G., M. Bullinger, and S. Hygge (1998)	Germany	New Munich International Airport	Aircraft noise		217	Primary (3rd and 4th Grades)
Evans G., P. Lercher, M. Meis, H. Ising, W. Kofler (2001)	Austria	small towns near Tyrol	Road and rail		115	Primary (Grade 4)

APPENDIX B. Catalog of Research Studies—Subjects

Authors (Pub. Year)	Country	Location	Noise Source	# Schools	# Students	School Grades
Federal Interagency Committee on Aviation Noise (FICAN) (2007)	US	3 major airports in Texas and Illinois	Aircraft noise	35		Primary (19 schools) Secondary (3 high schools and thirteen middle schools)
Green, K.B., B. Pastenak, and R. Shore (1982)	US	Brooklyn and Queens (JFK and LGA)	Aircraft noise	362		Primary (Grades 4 and 5)

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Authors (Pub. Year)	Country	Location	Noise Source	# Schools	# Students	School Grades
Green, Rochelle, S. Smorodinsky, J. Kim, R. McLaughlin, and B. Ostro1 (2004)	US	CA public schools	Road	7460		Primary and Secondary
Haines, M, S. Stansfeld, R. Job, B. Berglund, and J. Head (2001a	UK	schools near Heathrow and West London	Aircraft noise	4 noisy 4 control	340	Primary

APPENDIX B. Catalog of Research Studies—Subjects

Authors (Pub. Year)	Country	Location	Noise Source	# Schools	# Students	School Grades
Haines, M, S. Stansfeld, S. Brentnall, J. Head, B. Berry, M. Jiggins, and S. Hygge (2001b	UK	schools near Heathrow and West London	Aircraft noise	10 noisy 10 control	451	Primary
Haines, M., S. Stansfeld, R. Job, B. Berglund, and J. Head (2001c	UK	schools near Heathrow and West London	Aircraft noise	10 noisy 10 control	275	Primary
Haines, M., S. Stansfeld, J. Head and R. F. S. Job (2002)	UK	schools near Heathrow	Aircraft noise	123	11000	Primary (Year 6, 11 years old)
Haines, M., S. L. Brentnall, S. A. Stansfeld, and E. Klineberg (2003)	NA	NA	Aircraft noise	NA	275 West London 36 Millennium	Primary

APPENDIX B. Catalog of Research Studies—Subjects

Authors (Pub. Year)	Country	Location	Noise Source	# Schools	# Students	School Grades
Hiramatsu K., T. Tokuyama, T. Matsui, T. Miyakita, Y. Osada, T. Yamamoto (2004)	Japan	Okinawa (Kadena and Futenma AFBs)	Aircraft noise	8 noisy 3 quiet	2269	Primary (8-11 years old)
Houtgast, T (1981)	NTH		Road	5	500 students 20 teachers	Primary
Hygge, S. and I. Knez (2001)	Sweden	Lab at University of Gavle	Classroom environment		128	Secondary (18-19 years old)
Hygge, S., G. Evans, and M. Bullinger (2002)	Germany	old and new Munich airports	Aircraft noise		43 old airport; no noise 65 old airport; noise 107 new airport; no noise 111 new airport; noise	Elementary (10.4 average age)

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Authors (Pub. Year)	Country	Location	Noise Source	# Schools	# Students	School Grades
Hygge, S (2003)	Sweden		Aircraft, road, rail, and voice		1358	Secondary (12-14 years old)
Hygge, S., E. Boman, and I. Enmarker (2003)			Road and meaningful irrelevant speech		96	Secondary (18-20 years old)
Jamieson, D., G. Kranjc, K. Yu, W. Hodgetts (2004)	Canada	Ottawa	Classroom	1	40	Primary (Kindergarten, Grades 1-3)
van Kempen, E., I. Van Kamp, .P Fischer, H. Davies, et. al. (2006)	UK NTH	Heathrow Schiphol	Aircraft and road	62	864	Primary (9-10 years old)
van Kempen, E., I. van Kamp, E. Lebret, J. Lammers, H. Emmen and S. Stansfeld (2010)	NTH	Schiphol	Aircraft and road	24	553	Primary (9-11 years old)

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Authors (Pub. Year)	Country	Location	Noise Source	# Schools	# Students	School Grades
Klatte, M., M. Wegner and J. Hellbruk (2005)	Germany	Stuttgart	Rail	8	500	Primary
Klatte, M., M. Meis, H. Sukowski, and A. Schick (2007)	Germany	Lab at University of Oldenburg	Rail and irrelevant speech	2	22-25	Primary
Knecht H., P. Nelson, G. Whitelaw, L. Feth (2002)	US	3 Ohio School Districts	Background noise and reverberation	3 suburban 3 urban 2 rural	unoccupied	NA
Ko, N.W.M (1979)	Hong Kong	Kai Tak Airport	Aircraft	91	2100 teachers	Primary and Secondary
Kyzar, B.L (1977)	US	Minnesota school near new traffic artery	Road	1	56	NA
Lercher, P. G. W. Evans, M. Meis, W. W. Kofler (2002)	Austria	small Alpine towns and villages	Residential noise exposure	26	1280	Primary (Grades 3-4)

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Authors (Pub. Year)	Country	Location	Noise Source	# Schools	# Students	School Grades
Lukas, J.S., DuPree, R.B and Swing, J.W (1981)	US	California schools	Road	9 noisy 6 quiet	NA	Primary (Grades 3 and 6)
Lundquist, P., K. Holmberg, and U. Landstrom (2000)	Sweden		Classroom	2	216	Secondary (13-15 years old)
Maxwell, L., and G (2000)	US	Child care center in Corning NY	Classroom	1	90	Preschool
Meis, M., S. Hygge, G. Evans, and M. Bullinger (1998)	Germany	Munich (closing old airport and opening new)	Aircraft		111 (noisy area) 110 (control)	Primary (9-12 years old)

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Authors (Pub. Year)	Country	Location	Noise Source	# Schools	# Students	School Grades
Muller F., E. Pfeiffer, M. Jilg, R. Paulsen, and U. Ranft (1998)	Germany	Dusseldorf	Environmental noise		38 (city center) 38 (quiet suburb)	Primary (8-10 years old)
Nelson. P., K. Kohnert, S. Sabur, D. Shaw (2005)	US	Minneapolis	Classroom - before-and-after installation of sound field amplification system	1	1	Primary (2nd Grade)
Nelson. P., K. Kohnert, S. Sabur, D. Shaw (2005)	US	Minneapolis	Classroom	1	22	Primary (2nd Grade)
Neuman A., M. Wroblewski, J. Hajicek, A. Rubinstein (2010)			Classroom	1	63	Primary (6-12 years old)

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Authors (Pub. Year)	Country	Location	Noise Source	# Schools	# Students	School Grades
Ohrstrom, E., Hadzibajramovic, E., Holmes, M., et al (2006)	Sweden	Stockholm	Road	NA	160 students and mothers	Primary (9-12 years old)
Ristovska, G., D. Gjorgjev, and N. Pop Jordanova (2004)	Macedonia	central part of Skopje	Community	4 urban 3 suburban	266 urban 263 suburban	Primary (4th Grade)
Sanz S., A. M. Garcia, and A. Garcia (1993)	Spain	Valencia	Road	1 noisy 1 quiet	81 noisy 55 quiet	Primary (1st, 3rd, and 5th Grades)
Sargent, J.W., M.I. Gidman, M.A. Humphreys and W.A. Utle (1980)	UK	Hertfordshire, Buckinghamshire, Berkshire, Bedfordshire and London	Road (with implications for aircraft)	78	1148 teachers	Secondary

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Authors (Pub. Year)	Country	Location	Noise Source	# Schools	# Students	School Grades
Sato, H. and J. Bradley (2008)	Canada	Ottawa	Classroom			Primary (Grades 1, 3, and 6)
Shield B., J. Dockrell, R. Jeffery, and I. Tachmatzidis (2001)	UK	3 London Boroughs	Classroom and environmental noise			Primary (Year 2 and Year 6)
Shield, B. and J. Dockrell (2004)	UK	3 London Boroughs (Harringey, Islington, and Lambeth)	Environmental	142		Primary
Shield, B. and J.Dockrell (2008)	UK	3 London Boroughs (Harringey, Islington, and Lambeth)	Environmental (excluding aircraft)	142		Primary (6-11 years old)

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Authors (Pub. Year)	Country	Location	Noise Source	# Schools	# Students	School Grades
Stansfeld, S. A. B. Berglund, C. Clark, I. Lopez-Barrio, et. al. (2005)	UK	Heathrow	Aircraft and road traffic	29	1174	Primary (9-10 years old)
Stansfeld, S. A. B. Berglund, C. Clark, I. Lopez-Barrio, et. al. (2005)	NTH	Schiphol	Aircraft and road traffic	33	762	Primary (9-10 years old)
Stansfeld, S. A. B. Berglund, C. Clark, I. Lopez-Barrio, et. al. (2005)	Spain	Barajas	Aircraft and road traffic	27	908	Primary (9-10 years old)

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Authors (Pub. Year)	Country	Location	Noise Source	# Schools	# Students	School Grades
Stansfeld, S. A., C. Clark, R. Cameron, T. et. al. (2009)	UK NTH Spain	Heathrow Schiphol Barajas	Aircraft and road traffic	89	2844	Primary (9-10 years old)
Wålinder. R., K.Gunnarsson, R. Runeson, G. Smedje (2007)	Sweden	central Uppsala	Classroom	1	57	Primary (4th Grade)
Yang, W. and J. Bradley (2009)	Canada	Ottawa	Classroom		77 Grade 1 75 Grade 3 65 Grade 6	Primary

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CATALOG OF RESEARCH STUDIES – MEASURES AND METHODS

Authors (Pub. Year)	Student Performance Measure	Noise Measure	Research Method	Data Collection Method	Analytical Method
Ando, Y., Y. Nakane, and J. Egawa (1975)	Rate of work on simple tasks	Recorded B727s at 90 ± 5dBA	Causal-Comparison	Kraplan-Uchida Test (simple search and adding tasks) and Questionnaire	Two-tailed Kolmogorov–Smirnov test
Astolfi, A. and F. Pellerey (2008)	Perception of acoustic quality of the classroom	Measurements: * Teacher (LspA1 m) * Background (L90) * Reverberation time (RT)	Case study	Questionnaire (5-point scale)	Correlation analysis
Bistafa, S. and J. Bradley (2001)	NA	Computed: * Speech level (Ls) * Early-to-late sound ratios (C50) * Speech transmission index (STI)	Experimental	Computer simulation of classroom acoustics	
Boman, E., I. Enmarker, and S. Hygge (2005)	Episodic memory Semantic memory	Simulated Background (Leq) Road traffic recording (dBA) Meaningful irrelevant speech (dBA)	Cross-sectional	Lab observations	Analysis of variance (ANOVA) using SPSS 11.5
Boman, E. and I. Enmarker (2004) - Study 3	Episodic memory Semantic memory	Simulated Background (Leq) Road traffic recording (dBA) Meaningful irrelevant speech (dBA)	Experimental	Lab observations	Analysis of variance (ANOVA) using SPSS 11.5

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Authors (Pub. Year)	Student Performance Measure	Noise Measure	Research Method	Data Collection Method	Analytical Method
Boman, E. and I. Enmarker (2004) - Study 5	Annoyance Hearing status	~55 dBA outdoors at both schools	Survey	Questionnaire (Likert scale)	SSI LISREL analysis
Boman, E. and I. Enmarker (2004) - Study 1	Noise sensitivity Hearing status	NA	Survey	Questionnaire (Likert-like scale)	Factor analysis
Boman, E (2004)	Episodic memory Semantic memory	~62 dBA continuous road traffic or background babble	Experimental	Lab observations	Univariate F-test
Bradley, J (1986a	Speech intelligibility	Reverberation time (RT) Early-to-late sound ratios Speech transmission index	Experimental	Fairbanks Rhyme test	Multiple regression analysis
Bradley, J (1986b	Speech intelligibility	Reverberation time (RT) Early-to-late sound ratios Speech transmission index	Experimental	Fairbanks Rhyme test	Multiple regression analysis
Bradley, J. and H. Sato (2004)	Speech intelligibility	Signal-to-noise ratio	Correlation	Word Intelligibility by Picture Identification (WIPI) Rhyme test Listening Difficulty test	Multiple regression analysis

APPENDIX B. Catalog of Research Studies—Subjects

Authors (Pub. Year)	Student Performance Measure	Noise Measure	Research Method	Data Collection Method	Analytical Method
Bradley, J. and H. Sato (2008)	Speech intelligibility	Reverberation time (RT) Early-to-late sound ratios Signal-to-noise ratio	Correlation	Word Intelligibility by Picture Identification (WIPI)	Multiple regression analysis
Bronzaft, A. and D. P. McCarthy (1975)	Reading comprehension	Peak at 89 dBA every 4.5 min.	Causal-Comparison	Metropolitan Achievement Reading Test Attitude questionnaire	Analysis of variance (ANOVA) of test scores Chi-square analysis of questionnaire responses
Bronzaft, A (1981)	Reading comprehension	Effectiveness of rubber padding on tracks (reduced peak levels from 89 to 85-86 dBA) and sound absorbent ceilings in classrooms (3-4 dB reduction)	Causal-Comparison	California Achievement Test Teacher questionnaire	ANOVA
Christie, D. J. and C. Glickman (1980)	Intellectual tasks	Noisy = 70 dBA Quiet =40 dBA	Causal-Comparison	Standard Progressive Matrices, 1938 version	Factor analysis

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Authors (Pub. Year)	Student Performance Measure	Noise Measure	Research Method	Data Collection Method	Analytical Method
Clark, C., R. Martin, E. van Kempen, T. Alfred1, J. Head, H. W. Davies, et. al. (2005)	Reading comprehension	16 hr LAeq contours for aircraft noise Modeled road noise School noise surveys	Cross-sectional	Suffolk Reading Scale, level 2	Multi-level modeling using MLwiN
Clark, C., R. Martin, E. van Kempen, T. Alfred1, J. Head, H. W. Davies, et. al. (2005)	Reading comprehension	16 hr LAeq contours for aircraft noise Modeled road noise School noise surveys	Cross-sectional	CITO Readability Index for Elementary and Special Education	Multi-level modeling using MLwiN
Clark, C., R. Martin, E. van Kempen, T. Alfred1, J. Head, H. W. Davies, et. al. (2005)	Reading comprehension	16 hr LAeq contours for aircraft noise Modeled road noise School noise surveys	Cross-sectional	ECL-2 (Evaluacion Comprension Lectora)	Multi-level modeling using MLwiN

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Authors (Pub. Year)	Student Performance Measure	Noise Measure	Research Method	Data Collection Method	Analytical Method
Clark, C., S. Stansfeld, and J. Head. (2009)	Cognitive	16 hr LAeq for aircraft noise (predictions ranging from <50 dBA to 65.4 dBA)	Longitudinal epidemiological follow up	Suffolk Reading Scale 2 Level 2 (baseline) Suffolk Reading Scale 2 Level 3 (follow up) CAA predicted noise contours	ANOVA (multi-level regression models under development)
Cohen, S., G. Evans, and D. Stokol (1980)	Cognitive effects Hypertension	Maximum of 95 dBA measured indoors	Causal-Comparison	California Test of Basic Skills Treatment puzzle solving Student questionnaire Parent questionnaire	Multivariate cluster analysis and F-tests
Cohen, S., G. Evans, D. Krantz, D. Stokols, and S. Kelly (1981)	Cognitive effects Hypertension	Maximum of 95 dBA measured indoors Sound insulated classrooms ~ 16 dB lower on average	Longitudinal and cross-sectional	California Test of Basic Skills Treatment puzzle solving Student questionnaire Parent questionnaire	Multivariate cluster analysis and F-tests
Crook, M. and F. Langdon (1974)	Teacher interruption Student attention	NNI 55 at 4 schools and NNI 52 at 5th	Observation	Teacher questionnaire Classroom observations	Probability distribution
de Oliveira Nunes, M. F. & Sattler, M. A. (2006)	Annoyance and perception	Weighted Noise Index (IPR), LAmax, LA90	Association	Indoor and outdoor noise measurements Teacher and student questionnaires	Association test of variables

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Authors (Pub. Year)	Student Performance Measure	Noise Measure	Research Method	Data Collection Method	Analytical Method
Dockrell, J. and B. Shield (2004)	Ease of hearing Annoyance	External noise survey: LAeq,5 min , LA10,5 min , LA90,5 min , LAmax,5 min	Survey	Student questionnaire Teacher questionnaire	Nonparametric statistical analysis
Dockrell, J. and B. Shield (2006)	Aptitude, verbal, nonverbal, and arithmetic tests	Quiet, Recorded babble continuous 65 dBA), and babble with environmental noise (internal level of 58 dBA)	Causal-Comparison	AH4 ability test Suffolk Reading Scale British Abilities Scale I and II	Univariate analysis of variance
Emmen, H.,B. Staatsen, P. Fischer, and I. Kamp, IV (2001)	Attention, Psychomotor function, Perceptual coding, Memory and Reading ability	59 LAeq24 <50 LAeq24	Causal-Comparison	Computerized Neurobehavioral Evaluation System (NES) Children Behavior Checklist	Test retest reliability
Evans, G., S. Hygge and M. Bullinger (1995)	Physiological, Motivation, and Cognitive	LAeq24=68 dB and Peak=80 dBA LAeq24=59 dB and Peak=69 dBA	Causal-Comparison	Blood pressure reading Urine specimen Standardized German reading test	ANOVA t- and F-tests
Evans, G. and L. Maxwell (1997)	Reading skill	Laeq24 65 contour with peaks above 90 dB	Causal-Comparison	Woodcock Reading Mastery Test	Mediation analysis
Evans, G., M. Bullinger, and S. Hygge (1998)	Physiological, Motivation, and Cognitive	LAeq24=62 dB with L01=73 dB LAeq24=53 dB with L01=64 dB	Causal-Comparison	Blood pressure reading Urine specimen Standardized German reading test	Multivariate analysis of variance (MANOVA)

APPENDIX B. Catalog of Research Studies—Subjects

Authors (Pub. Year)	Student Performance Measure	Noise Measure	Research Method	Data Collection Method	Analytical Method
Evans G., P. Lercher, M. Meis, H. Ising, W. Kofler (2001)	Physiological and Motivation	>62 DNL versus <46 DNL	Causal-Comparison	Blood pressure reading Urine specimen Glass and Singer stress-aftereffects test	ANOVA
Federal Interagency Committee on Aviation Noise (FICAN) (2007)	Test scores (verbal and math/science)	DNL, Leq9hr, SEL, LAmax Number of events disrupting indoor speech (ANEv<0.98SII) Number of events disrupting indoor speech (ANEv>40SIL) Fraction of indoor time speech is disrupted(AFnTm>40SIL)	Cross-sectional	INM calculations of outdoor levels Computation of outdoor-to-indoor level reduction (OILR) Conversion of outdoor aircraft spectra (from INM) to indoor spectra, based upon the computed values of OILR Demographic data Illinois and Texas standardized test results	Multivariate multi-level regression

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Authors (Pub. Year)	Student Performance Measure	Noise Measure	Research Method	Data Collection Method	Analytical Method
Green, K.B., B. Pastenak, and R. Shore (1982)	Reading	Noise exposure score: 0, 1, 2, 3, 4, or 8	Correlation	NY standardized reading test Demographics from 1970 US Census NEF contours (1972 and 1978)	Regression analysis
Green, Rochelle, S. Smorodinsky, J. Kim, R. McLaughlin, and B. Ostro1 (2004)	NA	maximum average annual daily traffic (AADT) within 150 m of each school as an estimate of exposure to traffic	Correlation	California Department of Education (CDE) databases California Work Opportunity and Responsibility to Kids program (CalWORKS; aid for families and welfare-to-work program) Census 2000 Summary File 3 data 1997 Highway Performance Monitoring System (HPMS)	Polytomous logistic regression using SAS software (version 8.2 for Windows)

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Authors (Pub. Year)	Student Performance Measure	Noise Measure	Research Method	Data Collection Method	Analytical Method
Haines, M, S. Stansfeld, R. Job, B. Berglund, and J. Head (2001a	Stress response and health outcomes Cognitive and performance outcomes	Indoor noise measurements 1991 CAA noise contours	Cross-sectional	Salivary cortisol measurements Child Depression Inventory Revised Child Manifest Anxiety Scale Parent questionnaire Suffolk Reading Scale Level 2 Long-term memory test After-effects paradigm of soluble and insoluble animal puzzles Teacher questionnaire (24-item Student Behavior Checklist)	Analysis of Covariance (ANCOVA)
Haines, M, S. Stansfeld, S. Brentnall, J. Head, B. Berry, M. Jiggins, and S. Hygge (2001b	Stress response and health outcomes Cognitive and performance outcomes	1997 CAA noise contours: 16 h outdoor Leq>63 dBA 16 h outdoor Leq< 57 dBA	Cross-sectional	Salivary cortisol measurements Lewis Child Stress Scale Parent questionnaire (Strengths and Difficulties Questionnaire) Suffolk Reading Scale Level 2 Tests of Everyday Attention for Children (TEA-Ch) Townsend's Scale	ANCOVA

APPENDIX B. Catalog of Research Studies—Subjects

Authors (Pub. Year)	Student Performance Measure	Noise Measure	Research Method	Data Collection Method	Analytical Method
Haines, M., S. Stansfeld, R. Job, B. Berglund, and J. Head (2001c	Stress response and health outcomes Cognitive and performance outcomes	1997 CAA noise contours: 16 h outdoor Leq>63 dBA 16 h outdoor Leq< 57 dBA	Repeated measures	Lewis Child Stress Scale Child Depression Inventory Revised Child Manifest Anxiety Scale Suffolk Reading Scale Level 2 Tests of Everyday Attention for Children (TEA-Ch)	ANCOVA
Haines, M., S. Stansfeld, J. Head and R. F. S. Job (2002)	Math, science, and English	1994 CAA noise contours: 1= <54, 2=54>57, 3= 57>60, 4= 60>63, 5= 63>66, 6= 66>69, 7=69>72, 8= >72	Cross-sectional	Townsend's Scale 1996 and 1997 results of National Standardized Scores (SATs) for Key Stage 2	Multi-level modeling using Mln
Haines, M., S. L. Brentnall, S. A. Stansfeld, and E. Klineberg (2003)	Annoyance	NA	Qualitative examination of 2 distinct studies	Millennium Conference Study (focus groups from twelve countries) West London Study (Haines et al 2001c)	Structured analysis of interviews
Hiramatsu K., T. Tokuyama, T. Matsui, T. Miyakita, Y. Osada, T. Yamamoto (2004)	Short and long-term memory	Ldn	Correlation	Short-term and long-term memory tests Articulation test, Learning motivation test Noise contours	Logistic regression

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Authors (Pub. Year)	Student Performance Measure	Noise Measure	Research Method	Data Collection Method	Analytical Method
Houtgast, T (1981)	Speech intelligibility	Measured indoors; both windows open and closed	Experimental	similar to Fairbanks' Rhyme test Teacher and student questionnaires	Experimental relationship with theory
Hygge, S. and I. Knez (2001)	Cognitive and annoyance	Noise at 38 and 58 dBA as measured in the middle of the room	Factorial between-subject design	Lab observations: Memory-load search task Embedded figures task Long- and short-term recall Self-report circumplex measure	ANOVA
Hygge, S., G. Evans, and M. Bullinger (2002)	Reading, memory, attention, speech perception	Community noise analyzer for LAeq24	Longitudinal and cross-sectional	Standardized German reading test Short-term memory test Visual search and reaction time Speech perception during story listening	MANOVA
Hygge, S (2003)	Cognitive and mood	Recorded noise levels over loudspeakers at Leq of 55 and 66 dBA	Within subject and between subject experiments	Memory Questionnaire	MANOVA (SPSS-software)
Hygge, S., E. Boman, and I. Enmarker (2003)	Episodic memory Semantic memory	Road traffic at 62 dBA with peaks at 78 dBA	Context-dependency experiment	Lab observations: Face/name recognition Word fluency and comprehension Self-reported affects	ANOVA and MANCOVA using SPSS 7.5 for Windows

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Authors (Pub. Year)	Student Performance Measure	Noise Measure	Research Method	Data Collection Method	Analytical Method
Jamieson, D., G. Kranjc, K. Yu, W. Hodgetts (2004)	Speech intelligibility	Recorded classroom noise (60-70 dBA)	Causal-Comparison	Spoken word picture recognition	MANOVA
van Kempen, E., I. Van Kamp, .P Fischer, H. Davies, et. al. (2006)	Blood pressure and heart rate	Modeled LAeq16 (by NLR and CAA)	Causal effect relationship	Blood pressure readings Parent questionnaire	Multi-level modeling using the MIXED procedure of SAS version 8.1
van Kempen, E., I. van Kamp, E. Lebret, J. Lammers, H. Emmen and S. Stansfeld (2010)	Cognition	LAeq16	Cross-sectional	Neurobehavioral Evaluation System (NES) tests: - Simple Reaction Time - Switching Attention - Hand-Eye Coordination - Symbol-Digit Substitution - Digit Memory Span Parent and child questionnaire	Multi-level modeling using the MIXED procedure of SAS version 9.1
Klatte, M., M. Wegner and J. Hellbruk (2005)	Speech perception and cognition		Causal-Comparison	Standardized German reading and spelling tests Student and parent questionnaires	Descriptive statistics

APPENDIX B. Catalog of Research Studies—Subjects

Authors (Pub. Year)	Student Performance Measure	Noise Measure	Research Method	Data Collection Method	Analytical Method
Klatte, M., M. Meis, H. Sukowski, and A. Schick (2007)	Speech perception and cognition	Rail and speech (in Dutch) recordings	Causal-Comparison	Lab observations: - Speech perception - Short-term memory - Sentence comprehension Parent questionnaire	One-way ANOVA
Knecht H., P. Nelson, G. Whitelaw, L. Feth (2002)	NA	Measured indoors with HVAC on and off (34-69 dBA)	Experimental	Interior noise and reverberation measurements	Descriptive statistics
Ko, N.W.M (1979)	Teacher annoyance, speech interference, teaching interference, effects on students	Aircraft noise measurements in school compounds	Correlation	Questionnaire	Linear and non-linear regression
Kyzar, B.L (1977)	Student attention	Overall SPL	Case study	Indoor noise measurements Teacher survey Flander's Interaction Analysis Minnesota Clerical Test	Descriptive statistics
Lercher, P. G. W. Evans, M. Meis, W. W. Kofler (2002)	Mental health and classroom behavior	LAeq24 and Ldn	Cross-sectional	SoundPlan modeling road and rail with calibration measurement sampling Quality of life questionnaire (KINDL-R) Teacher survey	Multiple linear regression with SPSS 8.0 and S+4.5

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Authors (Pub. Year)	Student Performance Measure	Noise Measure	Research Method	Data Collection Method	Analytical Method
Lukas, J.S., DuPree, R.B and Swing, J.W (1981)	Cognition and interruption	Measured: L1, L10, L99, LNP, LAeq24	Correlation	Community noise monitoring survey Classroom noise measurements Observations of teacher and student behaviors Comprehensive Test of Basic Skills (reading and math) California Assessment Program	Multiple regression analysis
Lundquist, P., K. Holmberg, and U. Landstrom (2000)	Annoyance	Measured Leq	Correlation	Student and teacher questionnaire (7 pt scale)	Two-tailed T test Chi-squared test
Maxwell, L., and G (2000)	cognitive	Measured average and peak Leq before-and-after installation of sound absorption material	Causal-Comparison	Test of Early Reading Ability (TERA-2) and Metropolitan Readiness Tests (MTR6) -Number and letter recognition, Letter-sound correspondence, Rhyming	T test for independent samples

APPENDIX B. Catalog of Research Studies—Subjects

Authors (Pub. Year)	Student Performance Measure	Noise Measure	Research Method	Data Collection Method	Analytical Method
Meis, M., S. Hygge, G. Evans, and M. Bullinger (1998)	Memory	Leq, Peak dBA	Cross-sectional	Word production, free-recall, cued-recall tests Munich Airport Noise Study	Descriptive statistics and F-test
Muller F., E. Pfeiffer, M. Jilg, R. Paulsen, and U. Ranft (1998)	Cognitive	Leq-day, Leq-night, Leq	Cross-sectional	Recorded traffic noise (65 dBA) d-2 test, color-discrimination test, Go/No-go test, visual vigilance task	MANOVA
Nelson. P., K. Kohnert, S. Sabur, D. Shaw (2005)	Student on-task behavior of native English speaking (EO) and ESL students (L2)	Measured levels in dBA and dBC	Causal-Comparison	Observation	Descriptive statistics
Nelson. P., K. Kohnert, S. Sabur, D. Shaw (2005)	Cognition differences between native English speaking (EO) and ESL students (L2)	Multi-talker babble recordings at +10 dB SNR	Causal-Comparison	Picture-word identification task	2-way mixed ANOVA

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Authors (Pub. Year)	Student Performance Measure	Noise Measure	Research Method	Data Collection Method	Analytical Method
Neuman A., M. Wroblewski, J. Hajicek, A. Rubinstein (2010)	Speech intelligibility	Background noise and reverberation	Cross-sectional developmental	SNR required for 50% performance (SNR-50) BKB-SIN test (speech in noise test)	Mixed model repeated measures ANOVA, Tukey's Honestly Significant Differences (HSD) test
Ohrstrom, E., Hadzibajramovic, E., Holmes, M., et al (2006)	Sleep quality	Leq(24), Lden, Lnight	Exposure-effect	Outdoor noise levels using Nordic Prediction Method, parent/child questionnaires, sleep logs and wrist-actigraphy for 79 families	Jonckheere–Terpstra Test for trend, Linear-by-linear Association test
Ristovska, G., D. Gjorgjev, and N. Pop Jordanova (2004)	Mental health and classroom behavior	Measurements in schoolyards (LAeq8 and LAeq16)	Cross-sectional	General Anxiety Scale-Sarason to test anxiety Teacher questionnaire (Attention Deficit Disorder Questionnaire)	STATISTICA for Windows 1995: Kolmogorov-Smirnov test, Mann-Whitney U-Test
Sanz S., A. M. Garcia, and A. Garcia (1993)	Student attention	External and internal background	Cross-sectional	Difference Perception Test or "faces test" (Tecnicos Especialistes Asociados S A 1973)	Student T test, Chi-square test

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Authors (Pub. Year)	Student Performance Measure	Noise Measure	Research Method	Data Collection Method	Analytical Method
Sargent, J.W., M.I. Gidman, M.A. Humphreys and W.A. Utle (1980)	Teacher annoyance ("bothered")	L10, L50, L90, Leq Lax and NNI for aircraft	Cause-effect	Predicted road noise levels External and internal measurements of road and aircraft noise Questionnaire	Linear regression and probit analysis
Sato, H. and J. Bradley (2008)	Speech intelligibility	Reverberation time, Early decay time, and Clarity, Sound strength	Correlation	Impulse response measurements Student sound absorption	
Shield B., J. Dockrell, R. Jeffery, and I. Tachmatzidis (2001)	Cognitive	Average daily exposure = 72 dB LAeq	Correlation and causal-comparison	Student and teacher questionnaires Standard Assessment Tests (SAT) at Key Stage 1 and Key Stage 2	

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Authors (Pub. Year)	Student Performance Measure	Noise Measure	Research Method	Data Collection Method	Analytical Method
Shield, B. and J. Dockrell (2004)	Student activity	External noise: LAeq,5 min , LA10,5 min , LA90,5 min , LAmax,5 min Internal noise: LAmax, L90, and LAeq	Survey	External noise survey at all schools: LAeq,5 min , LA10,5 min , LA90,5 min , LAmax,5 min Internal noise survey at sixteen schools: LAmax, L90, and LAeq Classroom observations	Descriptive statistics and correlation analysis
Shield, B. and J.Dockrell (2008)	Cognitive	External noise: LAeq,5 min , LA10,5 min , LA90,5 min , LAmax,5 min Internal noise: LAmax, L90, and LAeq	Cross-sectional	External and internal noise surveys Standard Assessment Tests (SAT) at Key Stage 1 and Key Stage 2	Correlation and regression analyses
Stansfeld, S. A. B. Berglund, C. Clark, I. Lopez-Barrio, et. al. (2005)	Cognitive performance and health	LA, Leq16	Cross-sectional	External noise measurements CAA noise contours UK standard calculation of road traffic noise (CRTN) prediction method Suffolk reading scale Toulouse Pieron test Parent questionnaire on health	Multi-level modeling, fractional polynomial models

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Authors (Pub. Year)	Student Performance Measure	Noise Measure	Research Method	Data Collection Method	Analytical Method
Stansfeld, S. A. B. Berglund, C. Clark, I. Lopez-Barrio, et. al. (2005)	Cognitive performance and health	LA, Leq16	Cross-sectional	External noise measurements Modeled noise contours CITO (Centraal Instituute Toets Ontwikkeling) readability index Toulouse Pieron test Parent questionnaire on health	Multi-level modeling, fractional polynomial models
Stansfeld, S. A. B. Berglund, C. Clark, I. Lopez-Barrio, et. al. (2005)	Cognitive performance and health	LA, Leq16	Cross-sectional	External noise measurements Modeled noise contours ECL-2 (Evaluación de la Compresión Lectora, nivel 2) Toulouse Pieron test Parent questionnaire on health	Multi-level modeling, fractional polynomial models
Stansfeld, S. A., C. Clark, R. Cameron, T. et. al. (2009)	Mental health	LA, Leq16	Cross-sectional	External noise measurements Modeled noise contours Strengths and Difficulties Questionnaire (SDQ)	Multi-level modeling with Mlwin

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Authors (Pub. Year)	Student Performance Measure	Noise Measure	Research Method	Data Collection Method	Analytical Method
Wålinder. R., K.Gunnarsson, R. Runeson, G. Smedje (2007)	Stress	LAeq during school days	Correlation	Indoor noise measurements Blood pressure readings Salivary cortisol Human figure drawings	SAS package: Spearman's rank correlation coefficients, Kendall's rank correlation, linear mixed model with random intercept
Yang, W. and J. Bradley (2009)	Speech intelligibility	Clarity (C50), Reverberation (T60)	Correlation	Simulated classroom acoustics Word intelligibility by picture identification (WIPI) test	Multiple regression analysis

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CATALOG OF RESEARCH STUDIES – FINDINGS

Authors (Pub. Year)	Finding	Suggested Criteria
Ando, Y., Y. Nakane, and J. Egawa (1975)	"The result was that children from relatively noisy areas tended, when performing tasks, to show occasional short periods in which they produced substantially less than their average rate of work.	None
Astolfi, A. and F. Pellerey (2008)	"Acoustical satisfaction was lower in non-renovated classrooms, and one of the most important consequences of poor acoustics was a decrease in concentration. The stronger correlation between average noise disturbance scores and LA max levels, more than LAeq and LA90, showed that students were more disturbed by intermittent than constant noise."	None
Bistafa, S. and J. Bradley (2001)	"By varying the amount of sound absorption, and the location of the sound-absorbing material in a simulated classroom, it was possible to assess the accuracy of the prediction of speech metrics."	None
Boman, E., I. Enmarker, and S. Hygge (2005)	"The noise effects of episodic memory tasks were stronger than for semantic memory tasks. Further, in the reading comprehension task, cued-recall and recognition were more impaired by meaningful irrelevant speech than by road traffic noise. Contrary to predictions, there was no interaction between noise and age group, indicating that the obtained noise effects were not related to the capacity to perform the task."	None
Boman, E. and I. Enmarker (2004) - Study 3	"The main findings in this paper were that both meaningful irrelevant speech and road traffic noise affected episodic and semantic memory performance, and that the performance of a complex episodic task, reading comprehension, was more impaired by speech than by road traffic noise." [Authors' Paper IV]	None

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Authors (Pub. Year)	Finding	Suggested Criteria
Boman, E. and I. Enmarker (2004) - Study 5	"Taken together, despite mean differences in ratings on the items the results showed that the annoyance structure was of the same nature for pupils and teachers." [Authors Paper VII]	None
Boman, E. and I. Enmarker (2004) - Study 1	"Sounds generated by humans were perceived as the most disturbing noise sources in the school environment, and the disturbance was worst during math lessons."	None
Boman, E (2004)	"In conclusion, it has been shown that meaningful irrelevant speech impaired comprehension of a novel text in episodic memory and caused a poorer access to word comprehension in semantic memory. It was also found that girls outperformed boys in episodic as well as semantic memory tasks, but they could not take advantage of their higher memory performance during noise exposure."	None
Bradley, J (1986a)	"The results of this work suggest that several methods of almost equivalent prediction accuracy can be used for estimating expected speech intelligibility scores obtained using a Fairbanks rhyme test."	None
Bradley, J (1986b)	"Optimum reverberation times for classrooms were estimated to be in the range from 0.4-0.5 s, which is shorter than many standard reference suggest. To accommodate all age groups of normal hearing listeners, background levels of approximately 30 dBA are required."	"Optimum reverberation times for classrooms were estimated to be in the range from 0.4-0.5 s, which is shorter than many standard references suggest. To accommodate all age groups of normal hearing listeners, background levels of approximately 30 dBA are required."
Bradley, J. and H. Sato (2004)	"Grade 1 students are seen to require, on average, conditions with 7 dB better S/N than Grade 6 students to achieve the same 95% correct speech intelligibility scores."	None

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Bradley, J. and H. Sato (2008)	"Further calculations based on the new measurements led to estimates of maximum acceptable ambient noise levels that were very close to the 35 dBA recommendation in ANSI S12.60."	"It is therefore justifiable and practical to recommend a maximum ambient noise level in all elementary school classrooms of no more than 35 dBA. ... The results indicate that +15 dB signal-to-noise ratio is not adequate for the youngest children."

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Authors (Pub. Year)	Finding	Suggested Criteria
Bronzaft, A. and D. P. McCarthy (1975)	"Whatever the explanation for the present findings, the fact remains that the grade equivalent scores of children on the noisy side of the school building were found to lag behind their peers on the quieter side from three months to as much as one year."	None
Bronzaft, A (1981)	"After the classroom noise levels were somewhat abated (from 89 dBA to 81 to 86 dBA), the children on the noisy side were reading as well as those on the quiet side."	None
Christie, D. J. and C. Glickman (1980)	"The present study does not suggest that noise levels should be lowered. Rather, the thrust of the current research suggests that noise does not affect the performance of all children in the same way. In general, it appears that an optimal learning environment for boys would be relatively noisy, while girls tend to perform better in a quiet environment."	None
Clark, C., R. Martin, E. van Kempen, T. Alfred1, J. Head, H. W. Davies, et. al. (2005)	"Firstly, a linear exposure-effect relation was found between aircraft noise exposure at school and impaired reading comprehension, with a similar effect being observed in all three countries. Secondly, the effect of aircraft noise on reading comprehension could not be accounted for by sociodemographic variables, acute noise during testing, aircraft noise annoyance, episodic memory, working memory, or sustained attention. Thirdly, there was no evidence of a relation between road traffic noise at school and reading comprehension."	None

APPENDIX B. Catalog of Research Studies—Subjects

Authors (Pub. Year)	Finding	Suggested Criteria
Clark, C., R. Martin, E. van Kempen, T. Alfred1, J. Head, H. W. Davies, et. al. (2005)	"Firstly, a linear exposure-effect relation was found between aircraft noise exposure at school and impaired reading comprehension, with a similar effect being observed in all three countries. Secondly, the effect of aircraft noise on reading comprehension could not be accounted for by sociodemographic variables, acute noise during testing, aircraft noise annoyance, episodic memory, working memory, or sustained attention. Thirdly, there was no evidence of a relation between road traffic noise at school and reading comprehension."	None
Clark, C., R. Martin, E. van Kempen, T. Alfred1, J. Head, H. W. Davies, et. al. (2005)	"Firstly, a linear exposure-effect relation was found between aircraft noise exposure at school and impaired reading comprehension, with a similar effect being observed in all three countries. Secondly, the effect of aircraft noise on reading comprehension could not be accounted for by sociodemographic variables, acute noise during testing, aircraft noise annoyance, episodic memory, working memory, or sustained attention. Thirdly, there was no evidence of a relation between road traffic noise at school and reading comprehension."	None
Clark, C., S. Stansfeld, and J. Head. (2009)	"Preliminary analyses indicate a trend for reading comprehension to be poorer at 15-16 years of age for children who attended noise-exposed primary schools. There was also a trend for reading comprehension to be poorer in aircraft noise exposed secondary schools."	None
Cohen, S., G. Evans, and D. Stokol (1980)	"Thus children from noisy schools have higher blood pressure than those from matched control (quiet) schools. Noise school children are also more likely to give up before the time to complete the task has elapsed."	None

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Authors (Pub. Year)	Finding	Suggested Criteria
Cohen, S., G. Evans, D. Krantz, D. Stokols, and S. Kelly (1981)	"The cross-sectional comparison of noisy, abated, and quiet classrooms suggests only a minimal impact of the abatement intervention on the criterion variables. … The longitudinal data similarly provide little evidence that children who had been enrolled in a noise-impacted school showed improvement in their performance and/or health following a 1-(school) year experience in a noise-abated classroom."	None
Crook, M. and F. Langdon (1974)	"When talking to individuals or small groups teaching is less vulnerable to interference and is not seriously affected during flyovers which peak above 75 dB(A). "	"From our data it would appear that a very high level of insulation would be necessary to completely remove dissatisfaction since any flyover leaking at or above 60 dB(A) [indoors] is potentially intrusive."
de Oliveira Nunes, M. F. & Sattler, M. A. (2006)	"In this study, it was established that students aged from 11 to 13 years, who are in an important phase of cognitive development, were the most affected. … From the study it can be concluded that the schools' design was unsuitable as they fail to provide the basic requirements to promote a healthy and appropriate environment for oral communication."	
Dockrell, J. and B. Shield (2004)	"External LAmax levels are a significant factor in reported annoyance, whereas external LA90 and LA99 levels are a significant factor in determining whether or not children hear sound sources."	None
Dockrell, J. and B. Shield (2006)	"Performance on verbal tasks was negatively affected by classroom babble, whereas performance on the speed task was reduced in babble but further reduced when babble was superimposed with environmental noise. No obvious pattern of additional deficits was evident for children with English as an additional language."	None

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Authors (Pub. Year)	Finding	Suggested Criteria
Emmen, H.,B. Staatsen, P. Fischer, and I. Kamp, IV (2001)	"In conclusion, the results of this study demonstrate the feasibility of applying computerized behavioral testing methods in a school setting."	None
Evans, G., S. Hygge and M. Bullinger (1995)	"To summarize, our results reflect a general pattern of adverse psychological stress reactions associated with chronic exposure to noise among elementary-school-aged children. The children who were studied showed no apparent auditory damage during standard audiometric examination. Both neuroendocrinological and cardiovascular indices of chronic stress were elevated; long-term memory, speech perception, and standardized reading test scores indicate deficits; and children living proximate to a major airport reported more annoyance and a lower quality of life than did children in quiet communities."	None
Evans, G. and L. Maxwell (1997)	"Children chronically exposed to aircraft noise have poorer reading skills than children attending elementary school in a quiet neighborhood."	None
Evans, G., M. Bullinger, and S. Hygge (1998)	"Chronic living proximate to the new Munich International Airport experienced significant elevations in resting blood pressure after the airport opened."	None
Evans G., P. Lercher, M. Meis, H. Ising, W. Kofler (2001)	"Children in the noisier areas had elevated resting systolic blood pressure and 8-h, overnight urinary cortisol. The children from noisier neighborhoods also evidenced elevated heart rate reactivity to a discrete stressor (reading test) in the laboratory and rated themselves higher in perceived stress symptoms on a standardized index."	None

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Authors (Pub. Year)	Finding	Suggested Criteria
Federal Interagency Committee on Aviation Noise (FICAN) (2007)	"After controlling for demographics, the study found (1) a substantial association between noise reduction and decreased failure (worst-score) rates for high school students, and (2) significant association between noise reduction and increased average test scores for student/test subgroups. In general, the study found little dependence upon student group and upon test type."	None
Green, K.B., B. Pastenak, and R. Shore (1982)	"The regression coefficients indicate than an additional 3.6% of the students in the noisiest schools read at least one year below grade level …"	None

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Authors (Pub. Year)	Finding	Suggested Criteria
Green, Rochelle, S. Smorodinsky, J. Kim, R. McLaughlin, and B. Ostro1 (2004)	"Traffic exposure was related to race/ethnicity. For example, the overall percentage of non-white students was 78% at the schools located near high-traffic roads versus 60% at the schools with very low exposure (no streets with counted traffic data within 150 m)."	NA
Haines, M, S. Stansfeld, R. Job, B. Berglund, and J. Head (2001a	"First, chronic aircraft noise exposure was consistently and strongly associated with higher levels of noise annoyance in children. Secondly, the association between chronic aircraft noise exposure and reading comprehension and long-term memory recognition, is suggestive that chronic aircraft noise exposure impairs cognitive function. Thirdly, the association between aircraft noise exposure and reading comprehension could not be accounted for by noise annoyance, acute noise interference and sociodemographic factors (age, main language spoken at home, household deprivation, social class). Fourthly, chronic exposure to aircraft noise was not associated with child mental health problems (anxiety, depression, hyperactivity and conduct problems)."	None

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Authors (Pub. Year)	Finding	Suggested Criteria
Haines, M, S. Stansfeld, S. Brentnall, J. Head, B. Berry, M. Jiggins, and S. Hygge (2001b	"The noise effect on reading confirms previous studies that noise exposure is associated with poorer reading performance but that the effects are confined to difficult items and not on simple items. Taking the annoyance results of this study together with previous studies in children and adults, it can be concluded that chronic noise exposure is associated with raised noise annoyance in children."	None
Haines, M., S. Stansfeld, R. Job, B. Berglund, and J. Head (2001c	"The results of this repeated measures study are not conclusion. Nevertheless, they provide stronger evidence than previous studies to suggest that noise exposure affects child cognition and stress response and that these effects do not habituate over a one-year period."	None
Haines, M., S. Stansfeld, J. Head and R. F. S. Job (2002)	"The results suggest that chronic exposure to aircraft noise is associated with school performance in reading and mathematics in a dose-response function but this association is influenced by socio-economic factors."	None
Haines, M., S. L. Brentnall, S. A. Stansfeld, and E. Klineberg (2003)	" As expected, the impact of noise pollution on quality of life and everyday activities (e.g. school work, homework, and playing) was larger for the children exposed to high levels of aircraft compared with the control and focus group samples."	None

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Authors (Pub. Year)	Finding	Suggested Criteria
Hiramatsu K., T. Tokuyama, T. Matsui, T. Miyakita, Y. Osada, T. Yamamoto (2004)	"The result obtained in the present study is in line with the prior studies and suggests that chronic aircraft noise exposure lowers the ability of long-term memory of school children and as a result they run the risk of making lower learning ability of schoolwork."	None
Houtgast, T (1981)	"Intelligibility tests performed by teachers and pupils have shown that the interfering effect of (traffic) noise in classrooms becomes noticeable when the indoor level exceeds a critical value. This critical level equals - 15 dB with regard to a teacher's long-term (reverberant) speech level, all levels A-weighted."	"Intelligibility tests performed by teachers and pupils have shown that the interfering effect of (traffic) noise in classrooms becomes noticeable when the indoor level exceeds a critical value. This critical level equals - 15 dB with regard to a teacher's long-term (reverberant) speech level, all levels A-weighted."
Hygge, S. and I. Knez (2001)	"Taken together, this experiment reported interactions between noise and heat on the recall of a text, and between noise and light on the free-recall of emotionally toned words."	NA
Hygge, S., G. Evans, and M. Bullinger (2002)	"After the switch, long-term memory and reading were impaired in the noise group at the new airport and improved in the formerly noise-exposed group at the old airport. Short-term memory also improved in the latter group after the old airport was closed. At the new airport, speech perception was impaired in the newly noise-exposed group."	NA

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Authors (Pub. Year)	Finding	Suggested Criteria
Hygge, S (2003)	"Overall, there was a strong noise effect on recall, and a smaller, but significant effect on recognition. In the single-source studies, aircraft and road traffic noise impaired recall at both noise levels. Train noise and verbal noise did not affect recognition or recall."	None
Hygge, S., E. Boman, and I. Enmarker (2003)	"The results showed that both road traffic noise and meaningful irrelevant speech impaired recall of the text. Retrieval in noise from semantic memory was also impaired. Attention was impaired by both noise sources, but attention did not mediate the noise effects on episodic memory. Recognition was not affected by noise. Context-dependent memory was not shown."	None
Jamieson, D., G. Kranjc, K. Yu, W. Hodgetts (2004)	"These results suggest that the youngest children in the school system, whose classrooms also tend to be among the noisiest, are the most susceptible to the effects of noise."	None
van Kempen, E., I. Van Kamp, .P Fischer, H. Davies, et. al. (2006)	"The relationship between aircraft noise and blood pressure was not fully consistent: in the Dutch sample, blood pressure increased statistically significantly as aircraft noise exposure increased; this was not the case in the British sample. These findings, taken together with those from previous studies, suggest that no univocal conclusions about the association between aircraft noise exposure and blood pressure can be drawn."	None

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Authors (Pub. Year)	Finding	Suggested Criteria
van Kempen, E., I. van Kamp, E. Lebret, J. Lammers, H. Emmen and S. Stansfeld (2010)	"Based on these analyses the authors conclude that neurobehavioral tests can complement paper-and-pencil tests when investigating the effects of noise on children's cognitive functioning. ... Based on this study and previous scientific literature it can be concluded that performance on simple tasks is less susceptible to the effects of noise than performance on more complex tasks. It is not possible to draw definite conclusions about the relative importance of noise exposure at home and at school and possible interactions."	None
Klatte, M., M. Wegner and J. Hellbruk (2005)	NA	None
Klatte, M., M. Meis, H. Sukowski, and A. Schick (2007)	"Children's performance in tasks requiring storage and processing of verbal information was significantly impaired by background speech that they could not understand in three experiments. … Quite contrary to the marked effects of background speech, train sounds had no effect on performance of these tasks."	None
Knecht H., P. Nelson, G. Whitelaw, L. Feth (2002)	"Results indicated that most classrooms were not in compliance with ANSI noise and reverberation standards (ANSI S12.60-2002)."	None

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Authors (Pub. Year)	Finding	Suggested Criteria
Ko, N.W.M (1979)	" The subjective responses of teachers obtained in these schools indicate good correlation of annoyance ratings of teachers with the Noise and Number Index observed in the school period. … The speech interference and teaching interference due to noise are found to be the most severe disruption experienced by teachers. They seem to be interrelated."	None
Kyzar, B.L (1977)	"Noise pollution created by the proximity of the traffic artery to School adversely affects the ability of teachers to adequately practice their profession, and interferes with the capacity of students to maintain the necessary attention to details required in effective learning."	None
Lercher, P. G. W. Evans, M. Meis, W. W. Kofler (2002)	"Noise exposure was significantly associated in both samples with classroom adjustment ratings. Child self-reported mental health was significantly linked to ambient noise only in children with a history of early biological risk (low birth weight and preterm birth)."	None
Lukas, J.S., DuPree, R.B and Swing, J.W (1981)	"The design criterion for traffic noise levels inside classrooms should be Leq=58 dB C-weighted. ... Because of the apparent synergistic effects of community and classroom noise levels on academic achievement, in order for the above classroom noise level to be effective in preventing degradation of achievement from noise, efforts will be required to contain community noise levels so as not to exceed L1=65 dBA."	"The design criterion for traffic noise levels inside classrooms should be Leq=58 dB C-weighted."

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Authors (Pub. Year)	Finding	Suggested Criteria
Lundquist, P., K. Holmberg, and U. Landstrom (2000)	"The correlation between sound level and perceived annoyance and rated effect of noise on the students' schoolwork was poor. The correlation between the annoyance and rated effect of noise on the students' schoolwork was significant. ... The younger students were more annoyed than the older ones. The participants claimed that chatter in the classroom and scraping sounds from tables and chairs were the most annoying sound sources."	None
Maxwell, L., and G (2000)	"In the quieter condition, children scored higher than their noisier cohort on the letter-number-word recognition measure and were rated higher by their teachers on the language scale. In addition, children in the quieter classrooms were less susceptible than those in the noisy classrooms to induced helplessness."	None
Meis, M., S. Hygge, G. Evans, and M. Bullinger (1998)	"The main hypothesis of three experiments was confirmed: it was demonstrated that discontinuous traffic noise leads to reduced memory performance if the instructions are explicit, so that the nature of the effects induced by traffic noise on implicit and explicit memory are dissociative."	None

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Muller F., E. Pfeiffer, M. Jilg, R. Paulsen, and U. Ranft (1998)	"The finding that performance of the discrimination and vigilance task is improved in noise points on the activating property of sound either due to enhanced arousal, or caused by increased effort in order to overcome the compound working conditions. The performance in the d2 test, which to a high degree requires sustained focused attention and concentrative power, is worse for children in the noise area. The observation that this effect is more pronounced when related to the night-time sound levels leads to the assumption that the concentration deficits are caused by a lack of sufficient sleep for the children who presumably need to invest more fatiguing effort to meet the daily demands than children living in quiet areas. In this study no indications of coping strategies were found."	None
Nelson. P., K. Kohnert, S. Sabur, D. Shaw (2005)	"In contrast to the original hypothesis, results from Study 1 revealed no significant differences in on-task behavior between L2 learners and their monolingual peers, and no difference between pre- and post amplification measures."	None
Nelson. P., K. Kohnert, S. Sabur, D. Shaw (2005)	"The primary finding from the current study is that in noisy classrooms in which the target voice occurs at +10 dB SNR or less, processing linguistic information in English will be significantly more challenging for typically developing L2 learners as compared to their monolingual peers. These combined sources thus suggest that linguistically diverse children receiving primary instruction in English in typical classroom conditions do, in fact, experience double jeopardy with respect to the negative impact of noise."	"Classrooms that meet the standard [ANSI S12.60-2002] will provide SNRs that will be more favorable than +10 dB (that was shown to be insufficient here for L2 learners) and should allow optimal listening conditions for all students."
Neuman A., M. Wroblewski, J. Hajicek, A. Rubinstein (2010)	"Results highlight changes in speech recognition performance with age in elementary school children listening to speech in noisy, reverberant classrooms. The more reverberant the environment, the better the SNR required. The younger the child, the better the SNR required."	"To obtain average speech recognition scores of 95% at the back of the classroom, an SNR 10 dB is required for all children at the lowest reverberation time, of 12 dB for children up to age 11 yrs at the 0.6-sec reverberant condition, and of 15 dB for children aged 7 to 11 yrs at the 0.8-sec condition. The youngest children require even higher SNRs in the 0.8-sec condition."

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Authors (Pub. Year)	Finding	Suggested Criteria
Ohrstrom, E., Hadzibajramovic, E., Holmes, M., et al (2006)	"Conclusions based on present knowledge and the results of this study are that children have better perceived sleep quality and lower number of awakenings than parents, whereas there is no evidence of a difference in terms of difficulties falling asleep and alertness in the morning between children and parents."	
Ristovska, G., D. Gjorgjev, and N. Pop Jordanova (2004)	"Children exposed to LAeq, 8 h>55 dBA had significantly decreased attention (Z=-2.16; p=0.031), decreased social adaptability (Z =-2.16; p=0.029), and increased opposing behavior in their relations to other people (Z=-3; p=0.001).We did not find any correlation between socio-economic characteristics and development of psychosocial effects."	None
Sanz S., A. M. Garcia, and A. Garcia (1993)	"Test results were consistently better (both for tests and for children from different classrooms in each school) in the quiet school Exposure to high traffic noise levels in the noisy school over the whole school year is a plausible determinant of these results."	None
Sargent, J.W., M.I. Gidman, M.A. Humphreys and W.A. Utle (1980)	"Above an external road traffic noise level of 60 dB(A) L10 there is an increase in the response to questions about noise in general and a higher percentage of teachers consider the classroom to be an unsatisfactory working environment. Also, for the survey sample as a whole, a higher proportion of teachers were bothered by road traffic noise than by any internal noise source above an external road traffic noise level of about 60 dB(A) L10. ... There appears to be little difference between the proportion of teachers bothered by road traffic noise and the proportion bothered by aircraft noise at a given level of Leq dB(A)."	None

APPENDIX B. Catalog of Research Studies—Subjects

Authors (Pub. Year)	Finding	Suggested Criteria
Sato, H. and J. Bradley (2008)	"In the measured classrooms, excessive noise levels were a much more significant problem than poor room acoustics. ... Excessive noise levels make it impossible to achieve ideal signal-to-noise ratios and near ideal speech communication conditions. ... Student activity is the dominant noise source in active classrooms even when the children are quite well behaved."	None
Shield B., J. Dockrell, R. Jeffery, and I. Tachmatzidis (2001)	"Data from noise surveys, analysis of SATs results, children's reports and experimental studies provide converging evidence that noise levels influence children's performance and can negatively impact on their attainments."	None
Shield, B. and J. Dockrell (2004)	"A survey of noise levels outside 142 primary schools in 3 London boroughs has shown that the average LAeq, measured over a typical 5 min period during the school day, is approximately 57 dBA. … The predominant noise source outside the London schools surveyed was road traffic, in particular, cars, which could be heard outside 86% of the schools. ... The noise inside classrooms is, in general, dominated by the noise of children and depends upon the particular classroom activity in which they are engaged, there being a range of approximately 20 dBA between the quietest and noisiest activity."	None
Shield, B. and J.Dockrell (2008)	"This study has shown that chronic exposure to both external and internal noise has a detrimental impact upon the academic performance and attainments of primary school children. For external noise it appears to be the noise levels of individual events that have the most impact while background noise in the classroom also has a significant negative effect. Older primary school children, around 11 years of age, appear to be more affected by noise than the younger children."	None

APPENDIX B. Catalog of Research Studies—Subjects

Authors (Pub. Year)	Finding	Suggested Criteria
Stansfeld, S. A. B. Berglund, C. Clark, I. Lopez-Barrio, et. al. (2005)	"Our findings indicate a linear exposure-effect association between exposure to aircraft noise and impaired reading comprehension and recognition memory in children, and between exposure to road traffic noise and increased functioning of episodic memory, in terms of information and conceptual recall. Our results also show non-linear and linear exposure-response associations between aircraft and road traffic noise, respectively, and annoyance. Neither aircraft noise nor road traffic noise affected sustained attention, self-reported health, or mental health."	None
Stansfeld, S. A. B. Berglund, C. Clark, I. Lopez-Barrio, et. al. (2005)	"Our findings indicate a linear exposure-effect association between exposure to aircraft noise and impaired reading comprehension and recognition memory in children, and between exposure to road traffic noise and increased functioning of episodic memory, in terms of information and conceptual recall. Our results also show non-linear and linear exposure-response associations between aircraft and road traffic noise, respectively, and annoyance. Neither aircraft noise nor road traffic noise affected sustained attention, self-reported health, or mental health."	None
Stansfeld, S. A. B. Berglund, C. Clark, I. Lopez-Barrio, et. al. (2005)	"Our findings indicate a linear exposure-effect association between exposure to aircraft noise and impaired reading comprehension and recognition memory in children, and between exposure to road traffic noise and increased functioning of episodic memory, in terms of information and conceptual recall. Our results also show non-linear and linear exposure-response associations between aircraft and road traffic noise, respectively, and annoyance. Neither aircraft noise nor road traffic noise affected sustained attention, self-reported health, or mental health."	None

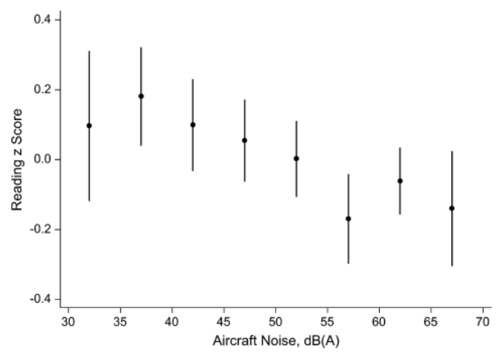
APPENDIX B. Catalog of Research Studies—Subjects

Authors (Pub. Year)	Finding	Suggested Criteria
Stansfeld, S. A., C. Clark, , R. Cameron, T. et. al. (2009)	"This study showed no effects of aircraft noise or road traffic noise on children's overall mental health measured by the Strengths and Difficulties Questionnaire. ... However, higher levels of aircraft noise were associated with higher scores on the hyperactivity subscale and higher levels of road traffic noise exposure were associated with lower scores on the conduct problems subscale."	None
Wålinder. R., K.Gunnarsson, R. Runeson, G. Smedje (2007)	"In conclusion, by considering noise in the classroom as either a direct stressor or a proxy variable for other troublesome conditions, we found positive correlations between equivalent sound levels and symptoms of fatigue, headache, and reduced diurnal cortisol variability."	None
Yang, W. and J. Bradley (2009)	"For conditions of constant signal-to-noise ratio, intelligibility scores increased with decreasing reverberation time. However, for conditions including realistic increases in speech level with varied reverberation time for constant noise level, intelligibility scores were near maximum for a range of reverberation times. Young children's intelligibility scores benefited from added early reflections of speech sounds similar to adult listeners. The effect of varied reverberation time on the intelligibility of speech for young children was much less than the effect of varied signal-to-noise ratio."	None

APPENDIX C. GAPS IN KNOWLEDGE

TABLE C-1 Answering the Research Questions.

1. *To what extent is student learning affected by aircraft noise?*

Finding related to the research question	Reference
• "In the adjusted model, as noise increased by 5 dB(A), performance on the reading test (measured by z scores) decreased by -0.040 marks for the overall sample." • "In the Netherlands and Spain, a 20-dB(A) increase in aircraft noise was associated with a decrement of one eighth of a standard deviation on the reading test; in the United Kingdom, the decrement was one fifth of a standard deviation."  **FIGURE 1.** Adjusted mean reading *z* scores and 95% confidence intervals for 5-dB(A) bands of aircraft noise at school (adjusted for age, gender, and country), the RANCH project, 2001–2003. dB(A), a measure of sound level in decibels A-weighted to approximate the typical sensitivity of the human ear.	Clark, Charlotte, R. Martin, E. van Kempen, T. Alfred1, J. Head, H. W. Davies, M. M. Haines, I. Lopez Barrio, M. Matheson and S. A. Stansfeld. (2005). Exposure-Effect Relations between Aircraft and Road Traffic Noise Exposure at School and Reading Comprehension. American Journal of Epidemiology Volume 163, Number 1 Pp. 27-37.
• "This analysis, which includes only those children who failed the second puzzle, indicates that the failures of noise-school children were associated with giving up (31% of those who failed gave up) more often than the failures of quiet-school children were (7% of those who failed gave up)" • "It should be noted that the failure of the present study to replicate the previously reported relationship between community noise and reading ability (Bronzaft & McCarthy, 1975; S. Cohen et al, 1973) may be attributable to an experimental design insensitive to noise-induced differences in school achievement."	Cohen, S., G. Evans, and D. Stokol. (1980). Physiological, motivational, and cognitive effects of aircraft noise on children. American Psychologist, 35, 231-243.
• "The present analyses also suggest that noisy-school children were poorer	Cohen, S., G. Evans, D. Krantz, D. Stokols, and

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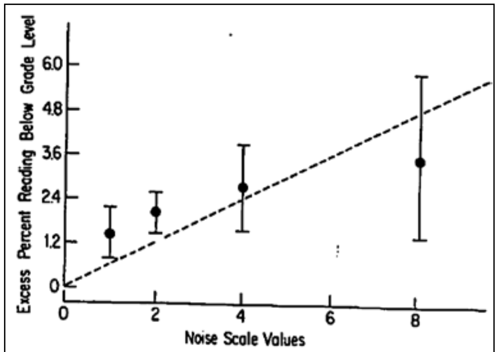
Finding related to the research question	Reference
than quiet-school children at solving the test puzzle at both testing periods. However, the increased "giving up" on the part of the noisy- as opposed to quiet-school children found in the analysis of the entire T1 sample was not found in the present study. This lack of such an effect may have occurred because of subject attrition, because the children had had a previous experience with the same puzzle, or because the effect disappeared, that is, adapted out over time."	S. Kelly. (1981). Aircraft noise and children: Longitudinal and cross-sectional evidence on adaptation to noise and the effectiveness of noise abatement. J. Pers Soc. Psychol. Vol.40, No. 2:331–345.
• "On the long-term recall task, children from noisy communities performed worse than their counterparts" • "… children from noisy communities had significantly more errors on the text subscale of the German standardized reading test than children from quiet communities. On the word list subscale, children from the noisy and quiet areas differed on the most difficult section of the test" • "Children from noisy communities persisted less than children from quiet communities on the insoluble puzzle in the aftereffects task" • "Children living in noisier areas were significantly more annoyed by the noise in their communities, as indexed by calibrated community measures".	Evans, G., S. Hygge and M. Bullinger. (1995). Chronic Noise and Psychological Stress. Psychological Science. Vol. 6 No. 6, Nov. 1995.
"Chronic noise exposure is significantly correlated with reading scores ($r=-.58$, $p <.001$)".	Evans, G. and L. Maxwell. (1997). Chronic noise exposure and reading deficits: the mediating effects of language acquisition. Environ. Behav. 29, 638–656.
"The regression coefficients indicate that an additional 3.6% of the students in the noisiest schools read at least 1 year below grade level with 95% confidence limits from 1.5% to 5.8%. The dose-response relationship suggests that the percent reading below grade level increases with increasing noise level."	Green, K.B., B. Pastenak, and R. Shore. (1982). Effects of aircraft noise on reading ability of school age children. Archives of Environmental Health, 37, 24-31.

APPENDIX C. GAPS IN KNOWLEDGE

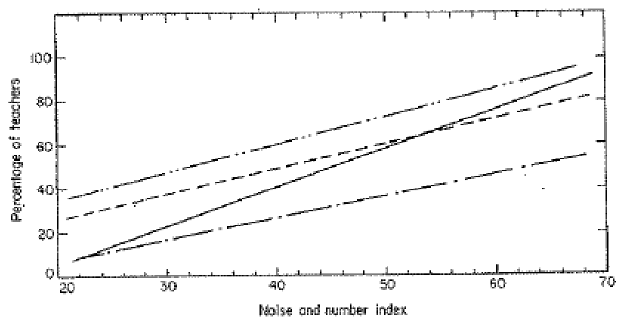
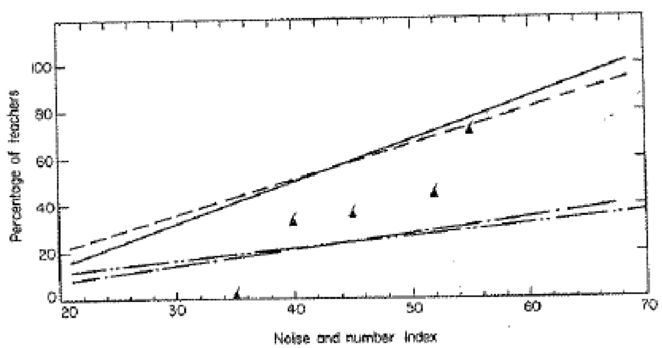
Finding related to the research question	Reference
 Fig. 2. Dose-response relationship between aircraft noise scale values	
• "Chronic exposure to high levels of aircraft noise was associated with higher levels of annoyance in the analyses of the eight schools". • "However, in the seven schools, children in the four high noise exposed schools had poorer reading comprehension than children in the three low-noise schools … This difference in mean performance is equivalent to 6 months delay in reading ability." • "However, in the seven schools, children in the four HN exposed schools had poorer long-term memory recognition than children in the three LN schools." • "Chronic exposure to aircraft noise had no significant effect on recall performance and short-term memory and recognition (in the analyses of the eight schools)." • "The HN and LN exposed groups did not differ in level of motivation measured by the Glass and Singer performance measures of motivation." • "The HN and LN exposed groups did not differ in child self-reported attributional style and teacher ratings motivation".	Haines, M, S. Stansfeld, R. Job, B. Berglund, and J. Head. (2001a). Chronic aircraft noise exposure, stress responses, mental health and cognitive performance in school children. Psychological Medicine, 2001, Vol. 31: 265-277.
• "High and low noise exposed children did not differ in cognitive performance across all the functions measured: mean reading comprehension , immediate recall, delayed recall and recognition memory, sustained attention and serial backward digit recall." • "Children in high noise schools had significantly poorer performance than children in the control schools on the difficult items on the reading test	Haines, M, S. Stansfeld, S. Brentnall, J. Head, B. Berry, M. Jiggins, and S. Hygge. (2001b). The West London Schools Study: the effects of chronic aircraft noise exposure on child health. Psychological Medicine, 2001, Vol. 31: 1385-1396.

APPENDIX C. GAPS IN KNOWLEDGE

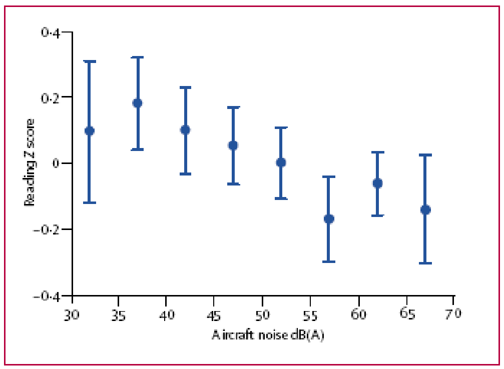
Finding related to the research question	Reference
[Suffolk Reading Scale]. When this analysis was re-run using multi-level modeling, the same results were obtained and the difference was still significant." • "Annoyance levels to aircraft noise were significantly higher among children in the high noise schools compared to the low-noise schools." • "Unexpectedly, aircraft noise was weakly associated with hyperactivity and psychological morbidity measured by the Strengths and Difficulties Questionnaire (SDQ) …"	

• "the association between chronic aircraft noise exposure and reading comprehension, noise annoyance and mental health were replicated at follow-up"
  o "Chronic exposure to high levels of aircraft noise was associated with higher levels of annoyance in the analyses of the eight schools."
  o "Chronic exposure to aircraft noise was associated with higher perceived stress."
  o "The two groups did not significantly differ in mean scores of anxiety and depression".
  o "Chronic exposure to aircraft noise had no significant effect on reading comprehension in the analyses of the eight schools. However, in the seven schools, children in the four high-noise exposed schools had poorer reading comprehension than children in the three low-noise schools."
  o "Chronic exposure to high levels of aircraft noise was associated with poorer sustained attention in the eight schools."
• Within-subject analyses – the effects of noise over time
  o "However, after further adjustments are made for age, main language spoken and deprivation, the difference in reading comprehension in both the seven and eight schools fails to reach significance. The inability to find a significant effect after full adjustment might be due to a reduction in statistical power, because of a drop in sample size."
  o "This [noise annoyance] did not remain significant after further adjustment for age, deprivation and main language spoken. There was
	Haines, M., S. Stansfeld, R. Job, B. Berglund, and J. Head. (2001c). A follow-up study of effects of chronic aircraft noise exposure on child stress responses and cognition. International Journal of Epidemiology 2001. Vol. 30: 839-845.

APPENDIX C. GAPS IN KNOWLEDGE

Finding related to the research question	Reference
no significant effect in the seven schools."	
"Chronic exposure to aircraft noise was significantly related to poorer reading and mathematics performance. After adjustment for the average socio-economic status of the school intake (measured by percentage of pupils eligible for free school meals) these associations were no longer statistically significant."	Haines, M., S. Stansfeld, J. Head and R. F. S. Job. (2002). Multi-level modeling of aircraft noise on performance tests in schools around Heathrow Airport London. Journal of Epidemiology and Community Health 2002; Vol. 56:139–144.
"The speech interference and teaching interference due to aircraft noise are found to be the most severe disruption experienced by the teachers."  Figure 6. Percentages of teachers reporting disruption of verbal communication. ——, "Speech interference"; – – –, "raise voice"; —·—, "shout"; —··—, "pause".  Figure 7. Percentages of teachers reporting disruption of teaching. ——, "Teaching interference"; – – –, "continuation"; —·—, "concentration"; —··—, "change teaching method" ("very" + "moderate"); ▲, "alter way you teach" [6].	Ko, N.W.M. (1979). Responses of Teachers to Aircraft Noise. Journal of Sound and Vibration 62: 277-292.
[Review of LAX, Munich, and West London studies]	Matheson, M.P., S. Stansfeld, and M. Haines.

APPENDIX C. GAPS IN KNOWLEDGE

Finding related to the research question	Reference
• "Taken together, the results from the reading tests in the Munich and West London School Studies seem to point to the same conclusion: that chronic exposure to aircraft noise impairs children's performance on difficult, and only difficult, reading test items. The results from the Los Angeles study are probably anomalous and attributable to experimental design." • "Taken together these results do not carry a clear message as to whether noise exposure has an effect on episodic memory." • "Taken together, these results do not provide evidence for an effect of chronic noise exposure on working memory." • "Taken together, these results would appear to provide evidence for an effect of chronic noise exposure on attention."	(2003) The effects of chronic aircraft noise exposure on children's cognition and health: 3 field studies. Noise and health. (5) 31-40.
 *Figure 1:* Adjusted mean reading Z score (95% CI) for 5 dB bands of aircraft noise (adjusted for age, sex, and country) • "A 5 dB difference in aircraft noise was equivalent to a 2-month reading delay in the UK and a 1-month reading delay in the Netherlands. There are no national data available for Spain. In the Netherlands and Spain, a 20 dB increase in aircraft noise was associated with a decrement of one-eighth of an SD on the reading test; in the UK the decrement was one-fifth of an SD." • "Aircraft noise was also not associated with impairment in working memory, prospective memory, or sustained attention." • "With respect to health effects, increasing exposure to both aircraft noise and road traffic noise was associated with increasing annoyance responses in	Stansfeld, S. A. B. Berglund, C. Clark, I. Lopez-Barrio, P. Fischer, E. Öhrström, M. M. Haines, J. Head, S. Hygge, I. van Kamp, B. F. Berry, on behalf of the RANCH study team. (2005) Aircraft and road traffic noise and children's cognition and health: a cross-national study. The Lancet Vol. 365 June 4, 2005.

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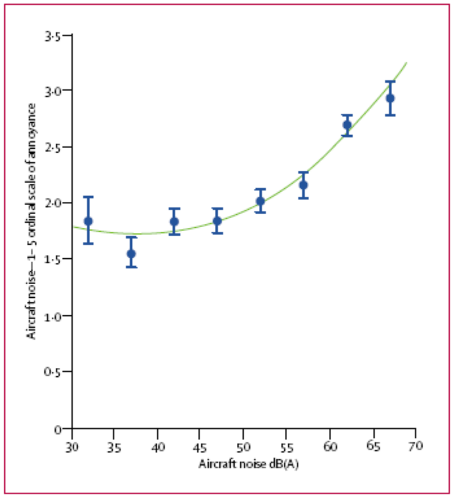
Finding related to the research question	Reference
children.”  *Figure 2:* Adjusted mean annoyance (95% CI) for 5 dB bands of aircraft noise (adjusted for age, sex, and country) and fitted curve* *Fractional polynomial curve fitted to continuous aircraft noise of form $-0{\cdot}188\times^2+0{\cdot}107\times^{2*}\log(x)$ (where x=aircraft noise/10).	

2. What is the most appropriate noise metric for describing aircraft noise as it affects learning?

Finding related to the research question	Reference
“External LAmax levels are a significant factor in reported annoyance, whereas external LA90 and LA99 levels are a significant factor in determining whether or not children hear sound sources.” (refers to road noise only)	Dockrell, J. and B. Shield. (2004). Children’s perceptions of their acoustic environment at school and at home. J. Acoust. Soc. Am., Vol. 115, No. 6, June 2004
“That substantial association was detected most “efficiently” when noise exposure was quantified as the percent time that the classroom LA exceeded 40 dB.”	FICAN. (2007). Findings of the FICAN Pilot Study on the Relationship between Aircraft Noise Reductions and Changes in Standardized Test Scores. Found at http://www.fican.org/pages/ findings.html.
"… an appropriate set of criteria for speech interference in schools is an indoor noise level of Leq of 40 dB (for intermittent noise), and a single event level of Lmax 50 dB. These criteria can be applied in the analysis of classroom noise using the Leq and NA metrics."	DNWG [Department of Defense Noise Working Group]. (2009). Improving Aviation Noise Planning, Analysis and Public Communication with Supplemental Metrics: Guide to Using Supplemental Metrics. (Found at

APPENDIX C. GAPS IN KNOWLEDGE

Finding related to the research question	Reference
	https://www.denix.osd.mil/portal/page/portal/DNWG/Documents)
Recommendation that "A SIL [speech interference level] of 50 dB for maximum overflight noise is recommended as the criterion for soundproofing school classrooms."	Sharp, B. and K. Plotkin. (1984). Selection of Noise Criteria for School classrooms. Prepared by the PONYNJ, Wyle TN 84-2, October 1984.
"From the correlations between objective and subjective data, a stronger relation has been noticed between both noise disturbance and intensity average scores and $L_{A\,max}$ levels, more than L_{Aeq} and L_{A90},"	Astolfi, A. and F. Pellerey (2008), Subjective and objective assessment of acoustical and overall environmental quality in secondary school classrooms. J. Acoust. Soc. Am. Vol 123, No. 1, January 2008

3. *What is the threshold above which the effect is observable?*

<table>
<tr><th>Finding related to the research question</th><th>Reference</th></tr>
<tr><td>"From our data it would appear that a very high level of insulation would be necessary to completely remove dissatisfaction since any flyover leaking at or above 60 dB(A) [indoors] is potentially intrusive."</td><td>Crook, M. and F. Langdon. (1974). The Effects of Aircraft Noise In Schools around London Airport. Journal of Sound and Vibration (1974) Vol. 34, No. 2:221-232.</td></tr>
<tr><td>"Exposure to 50 dB(A) in the daytime (outside) is associated with relevant learning difficulties in schoolchildren." [with reference to Bullinger M, Gray WE, Hygge S, Evans G: Chronic noise and psychological stress. Psychological Science 1995; 6: 333–8.]
<table>
<tr><th colspan="4">Protection goal: prevention of learning impairments</th></tr>
<tr><td>Critical tolerance value school attendance hours</td><td>–</td><td>55 dB(A) outdoors</td><td>Upper limit of level class with significantly increased annoyance compared to 35 to 40 dB(A). Marked impairment of reading comprehension (16).</td></tr>
<tr><td>Preventive guide value school attendance hours</td><td>40 dB(A) indoors equivalent to 55 dB(A) outdoors</td><td>50 dB(A) outdoors</td><td>Lower limit of level class with significantly increased annoyance compared to 35 to 40 dB(A). Latest onset of reading comprehension (16).</td></tr>
</table>
</td><td>Kaltenbach, M., C. Maschke, R. Klinke. (2008). Health Consequences of Aircraft Noise. Deutsches Ärzteblatt International; 105(31–32): 548–56.</td></tr>
<tr><td>Reading comprehension falls below average at exterior exposure noise levels greater than L_{Aeq16} of 55 dB</td><td>Clark, Charlotte, R. Martin, E. van Kempen, T. Alfred1, J. Head, H. W. Davies, M. M. Haines, I. Lopez Barrio, M. Matheson and S. A. Stansfeld. (2005). Exposure-Effect Relations between Aircraft and Road Traffic Noise Exposure at School and Reading Comprehension. American Journal of Epidemiology Volume 163, Number 1 Pp. 27-37.</td></tr>
</table>

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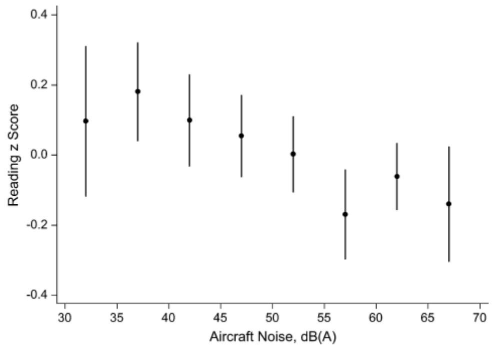

FIGURE 1. Adjusted mean reading *z* scores and 95% confidence intervals for 5-dB(A) bands of aircraft noise at school (adjusted for age, gender, and country), the RANCH project, 2001–2003. dB(A), a measure of sound level in decibels A-weighted to approximate the typical sensitivity of the human ear.

4. *We must add the RANCH exposure-effect in here – as this study was designed to look at thresholds per se. Munich study is also relevant, as any study which shows where effects are shown sheds some light on the threshold such as at what level were effects observable over.*

5. *Has insulation meeting existing classroom acoustic criteria improved student achievement?*

Finding related to the research question	Reference
• "Although there were no effects for the noise or Noise X Grade interaction on either reading achievement or auditory discrimination, there was a Grade X Noise interaction for performance on the math achievement test … third graders in abated classrooms performed substantially better than those in nonabated classrooms, whereas the reverse was true for fourth graders."	Cohen, S., G. Evans, D. Krantz, D. Stokols, and S. Kelly. (1981). Aircraft noise and children: Longitudinal and cross-sectional evidence on adaptation to noise and the effectiveness of noise abatement. J. Pers Soc. Psychol. Vol.40, No. 2:331–345.

Table 3
Mean (Adjusted) School Achievement Percentiles for Cross-Sectional (T1) Data as a Function of Classroom Noise Abatement and Grade

	Reading		Math	
Classroom	3rd grade	4th grade	3rd grade	4th grade
Noisy	30.30	35 96	34.35	39 35
Abated	47 36	37.90	56.24	37 54
Quiet	37 85	39.09	36.96	42.76

APPENDIX C. GAPS IN KNOWLEDGE

Finding related to the research question	Reference
• “Analysis of the distraction task data indicated no significant effects.	
• “When that noise exposure decreased by 5 percentage points, the associated improvement was a substantial 20- percentage-point decrease in failure rate (with 99% certainty).” • “Measured by the percent time LA was greater than 40 dB, all subgroups showed modest average-score improvement – between 7 and 9 percentage points, when this noise exposure decreased by 5 percentage points.” • “…, when measured by the number of events with LAmax greater than 40 dB, middle and elementary students showed modest average-score improvement – between 4 and 5 percentage points, when the number of such events decreased by 20.”	FICAN. (2007). Findings of the FICAN Pilot Study on the Relationship between Aircraft Noise Reductions and Changes in Standardized Test Scores. Found at http://www.fican.org/pages/ findings.html.

6. *How does aircraft noise affect learning for students with different characteristics?*

Finding related to the research question	Reference
“The effect of aircraft noise exposure on reading comprehension remained when the model was further adjusted for dyslexia, hearing impairment, and acute noise during testing, …”	Clark, Charlotte, R. Martin, E. van Kempen, T. Alfred1, J. Head, H. W. Davies, M. M. Haines, I. Lopez Barrio, M. Matheson and S. A. Stansfeld. (2005). Exposure-Effect Relations between Aircraft and Road Traffic Noise Exposure at School and Reading Comprehension. American Journal of Epidemiology Volume 163, Number 1 Pp. 27-37.
“This study found moderate association between noise reduction and change in top-score rates, mainly for IEP [Individualized Education Program] students on verbal tests. For those, a 5-point decrease in “percent time LA was greater than 40 dB” was associated with reduction in the top-score rate by 5 percentage points.”	FICAN. (2007). Findings of the FICAN Pilot Study on the Relationship between Aircraft Noise Reductions and Changes in Standardized Test Scores. Found at http://www.fican.org/pages/ findings.html.
“The results of the stratified analyses indicate that for reading and annoyance there was no difference in the size of the noise effect between: boys and girls, white and non-white, English and Non-English as the main language spoken at home, children in employed and unemployed households, children in deprived and not deprived households.”	Haines, M, S. Stansfeld, S. Brentnall, J. Head, B. Berry, M. Jiggins, and S. Hygge. (2001b). The West London Schools Study: the effects of chronic aircraft noise exposure on child health. Psychological Medicine, 2001, Vol. 31: 1385-1396.

APPENDIX C. GAPS IN KNOWLEDGE

TABLE C-2 Knowledge Gaps with Respect to the Research Questions.

1. *To what extent is student learning affected by aircraft noise?*
2. *What is the threshold above which the effect is observable?*

Research recommendation related to the research question	Reference
"Future research needs to further develop understanding not only of the magnitude of effects and exposure-effect relationships, which can inform interventions and policy, but also needs to further consider mechanisms for the effects such as the role of annoyance, adaptation, habituation, acclimation, and coping strategies and the role these may play in non-auditory effects of noise."	Clark, C and Sa A. Stansfeld. (2007). The Effect of Transportation Noise on Health and Cognitive Development: A Review of Recent Evidence. **International Journal of Comparative Psychology**, 2007, Vol. 20, 145-158.
• "The current research has not examined the psycholinguistic mechanisms that may underlie the effect, and further research on psycholinguistic mechanisms will inform the design of educational and environmental interventions for children in schools exposed to high levels of aircraft noise." • "It was not possible to fully establish the relative contribution of home and school exposure over a full 24- hour period to cognitive deficits in children in this study, and this is an important challenge for future research." • "While the Munich study (12) demonstrated that the effects of aircraft noise exposure on reading comprehension are reversible if the noise ceases, studies have yet to examine the long-term developmental consequences of exposure that persists throughout a child's education. Demand for air travel continues to increase, and further knowledge about cumulative exposure would inform intervention strategies and policy decisions."	Clark, Charlotte, R. Martin, E. van Kempen, T. Alfred1, J. Head, H. W. Davies, M. M. Haines, I. Lopez Barrio, M. Matheson and S. A. Stansfeld. (2006). Exposure-Effect Relations between Aircraft and Road Traffic Noise Exposure at School and Reading Comprehension. **American Journal of Epidemiology** Volume 163, Number 1 Pp. 27-37.
"When a full examination of the relationship between aircraft noise exposure and cognitive functioning in children in a school environment would be called for, it is recommended; 1) to conduct an extensive study employing at least 500 children, 2) to draw groups from schools comparable in terms of size, class size, teaching method, and type of students, 3) to select children with a maximum contrast in noise exposure levels, 4) to determine the individual aircraft noise exposure of each child, and 5) to limit the selection of tests to those which show high test-retest reliabilities and good acceptance by the children and their parents. A combination of methods, testing different aspects of cognitive and psycho-motor functioning and behavior is required (including memory, reading ability etc.) ."	Emmen, H.,B. Staatsen, P. Fischer, and I. Kamp, IV. (2001). Neurobehavioral Measurements in Children Living Around Schiphol Airport; Further Methodological Considerations. *Proceedings of the International Congress and Exhibition on Noise Control Engineering*. Vol. 2001.
"This research area is now at a stage where more rigorous, prospective longitudinal studies are necessary, along with more analyses of underlying cognitive and social processes that can account for the adverse affects of chronic noise exposure on human health and development."	Evans, G. and L. Maxwell. (1997). Chronic noise exposure and reading deficits: the mediating effects of language acquisition. **Environ. Behav.** 29, 638–656.
• "Clearly more research needs to test the hypothesized mediational pathway between chronic exposure to environmental stressors and adverse mental health outcomes." • "More motivation research needs to examine a wider range of stressor intensity since	Evans, G. and R. Stecker. (2004). Motivational consequences of environmental stress. **Journal of Environmental Psychology** 24 (2004) 143–165.

APPENDIX C. GAPS IN KNOWLEDGE

Research recommendation related to the research question	Reference
nearly all studies have examined high versus low stressor conditions." • "More research is called for to assess children's motivation under poor environmental conditions at home and in school." • "The potential linkages between such deficits and other behavioral endpoints of concern including cognitive development (e.g. reading acquisition, scholastic achievement) or psychological well being (e.g. depression) warrant further examination."	
• "Airports and schools. Include a larger number of airports and schools." • "Students. Follow individual students from year to year, rather than using only class-average results. … if scores of individual students were followed from grade to grade, such an analysis would intrinsically offer better precision." • "Testing location. Determine which tests were actually given in "teaching" classrooms and which were given elsewhere. Such knowledge would help distinguish between chronic and acute noise stress." • "Precision of noise computations. Obtain airport data directly from airports. Also incorporate actual outdoor-to-indoor measurements at each school."	FICAN. (2007). Findings of the FICAN Pilot Study on the Relationship between Aircraft Noise Reductions and Changes in Standardized Test Scores. Found at http://www.fican.org/pages/findings.html.
"Taken together, the next step should be to confirm these findings by further research and to understand the mechanisms underlying the increased stress and impaired cognitive performance associated with chronic exposure to aircraft noise."	Haines, M, S. Stansfeld, R. Job, B. Berglund, and J. Head. (2001a). Chronic aircraft noise exposure, stress responses, mental health and cognitive performance in school children. **Psychological Medicine**, 2001, Vol. 31: 265-277.
"The next step for future research is to examine the dose-response relationship between aircraft noise exposure and child annoyance with a standardized child annoyance scale."	Haines, M, S. Stansfeld, S. Brentnall, J. Head, B. Berry, M. Jiggins, and S. Hygge. (2001b). The West London Schools Study: the effects of chronic aircraft noise exposure on child health. **Psychological Medicine**, 2001, Vol. 31: 1385-1396.
"Future research with an international sample of children should use larger sample, conduct in-depth interviews, and measure cultural expectations of ideal noise exposure in environments."	Haines, M., S. L. Brentnall, S. A. Stansfeld, and E. Klineberg. (2003). Quantitative Responses of Children to Environmental Noise. **Noise & Health** 2003. Vol. 5:19-30.
• "As a priority, future research ought to address the main question that these results beg: to understand to what extent does noise exposure adversely affect child school performance over and above the influence of socio-economic status on performance? Future research should be conducted concurrently with detailed theoretical consideration of the nature of the pathways between socio-economic status, noise exposure, and performance." • "Future studies need to sample a sufficient enough number of schools so that both school level and individual level factors can be adjusted for accordingly with multi-level modelling statistical techniques."	Haines, M., S. Stansfeld, J. Head and R. F. S. Job. (2002). Multilevel modeling of aircraft noise on performance tests in schools around Heathrow Airport London. **Journal of Epidemiology and Community Health** 2002; Vol. 56:139–144.
• "Further research should test and refine the other theories to account for these reading effects, especially testing psycholinguistic mechanisms where there is preliminary evidence of mediation by impairment of speech perception and auditory	Haines, M., S. Stansfeld, R. Job, B. Berglund, and J. Head. (2001c). A follow-up study of effects of chronic aircraft noise exposure on child stress responses and cognition**. International**

APPENDIX C. GAPS IN KNOWLEDGE

Research recommendation related to the research question	Reference
discrimination." • "Noise annoyance remains constant over a year with no strong evidence of habituation. Further research should look at the long-term implications of these effects and examine further underlying mechanisms."	**Journal of Epidemiology** 2001. Vol. 30: 839-845.
• "Future research needs to address the importance of both the developmental timing and the duration of noise exposure in determining the effect of noise on reading and cognitive development." • "Research also needs to sample a wider range of noise levels in order to generate a dose-response function for reading, which would provide additional basic evidence and better inform public policy for noise protection of children."	Hygge, S., G. Evans, and M. Bullinger. (2002) A prospective Study of Some Effects of Aircraft on cognitive Performance in Schoolchildren. **Psychological Science**. Vol. 13, No. 2: 469-474.
• "It is largely recommended that future research needs to focus on longitudinal studies, to assess the long-term effects of chronic aircraft noise exposure on learning and cognitive ability in children. • "It would be useful to include measures of noise levels at home as well as at school. This would allow for the relative contribution of noise exposure at home to be assessed as well as at school, and allow for comparison between the two."	Jones, K. (2010). Aircraft Noise and Children's Learning. Environmental Research and Consultancy Department, UK CAA, ERCD Report 0908. Feb. 2010.
• "In particular, research must examine whether the effects which have been observed in the existing research persist over time, or whether children are able to adapt to noise and catch up with their non-noise-exposed counterparts." • "Another direction in which research should be taken is to address dose-response relationships. At what levels of noise do effects appear? This of course may be different for different noise sources." • "The issue of the effects of chronic noise exposure on sleep was not examined in any of the three studies here discussed. This is however an important area which requires further research."	Matheson, M.P., S. Stansfeld, and M. Haines. (2003) The effects of chronic aircraft noise exposure on children's cognition and health: 3 field studies. **Noise and health**. (5) 31-40.
"However, as the internal classroom noise depends on classroom activity, it could be assumed that internal levels in other schools would be similar to those in schools in urban areas. Further investigation is needed to examine noise levels in schools in suburban and rural areas for comparison with urban schools."	Shield, B. and J. Dockrell. (2004). External and internal noise surveys of London primary schools. **J. Acoust. Soc. Am**. 115 (2), February 2004.
"Further field and experimental studies are required to determine the levels at which different types of external and internal noise affect children's academic performance in different circumstances."	Shield, B. and J.Dockrell. (2008). The effects of environmental and classroom noise on the academic attainments of primary school children. **J Acoust Soc Am.** 2008 Jan;123(1):133-44.
• "Adaptation to long-term noise exposure needs further study. Most people exposed to chronic noise, for instance from major airports, seem to tolerate it. Yet, questionnaire studies suggest that high levels of annoyance do not decline over time. Another possibility is that adaptation to noise is only achieved with a cost to health." • "Undoubtedly, there is a need for further research to clarify this complex area, including	Stansfeld, S. A. and M .P. Matheson. (2003). Noise pollution: non-auditory effects on health. **British Medical Bulletin** 2003; 68: 243–257.

APPENDIX C. GAPS IN KNOWLEDGE

Research recommendation related to the research question	Reference
better measurement of noise exposure and health outcomes. Moreover, there should be a greater emphasis on field studies using longitudinal designs with careful choice of samples to avoid undue bias related to prior noise exposure."	
"Further research is needed to understand the psychological mechanisms of these cognitive effects. Children might adapt to noise interference during activities by filtering out the unwanted noise stimuli. This tuning out strategy might over generalise to situations where noise is not present, such that children tune out stimuli indiscriminately."	Stansfeld, S. A. B. Berglund, C. Clark, I. Lopez-Barrio, P. Fischer, E. Öhrström, M. M. Haines, J. Head, S. Hygge, I. van Kamp, B. F. Berry, on behalf of the RANCH study team. (2005) Aircraft and road traffic noise and children's cognition and health: a cross-national study. **The Lancet** Vol 365 June 4, 2005.
"Most child noise research has been exploratory and cross-sectional, which means that future research should examine the explanatory power of these cognitive and motivation mechanisms [teacher frustration, communication problems, learned helplessness]. In addition, the inter-relation between psychophysiological responses and cognitive noise effects must be examined."	Stansfeld, S. A., Haines, M. M. & Brown, B. (2000) Noise and health in the urban environment. *Reviews of Environmental Health*, 15, 43:82.
"In future, studies should be carried out on whether cognitive impairments diminish and annoyance and/or blood pressure elevations reduce if children are removed from noisy environments, or whether these effects increase if children remain in noisy environments."	van Kempen, E. (2008). *Transportation noise exposure and children's health and cognition*. (Doctoral thesis, University of Utrecht, The Netherlands).
"Based on our study it is not possible to draw definite conclusions about the relative importance of noise exposure at home and at school and possible interactions. For a better understanding of the underlying mechanisms, more research is necessary to disentangle the effects of home and school noise exposure."	van Kempen, E., I. Van Kamp, .P Fischer, H. Davies, D. Houthuijs, R. Stellato, C. Clark, S. Stansfeld. (2006). Noise exposure and children's blood pressure and heart rate: the RANCH project. **Occupational and Environmental Medicine** 2006; Vol. 63:632–639.

3. *What is the most appropriate noise metric for describing aircraft noise as it affects learning?*

Research recommendation related to the research question	Reference
"Metrics. Further work should be done to establish whether school day Leq is the appropriate measure for determining the effect of aircraft noise on classroom learning. An important question is the role of classroom interruptions. … At what indoor sound level does a teacher pause? Is SEL the best predictor of interruption?	FICAN. (2000). FICAN Position on Research into Effects of Aircraft Noise on Classroom Learning.
"The analysis suggested that children are particularly affected by the noise of individual external events"	Shield, B. and J.Dockrell. (2008). The effects of environmental and classroom noise on the academic attainments of primary school children. **J Acoust Soc Am.** 2008 Jan;123(1):133-44.

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4. Has insulation meeting existing classroom acoustic criteria improved student achievement?

Research recommendation related to the research question	Reference
"… the potential protective effect of classroom insulation against noise, and what children and teachers can do to overcome these effects deserve further inquiry."	Stansfeld, S. A. B. Berglund, C. Clark, I. Lopez-Barrio, P. Fischer, E. Öhrström, M. M. Haines, J. Head, S. Hygge, I. van Kamp, B. F. Berry, on behalf of the RANCH study team. (2005) Aircraft and road traffic noise and children's cognition and health: a cross-national study. **The Lancet** Vol 365 June 4, 2005
Recommendation that follow-up studies should include a larger number of airports and schools, follow individual students from year to year, determine which tests were given in "teaching" classrooms and which were given elsewhere, and improve the precision of the noise computations.	FICAN. (2007). Findings of the FICAN Pilot Study on the Relationship between Aircraft Noise Reductions and Changes in Standardized Test Scores. Found at http://www.fican.org/pages/findings.html.

5. How does aircraft noise affect learning for students with different characteristics?

Research recommendation related to the research question	Reference
"Future work will need to specify the bases for developmental changes and physical and locational factors that determine the school effects."	Dockrell, J. and B. Shield. (2004). Children's perceptions of their acoustic environment at school and at home. **J. Acoust. Soc. Am.**, Vol. 115, No. 6, June 2004
"In addition to studies with stronger research designs examining the role of environmental qualities in child development, more work is needed on underlying mechanisms to account for developmental impacts of the physical environment. Prime candidates include parent-child interaction and other interpersonal processes, self-regulation, physiological adaptations, and control beliefs. This work should investigate how the intensity—but also the predictability and continuity of such mechanisms—is altered by the physical environment. In addition to examining the role of age, other moderators warranting attention are gender, temperament, nutrition, intelligence, and prematurity."	Evans, G. (2006) Child Development and the Physical Environment. **Annual Review of Psychology**. 2006. 57:423–51.
" More detailed exploration of the mechanisms underlying the development of memory, attention and reading processes is needed, and how exposure to noise affects these."	Jones, K. (2010). Aircraft Noise and Children's Learning. Environmental Research and Consultancy Department, UK CAA, ERCD Report 0908. Feb. 2010.

APPENDIX D. Development of Alternative Research Designs

D.1. Datum—Macro-Analysis (Top 60 Airports)

Description

The plan is to conduct a nationwide macro-analysis of the relationship between noise exposure and student performance taking into account the effect of school sound insulation and other confounding factors. We will use the top 60 airports on the US MAGENTA airports list; sorted by the number of schools exposed to DNL 55 dB and higher. Our student performance measure is the standardized test scores (reading and mathematics) available from the NLSLSACD.

Outcomes

This plan answers the project research questions as follows:

1. *To what extent is student learning affected by aircraft noise?*

We will examine the exposure-effect association between aircraft noise level and standardized test scores to quantify the magnitude of the noise-induced impairment and to discover a statistically significant relationship between test scores and aircraft noise. However, there is a chance that we will not find an effect above DNL 65 due to small sample of schools.

2. *What is the most appropriate noise metric for describing aircraft noise as it affects learning?*

Through modeling, we will have a variety of aircraft noise metrics to analysis with standardized test scores to find the best metric-score correlation.

3. *What is the threshold above which the effect is observable?*

The critical statistic to answer this question will be the differences in mean test scores between target schools at varying levels of aircraft noise and control schools (not exposed to aircraft noise). The key assumption in being able to answer this question is that the effect of aircraft noise on learning becomes significant near or above DNL 55 dB.

4. *Has insulation meeting existing classroom acoustic criteria improved student achievement?*

Two analyses will supply the answer. A before-and-after analysis will provide the difference in mean test scores before and after insulation. A comparison with control schools will provide the difference in mean scores between insulated schools at varying levels of aircraft noise and control schools.

5. *How does aircraft noise affect learning for students with different characteristics?*

The answer will come from analyses of subpopulations of students in each school, by race, gender, poverty level, grade, English proficiency, learning disability, and proficiency on the standardized tests when these subpopulation sizes are sufficient.

Methods

<u>1. Airport Selection</u>

The scope of this effort is the top 60 airports from the FAA's US MAGENTA list found in the Overview as ranked by the number of public schools exposed to DNL 55 dB or higher in 2000.

2. School Selection

School information will be obtained from the CCD.
After a preliminary examination of our databases, we find the numbers of target schools (public schools exposed to aircraft noise) around the top 60 airports are as follows:

Noise Bin	# Schools
DNL 55-60	694
DNL 60-65	240
>DNL 65	76
Total	**1010**

We also expect to capture 99% of the insulated schools at these top 60 airports.

3. Student Performance Measure

We will use school-level student test scores from the NLSLSACD. We will focus on Grades 3-8 since the 2002 No Child Left Behind Act (NCLB) calls for testing children in these grades every year.

4. Noise Measure

As stated in the Overview, we will examine the following exterior noise metrics:

- Arithmetic Average L_{Amax}
- Energy Average SEL
- L_{eq}(School)
- TA(55), TA(60), TA(65), TA(70), TA(75), and TA(80)
- NA(55), NA(60), NA(65), NA(70), NA(75), and NA(80)

5. School Characteristic and Student Population Measures

We will draw these variables from the NLSLSACD and the ED CCD databases.

6. Analytical Techniques

According to our preliminary power analysis (see Appendix D.6), we have sufficient sample sizes of target schools below DNL 65 dB to find an effect; but not above DNL 65 unless the actual size of the effect is much larger than our estimate based on the RANCH finding. At 95% confidence interval; we estimate that the probability of not finding an effect above DNL 65 (when it exists, type II error) increases by almost 20%.

Plan Assessment

Pros	Cons
• Largest sampling of schools for a study of this kind, which should produce more precision (and confidence) in drawing inferences about the effect. • The power analysis supports the probability that the study will find a statistically significant relationship where such a relationship exists. • Data gathering and analysis workloads fit	• No insight into the mechanism of how aircraft noise affects learning. • Above DNL 65, probability of type II error is around 40% unless actual effect is much larger than the RANCH finding. • No follow-up study on what makes atypical schools different, which would have provided insight into any study design issues.

Pros	Cons
within the budget. • Provides quantitative answers for the first five research questions.	

D.2. Alternative—Macro-Analysis (Top 50 Airports) with Follow-up Analysis

Description

This is the same type of macro-analysis as the Datum except we will use the top 50 airports from the US MAGENTA list instead of the top 60. We shift resources in order to conduct a follow-up study. We will follow up the macro-analysis with a more detailed examination at a small sample of schools that the analysis identifies as atypical.

Outcomes

This plan answers the project research questions as follows:

1. *To what extent is student learning affected by aircraft noise?*

The analysis to derive the answer is the same as the Datum and the probability of a type II error is the same.

2. *What is the most appropriate noise metric for describing aircraft noise as it affects learning?*

The analysis to derive the answer is the same as the Datum.

3. *What is the threshold above which the effect is observable?*

The analysis to derive the answer is the same as the Datum. The key assumptions are the same.

4. *Has insulation meeting existing classroom acoustic criteria improved student achievement?*

The analysis to derive the answer is the same as the Datum.

5. *How does aircraft noise affect learning for students with different characteristics?*

The analysis to derive the answer is the same as the Datum.

6. *What other knowledge will be gained by this research?*

Unlike the Datum, the follow-up detailed examination at a selected small sample of schools will produce information on what is it about these schools that make them atypical. This should provide insight into the capability of the study design to account for confounding factors that can influence the exposure-effect association.

Methods

<u>1. Airport Selection</u>

The scope of this effort is the top 50 airports from the FAA's US MAGENTA list found in the Overview as ranked by the number of public schools exposed to DNL 55 dB or higher in 2000.

2. School Selection

School information will be obtained from the CCD as noted in the Overview. After a preliminary examination of our databases, we find the numbers of target schools (public schools exposed to aircraft noise) around the top 50 airports are as follows:

Noise Bin	# Schools
DNL 55-60	662
DNL 60-65	234
>DNL 65	76
Total	**972**

We also expect to capture 97% of the insulated schools at these top 50 airports.

3. Student Performance Measure

We will use school-level student test scores from the NLSLSACD. We will focus on Grades 3-8 since the 2002 No Child Left Behind Act (NCLB) calls for testing children in these grades every year.

4. Noise Measure

We will examine the same exterior noise metrics as the Datum.

5. School Characteristic and Student Population Measures

We will draw these variables from the NLSLSACD and the ED CCD databases.

6. Analytical Techniques

We will perform the same macro-analysis as the Datum.

According to our preliminary power analysis (see Appendix D.6), we have sufficient sample sizes of target schools below DNL 65 dB to find an effect; but not above DNL 65 unless the actual size of the effect is much larger than our estimate based on the RANCH finding. At 95% confidence interval, we estimate that the probability of not finding an effect above DNL 65 is the same as the Datum.

Follow-Up Analysis

The macro-analysis should produce relationships between aircraft noise and student performance based on our analysis model. The statistical analysis should also reveal data points that deviate markedly from the other data points, which we label atypical schools. We define these atypical schools as falling ±2.5 standard deviations (s.d.) from the mean. Our preliminary estimate is that the size of the atypical sample will be less than twenty schools. We will conduct a follow-up analysis to try to understand why these atypical schools exist.

This will require a more detailed look at these atypical schools beyond the databases we used in the macro-analysis. We will look for erroneous data, such as, incorrect coding in the databases we used. We will also look for differences about the atypical schools not captured in the school or student population characteristics we used for examination. For example, we could turn up information indicating that an atypically high performing school was sound insulated some years ago that is not reflected our data. Or we could find that an atypically low performing school conducts most of the classes in temporary buildings with little sound insulation. We will also examine the role of any limitation in the aircraft noise modeling, such as, gross over- or under-prediction of aircraft noise levels due to incorrect model input assumptions. The idea is to look for patterns or trends in the information on the atypical schools and the neighboring airport that would help in future study designs. As this is a very labor intensive effort, the follow up will be limited to a handful of atypical airports.

Plan Assessment

Pros	Cons
• Data gathering and analysis workloads fit within the budget. • Provides quantitative answers to the first five research questions. • The power analysis supports the probability that the study will find a statistically significant relationship where such a relationship exists. • The follow-up analysis should reveal weaknesses in the research design.	• No insight into the mechanism of how aircraft noise affects learning. • Above DNL 65, probability of type II error is around 40% unless actual effect is much larger than the RANCH finding.

D.3. Alternative 2—Macro-Analysis (Top 40 Airports) with Observation Case Study

Description

This is the same type of macro-analysis as the Datum and Alternative 1 except we will use the top 40 airports from the US MAGENTA list instead of the top 60 or 50, respectively. We shift resources in order to conduct a case study. In the case study, we will observe changes in classrooms when exposed to aircraft noise and measure the noise events.

Outcomes

This plan answers the project research questions as follows:

1. *To what extent is student learning affected by aircraft noise?*

The analysis to derive the answer is the same as the Datum and Alternative 1 and probability of type II error is the same.

2. *What is the most appropriate noise metric for describing aircraft noise as it affects learning?*

The analysis to derive the answer is the same as the Datum and Alternative 1.

With the added case study, we will use the classroom observations and aircraft noise measurements to discover which noise metric best matches up with the degree that aircraft noise disrupts the classroom environment; looking for confirmation of the correlation finding from the macro-analysis.

3. *What is the threshold above which the effect is observable?*

The analysis to derive the answer is the same as the Datum and Alternative 1.

4. *Has insulation meeting existing classroom acoustic criteria improved student achievement?*

The analysis to derive the answer is the same as the Datum and Alternative 1.

5. *How does aircraft noise affect learning for students with different characteristics?*

The analysis to derive the answer is the same as the Datum and Alternative 1.

6. *What other knowledge will be gained by this research?*

Unlike the Datum, which focused on answering the first five questions, and Alternative 1, which added a follow-up study of atypical schools; this plan includes a case study to provide insights into the mechanisms of the aircraft noise impacts upon classroom learning.

Methods

1. Airport Selection

The scope of this effort is the top 40 airports from the FAA's US MAGENTA list found in the Overview as ranked by the number of public schools exposed to DNL 55 dB or higher in 2000.

For the case study, we will choose a single airport; one with a high frequency and mix of aircraft operations with several schools nearby. Los Angeles (LAX) and Miami (MIA) International Airports are the leading candidates.

2. School Selection

School information will be obtained from the CCD as noted in the Overview. After a preliminary examination of our databases, we find the numbers of target schools (public schools exposed to aircraft noise) around the top 40 airports are as follows:

Noise Bin	# Schools
DNL 55-60	624
DNL 60-65	219
>DNL 65	74
Total	**917**

We also expect to capture 95% of the insulated schools at these top 40 airports. For the case study, we will choose one elementary school nearby the airport selected. In the pre-selection process, we identify candidate schools around both LAX and MIA. An important consideration in the school selection are the processes to obtain school district cooperation and participation and then to obtain parent permission and informed consent. There also the need for an institutional review board (IRB) approval for a study of this kind.

Dr. Hervey, as a member of the faculty of Liberty University, has experience with their IRB process (https://www.liberty.edu/index.cfm?PID=12606). Since minors are involved, this case study automatically comes under the expedited or full review process, which takes about 2 months; after which we would begin the process of approval with the school district.

3. Student Performance Measure

We will use the same school-level student test scores (from NLSLSACD) as the Datum and Alternative 1 for the macro-analysis.

In the case study, as was done in the Crook and Langdon 1974 study at schools close to London Heathrow, we will categorize classroom interruptions due to aircraft events. We plan to videotape the classroom sessions for later analysis.

4. Noise Measure

We will have same INM input files and ETMS operational data as the Datum and Alternative 1 and can calculate the same noise metrics as we proposed in those other candidates.

For the case study, we will conduct measurements of aircraft noise outside and inside the school classrooms where observations are being performed – see below. Digital time-histories of noise levels will be obtained for subsequent analysis and correlation with observations.

5. School Characteristic and Student Population Measures

We will draw, from NLSLSACD and ED CCD databases, the same characteristics for analysis as the Datum and Alternative 1.

6. Analytical Techniques

We will perform the same macro-analysis as the Datum and Alternative 1.

According to our preliminary power analysis (see Appendix D.6), we have sufficient sample sizes of target schools below DNL 65 DB to find an effect; but not above DNL 65 unless the actual size of the effect is much larger than our estimate based on the RANCH finding. At 95% confidence interval; we estimate that the probability of not finding an effect above DNL 65 is the same as the Datum and Alternative 1.

Observation Case Study

Like the Crook and Langdon study, we will collect observations of how aircraft noise disrupts the classroom, such as, teacher pauses, teacher speech masking, pupil speech pause and masking, classroom behavior, and pupil distraction. While Crook and Langdon plotted frequency of disruptions, such as, teacher pauses against peak aircraft noise level; we will examine other metrics (TA, NA, etc.) that we can derive from the noise measurements.

Plan Assessment

Pros	Cons
• Data gathering and macro-analysis workloads fit within the budget. • Provides quantitative answers to the first five research questions. • The power analysis supports the probability that the study will find a statistically significant relationship where such a relationship exists. • The case study should provide insight into the mechanisms of how aircraft noise affects classroom learning. • The case study should also confirm findings of the macro-analysis on the best noise metric to represent the relationship with test scores.	• Above DNL 65, probability of type II error is around 40% unless actual effect is much larger than the RANCH finding. • Process to obtain school cooperation and parent process for the case study might not fit in the project schedule. • No information on whether case study is representative. • No follow-up study on what makes atypical schools different, which would have provided insight into any study design issues.

D.4. Alternative 3—Macro-Analysis (Top 30 Airports) with Follow-up Analysis and Case Study

Description

This is the same type of macro-analysis as the Datum and Alternatives 1 and 2 except we will use the top 30 airports. We shift resources in order to conduct both a follow-up study and observation case study. The follow-up analysis is like Alternative 1. The case study is the same as Alternative 2.

Outcomes

This plan answers the project research questions as follows:

1. *To what extent is student learning affected by aircraft noise?*

The analysis to derive the answer is the same as the Datum and Alternatives 1 and 2. Chance of type II error above DNL 60 is slightly higher than the other candidates mentioned.

2. *What is the most appropriate noise metric for describing aircraft noise as it affects learning?*

Like the Datum and Alternatives 1 and 2, we will analyze a variety of aircraft noise metrics to find the best metric-score correlation.

Through the case study, we will use the classroom observations and aircraft noise measurements to discover which noise metric best matches up with the degree that aircraft noise disrupts the classroom environment; looking for confirmation of the correlation finding like Alternative 2.

3. *What is the threshold above which the effect is observable?*

   The analysis to derive the answer is the same as the Datum and Alternatives 1 and 2.

4. *Has insulation meeting existing classroom acoustic criteria improved student achievement?*

   The analysis to derive the answer is the same as the Datum and Alternatives 1 and 2.

5. *How does aircraft noise affect learning for students with different characteristics?*

   The analysis to derive the answer is the same as the Datum and Alternatives 1 and 2.

6. *What other knowledge will be gained by this research?*

Like the Alternative 1, the follow-up analysis will help us understand the characteristics of the atypical schools.

Like Alternative 2, the case study will provide insights into the mechanisms of the aircraft noise impacts upon classroom learning.

Methods

1. Airport Selection

The scope of this effort is the top 30 airports from the FAA's US MAGENTA list found in the Overview as ranked by the number of public schools exposed to DNL 55 dB or higher in 2000.

For the case study, we will choose a single airport; one with a high frequency and mix of aircraft operations with several schools nearby. Los Angeles (LAX) and Miami (MIA) International Airports are the leading candidates.

2. School Selection

School information will be obtained from the CCD as noted in the Overview. After a preliminary examination of our databases, we find the numbers of target schools (public schools exposed to aircraft noise) around the top 30 airports are as follows:

Noise Bin	# Schools
DNL 55-60	576
DNL 60-65	199
>DNL 65	70
Total	**845**

We also expect to capture 95% of the insulated schools at these top 30 airports. We will choose one elementary school for the case study nearby the airport selected as we would in Alternative 2 involving the same IRB, school district, school and parent approval processes.

3. Student Performance Measure

We will use the same school-level student test scores (from NLSLSACD) for the macro-analysis as the Datum and Alternatives 1 and 2.

The case study captures the same classroom observations as Alternative 2.

4. Noise Measure

We will have same INM input files as the Datum and Alternatives 1 and 2 to calculate the same noise metrics as we proposed for these other candidates.

For the case study, the noise measurement protocol is the same as Alternative 2.

5. School Characteristic and Student Population Measures

We will draw from NLSLSACD and ED CCD databases the same characteristics for analysis as the Datum and Alternatives 1 and 2.

6. Analytical Techniques

We will perform the same macro-analysis as the Datum and Alternative 1.

According to our preliminary power analysis (see Appendix D.6), we have sufficient sample size of target schools at DNL 55-60 to find an effect; but fall a little short at DNL 60-65. At 95% confidence interval, we estimate that the probability of not finding an effect at DNL 60-65 is about 2% higher than the Datum or Alternatives 1 and 2. Our sample size above DNL 65 is about the same as Datum and Alternatives 1 and 2. At 95% confidence interval, we estimate that the probability of not finding an effect above DNL 65 is about the same as the Datum and Alternatives 1 and 2.

Follow-Up Study

The follow-up study is like Alternative 1 involving less than twenty atypical schools.

Case Study

The case study is the same as Alternative 2.

Plan Assessment

Pros	Cons
• Data gathering and macro-analysis workloads fit within the budget. • Provides quantitative answers for the first five research questions. • The power analysis supports the probability that the study is likely find a statistically significant relationship where such a relationship exists at lower noise levels. • The follow-up analysis should reveal weaknesses in the research design. • The case study should provide insight into the mechanisms of how aircraft noise affects classroom learning from the case study.	• At DNL 60-65, probability of type II error is 2% higher than Datum, Alternatives 1 and 2 unless actual effect is much larger than the RANCH finding. • Above DNL 65, probability of type II error is around 42% unless actual effect is much larger than the RANCH finding. • Process to obtain school cooperation and parent process for the case study might not fit in the project schedule. • No information on whether case study is representative.

D.5. Alternative 4—Macro-Analysis (Top 15 Airports) with Follow-up Analysis and Expanded Case Study

Description

This is the same type of macro-analysis as the Datum and Alternatives 1, 2, and 3 except we will use the top 15 airports. We shift resources in order to conduct both a follow-up analysis and expanded case study. The follow-up analysis is like Alternatives 1 and 3. The case study involves classroom observations as proposed in Alternatives 2 and 3, but now includes two schools with the addition of student and teacher questionnaires given through focus groups.

Outcomes

This plan answers the project research questions as follows:

1. *To what extent is student learning affected by aircraft noise?*

The analysis to derive the answer is the same as the Datum and Alternatives 1, 2, and 3. However, the probability of finding an effect is substantially less than the other candidates mentioned.

2. *What is the most appropriate noise metric for describing aircraft noise as it affects learning?*

Like the Datum and Alternatives 1, 2 and 3, we will analyse a variety of aircraft noise metrics to find the best metric-score correlation.

Through the case study, we will use the classroom observations and aircraft noise measurements to discover which noise metric best matches up with the degree that aircraft noise disrupts the classroom environment; looking for confirmation of the correlation finding like Alternatives 2 and 3.

3. *What is the threshold above which the effect is observable?*

The analysis to derive the answer is the same as the Datum and Alternatives 1, 2, and 3. However, chance of finding the effect is less than the other candidates mentioned.

4. *Has insulation meeting existing classroom acoustic criteria improved student achievement?*

The analysis to derive the answer is the same as the Datum and Alternatives 1, 2, and 3. However, the probability of finding an effect is substantially less than the other candidates mentioned due to a much smaller sample of insulated schools.

5. *How does aircraft noise affect learning for students with different characteristics?*

The analysis to derive the answer is the same as the Datum and Alternatives 1, 2, and 3. However, the probability of finding an effect is substantially less than the other candidates mentioned.

6. *What other knowledge will be gained by this research?*

Like the Alternative 1, the follow-up analysis will help us understand the characteristics of the atypical schools.

Like Alternative 2, the case study will provide insights into the mechanisms of the aircraft noise impacts upon classroom learning. Through the focus group questionnaire, we will discover what students and teachers perceive to be the effects of aircraft noise.

Methods

1. Airport Selection

The scope of this effort is the top 15 airports from the FAA's US MAGENTA list found in the Overview as ranked by the number of public schools exposed to DNL 55 dB or higher in 2000.

For the case study, we will choose a single airport; one with a high frequency and mix of aircraft operations with several schools nearby. Los Angeles (LAX) and Miami (MIA) International Airports are the leading candidates.

2. School Selection

School information will be obtained from the CCD as noted in the Overview.
After a preliminary examination of our databases, we find the numbers of target schools (public schools exposed to aircraft noise) around the top 15 airports are as follows:

Noise Bin	# Schools
DNL 55-60	437
DNL 60-65	154
>DNL 65	59
Total	**650**

We also expect to capture only 68% of the insulated schools at these top 15 airports. We will choose a target elementary school and a control elementary school for the case study in the vicinity of the airport selected. As with Alternatives 2 and 3, this part of the plan requires IRB, school district, school and parent approval processes.

3. Student Performance Measure

We will use the same school-level student test scores (from NLSLSACD) for the macro-analysis as the Datum and Alternatives 1, 2, and 3.

The case study captures the same classroom observations as Alternatives 2 and 3, but now we can compare any difference in-classroom behavior between a target school and a control school. Through use of student and teacher focus groups, we will gather information on their perceptions regarding the influence of aircraft noise on such effects as:

- Student stress
- Teacher stress
- Teacher's vocal strain and fatigue
- Annoyance
- Attitudes

For the focus group questionnaire, we intend to adapt questions from the form used by Haines et al in the West London Schools Study cited in the literature review.

4. Noise Measure

We will have same INM input files as the Datum and Alternatives 1, 2, and 3 to calculate the same noise metrics as we proposed for these other candidates.

For the case study, the noise measurement protocol is the same as Alternatives 2 and 3.

5. School Characteristic and Student Population Measures

We will draw from NLSLSACD and ED CCD databases the same characteristics for analysis as the Datum and Alternatives 1, 2, and 3.

6. Analytical Techniques

We will perform the same macro-analysis as the Datum and Alternatives 1, 2, and 3.

According to our preliminary power analysis (see Appendix D.6), we do not have sufficient sample sizes of target schools to find an effect. At 95% confidence interval, we estimate that the probability of not finding an effect at DNL 55-60 is about 2% higher than the Datum and Alternatives 1, 2, and 3; 13% higher at DNL 60-65 and 30% higher above DNL 65.

The sample of insulated schools also falls well short of what is needed.

Follow-Up Study

The follow-up study is like Alternatives 1 and 3 involving less than twenty atypical schools.

Case Study

The case study expands on the case study concepts of Alternatives 2 and 3 with the addition of a control school and focus groups to try to answer the following:

- How do students who are regularly exposed to aircraft noise at school differ from similar students who are not exposed to aircraft noise at school with respect to inhibitory factors including distraction, learned helplessness, memory difficulties, hearing and auditory processing difficulties, stress, health difficulties, noise annoyance, and absenteeism?

- How do teachers who are regularly exposed to aircraft noise at school differ from teachers who are not exposed to aircraft noise at school with respect to inhibitory factors including stress, health difficulties, noise annoyance, absenteeism, and vocal strain?
- According to students and teachers, how, if at all, does aircraft noise influence teaching and learning?

Plan Assessment

Pros	Cons
• Data gathering and macro-analysis workloads fit within the budget. • The follow-up analysis should reveal weaknesses in the research design. • The case study should provide insight into the mechanisms of how aircraft noise affects classroom learning. • The case study could confirm findings of the macro-analysis on the best noise metric if the macro-analysis finds a statistically significant relationship with test scores. • The focus group portion of the case study should provide student and teacher perspectives on the problem.	• Do not have statistical confidence that the macro-analysis will be able to provide quantitative answers to the first five research questions. • Process to obtain school cooperation and parent process for the case study might not fit in the project schedule. • No information on whether case study is representative.

D.6. Power Analysis

For the macro-analysis, we will conduct power analyses to determine if the target school sample sizes are sufficient to provide statistically significant results. The parameters for the power analysis are: statistical significance (α, probability of Type I Error), effect size (z), and power of the test (β, probability of Type II Error). For significance, the confidence interval was set at 95% and a two-tailed α set at 0.05 was used. For power, probability was set at 80% (β=0.20)..

The effect size is the minimum deviation from the null hypothesis that it hoped to detect. The RANCH study (Stansfeld 2005) found that adjusted mean reading z score (at 95% confidence interval) fell below zero at exposure greater than 55 dB L_{Aeq16} and the relationship was linear at exposures less than 55 dB (see Figure 1 in Chapter 2). The effect found in the RANCH study is approximately 0.05 standard deviations per 5 dB change in aircraft noise.

The RANCH study only included schools in the general vicinity of airports, whereas the present study will include many control schools located away from the nearest large airport. Assuming that the average airport noise difference between the lowest level at which detection is desired and the average of control schools is double the differences found in the RANCH study, leads our choice of a the value of $z=0.1\sigma$ for this study.

Other key assumptions for the power analysis are as follows:

- Other than the known insulated schools, schools have equivalent differences between exterior and interior noise levels.

- There is no "state" effect. Test scores are standardized to the same mean and standard deviation in each state in order to enable aggregation of results across states.
- Differences in scores between schools at different airport noise exposure levels can be attributed to the effects of noise. Differences in achievement due to demographic and resource differences between schools at different airport noise levels are eliminated by statistical adjustment.
- The availability of scores for multiple years (instead of a single year) for most schools reduces the standard errors of estimates by approximately 40 percent.[1] This reduction in the standard error translates into the need for a smaller sample of schools.

The preliminary power analysis indicated the need for a minimum sample size of 470 to detect an achievement difference of 0.1σ between schools with airport noise exposure between 55 dB and 60 dB and control schools in order to answer Research Questions 1, 2, 3, and 5. For higher noise levels, the required numbers of target schools are smaller, because the expected true value of z, the airport noise effect, is correspondingly larger. If for the interval from 55dB to 60 dB the value of z is 0.1σ, the value for the interval from 60dB to 65 dB might be 0.15σ, the value for the 65 – 70 dB interval might be 0.2σ, and 0.25σ for the interval 70 to 75dB. The corresponding minimum sample sizes would be approximately 210 at DNL 60-65, 120 at DNL 65-70, and 80 at DNL 70-75 to answer these same research questions.

For the effect of insulation (Research Question 4), the critical statistic for the first part of this question is the mean difference between achievement scores after insulation and scores in the same schools before insulation. Because scores in the same school are correlated from one year to the next, the standard error of the difference is roughly 10 percent smaller than the standard error of the mean score before insulation.[2] The preliminary power analysis suggests a sample of around 300 insulated schools assuming that we are trying to detect the effect when the true insulation effect is 10dB.

The preliminary power analyses indicate that the research plan candidates fall short of meeting sample size minimums to varying degrees. However, the power analysis was based on previous research involving only L_{eq}-based aircraft noise metric. The current study is planned to explore metrics that are distinctly different from L_{eq} in hopes of finding one that has a better relationship with learning. Thus, the preliminary estimates of sample size requirements could be viewed as a worst case scenario.

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[1] Evidence to support this assumption is based on Don McLaughlin's analyses of grade 4 reading scores for schools in two states and 5 years, California and Illinois in 1998-1999 through 2002-2003.
[2] Ibid.

APPENDIX E. Estimation of Test Score Validity

States have experimented with a wide variety of achievement assessment design, administration, and scoring in the past quarter century, and some of the test scores are more reliable and valid than others. Virtually no systematic studies are available to show that elementary school test scores have predictive validity over years, possibly because teachers are encouraged to help the students who have not achieved well coming into their class to catch up during the year.

Nevertheless, one can estimate their validity for use as dependent variables in an investigation of the effects of an external factor or intervention on educational achievement by examining their relations to factors that are known from the wealth of past research to be associated with educational achievement. In this study, each candidate test score measure was entered into an analysis to determine its predictability (i.e., how much of school-to-school variance could be accounted for) by three school-level factors known to account for substantial portions of the variance in achievement among schools: poverty (percent of students eligible for the federal free and reduced price lunch program), minority concentration (percent of students who are African American, Hispanic American, or Native American), and the student/teacher ratio.

The r squared for the multiple linear regression of each candidate test score on these three factors was recorded. For 1,309 verbal tests, the average r^2 was 0.52, with a standard deviation of 0.16; and for 979 math tests, the average r^2 was 0.44, with a standard deviation of 0.14. Thus, most of the test scores seem appropriate for use in this investigation. However, approximately 2 percent of the r^2 values were less than 0.1. Many of these were in a single state, which was removed from the analysis. Achievement test scores in that state had been designed mainly for use within a school, not to compare schools across the state.

In some states, several alternative verbal measures were available, either from alternative tests (e.g., reading, language arts, or writing) or from alternative scorings of the same test (e.g., average scale scores versus percent meeting standards). In those cases, the measure selected was the one with the highest r^2 in this test, except that when two alternatives were with 0.1 of each other, their (standardized) average, which should have a slightly greater reliability than either measure alone, was used.

An additional check on the validity and reliability of the scores used in the main analysis was provided as part of the estimation of the design effect of the analyses, discussed later. For that analysis, the correlations of scores between adjacent years were computed after the effects of demographic and resource factors had been removed from each score. The average correlation (not r^2) was .46, with a standard deviation of 0.11. This provided corroboration that the dependent variables in the analyses have sufficient reliability and validity.

APPENDIX F. Adjustments to Test Scores

F.1. Adjustment for Demographics

To reduce the extent to which differences in test scores between schools exposed to airport noise might be related to demographics and resources associated with those schools, the scores in each state and for each school year were analyzed by the general linear regression model (PROC GLM in the Statistical Analysis System (SAS (r)), version 9.1.3), estimating the extent to which variation in school-level test scores in that state and year is accounted for by four measures of demographic and resource characteristics as derived from the CCD, namely:

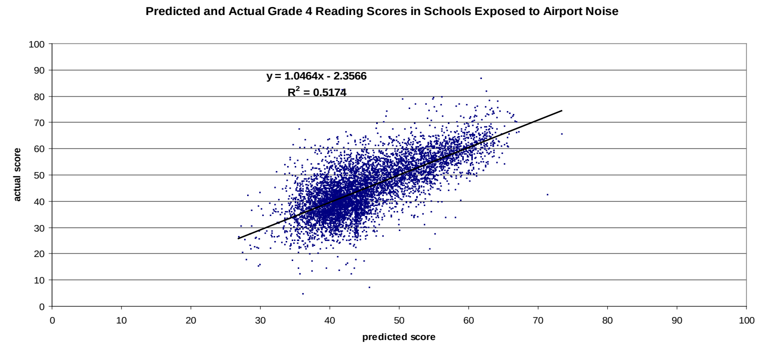
1. The fraction of students eligible for the government free and reduced price lunch program, which provides a powerful measure of poverty, known to be highly correlated with school test scores.
2. The fraction of the school's enrollment of children who are African American, Native American, or Hispanic, a measure of the disadvantages of students.
3. The pupil-teacher ratio, a measure of school resources. Information about the experience and expertise of teachers in the schools is not available in any systematic database.
4. The average enrollment per Grade in the school, an indicator of the size of the school.

This analysis yields a "predicted" test score for each school for each year, taking into account local demographic and resource characteristics. The deviation of actual (raw) test scores from the predicted scores provided an adjusted test score for each school, to be used in the main analysis.

Adjusted score = actual (raw) score – predicted score + 50

In order to avoid contaminating this covariate analysis with the effects of airport noise, the covariance analysis was based entirely on schools *not* exposed to airport noise. The resulting prediction equations were then used to compute predicted scores for *all* schools, including those target schools exposed to airport noise, and these adjusted scores were used in the analysis. Scatterplots for predicted and actual Grade 4 reading scores for schools exposed and not exposed to airport noise are shown in Figure F1, where it can be seen that the relationships are similar.

The adjustments for covariates were based on separate equations for each state and year. As a separate descriptive analysis of the covariate relations, a single aggregate regression of test scores on the four predictors, including all schools in districts containing at least one school exposed to airport noise, was performed. The resulting coefficients are shown in Table F.1. All of the coefficients are statistically significantly different from zero. More than half of the variance in school-level averages of test scores is accounted for by these four demographic and resource factors. Controlling for these factors is clearly necessary in any study of the potential effects of other factors on achievement at the school level. They were included by using the adjusted scores computed from the equation before the preceding paragraph. As a result, none of those variables is related to variation in test scores between schools in a state.



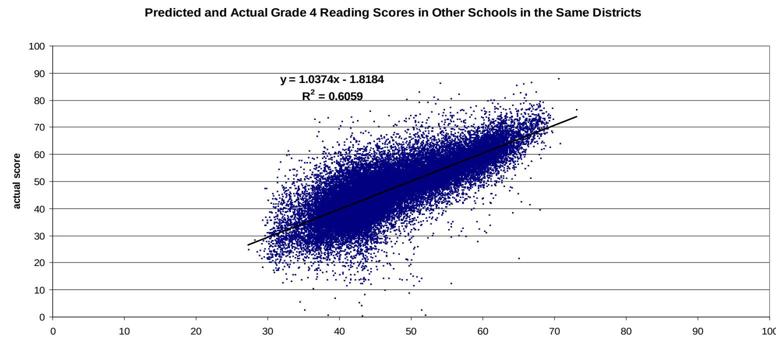


Figure F-1. Predicted and actual grade 4 reading scores, based on demographic covariates.

TABLE F-1 Aggregate Regression Coefficients for Covariates Used in the Study.

Test	Free Lunch Eligible	Minority	Pupil Teacher Ratio	Enrollment per Grade	R Squared
Grade 3 Reading	-1.841	-0.943	-0.07	0.015	0.576
Grade 4 Reading	-1.285	-1.332	0.04	0.007	0.532
Grade 5 Reading	-1.778	-1.003	-0.07	0.005	0.592
Grade 3 Math	-1.590	-1.085	-0.18	0.026	0.515
Grade 4 Math	-1.560	-1.098	-0.13	0.018	0.504
Grade 5 Math	-1.528	-1.059	-0.14	0.012	0.508

Notes: Scaling of entries in Table 6 is as follows. For free Lunch Eligible and Minority, the entry indicates the number of standard deviations of change in school means for a change from 0% to 100% eligible or minority. Thus, -1.841 signifies that a change from none eligible to all eligible is associated with a Grade 3 reading deficit of 1.841 standard deviations; and -0.943 signifies that a change from no minorities to all minorities is associated with a deficit of 0.943 standard deviations. Pupil teacher ratio and enrollment per Grade entries indicate the number of standard deviations of change in school means for a change of 10 in the pupil teacher ratio or number of students per Grade. Thus, -0.07 indicates that a deficit of 0.07 standard deviations in Grade 3 reading is associated with addition of 10 to the pupil teacher ratio; and 0.015 indicates that an advantage of 0.015 standard deviations is associated with an increase of 10 students per Grade

F.2. Use of Weighted Averages

The reliability of school test score averages is strongly related to the number of students tested, so the next step in the test score file preparation was to incorporate the number of students tested in each subject, grade, and year for which a test score was included. The averages in some schools were based on only a few students, while the averages in other schools were based on a hundred or more students. The measurement error of the average score is larger in schools where the average is based on only a few students. In most cases, the number of students tested was available on the state test score file from which scores were extracted for this study. When the number tested was not reported, the number was imputed from CCD, either from the reported number of students in the grade or, when that was not reported, from the ratio of the total school enrollment to the number of grades served in the school. If none of those statistics was available, the average enrollment per grade over the decade was used.

Based on an analysis of the variances of Grade 4 reading scores in 100 subsets of schools with varying numbers of students tested, the variation (standard deviation) of average Grade 4 reading scores, as a function of the inverse of the number of students tested, is shown in Figure F.2. About 91 percent of the variance in school test score means is associated with the inverse of the number of students tested.

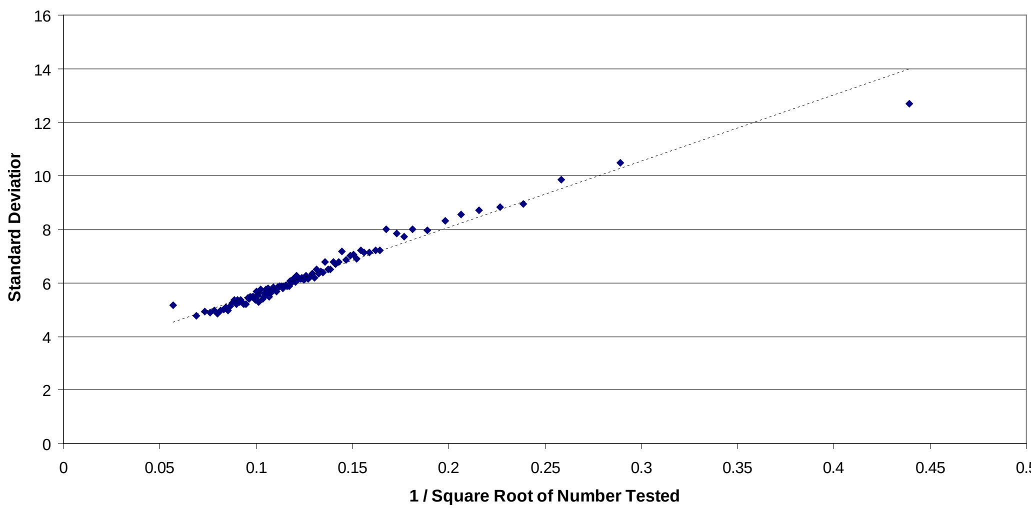


Figure F-2. Standard deviation of school test scores as a function of inverse square root of number tested.

The method for computing the average, whether by weighting schools equally or according to the number of students tested, does not affect the validity of the statistic; however, weighting the schools by a factor inversely related to the measurement variance of each school average increases the precision of the statistic. Therefore, to increase the precision of the critical statistic, thereby increasing the power of the test of airport noise effects on school achievement, the school averages were weighted by the number of students tested.

F.3. The District Effect

The analysis plan was to compare test scores for airport noise-exposed schools with comparable schools in the same state, relying on covariate measures to adjust for demographic and resource variation. A final step in preparing for the analysis was to test whether schools exposed to airport noise could be compared to all other schools in the same state or whether that comparison should only involve other schools in the same district. To address this question, the test scores of schools not exposed to airport noise but in the same school district as schools exposed to airport noise were compared to test scores of schools in other districts in the same state. A variable indicating that a comparison school was in the same school district as one or more schools exposed to airport noise was added to the covariance analysis. Unfortunately, that indicator was statistically significantly different from zero indicating that there were significant differences in test scores between these two sets of schools.

The distributions of school demographic and resource measures are shown in Table F2. It can be seen that the indicators for three of the four school characteristics are similar for target and other schools in the same district, but quite dissimilar for other schools in the same state. For example, 61 percent of students in the districts with some schools close to airports were eligible for the federal free and reduced price lunch program, compared to 45 percent in other districts in the same state, and there was no difference in this poverty measure between schools exposed to airport noise and other schools in the same district, on average. Clearly, the demographics of school districts adjacent to airports, which tend to be close to urban centers, are different from those of other schools in more suburban and rural areas of the state. Furthermore, the scores also tend to be different. As a result of the pattern in this table**, all comparisons of the scores from schools exposed to airport noise in this study are with other schools in the same school district**[3].

TABLE F-2 Distributions of Characteristics of Schools Exposed to Airport Noise and Other Schools in the Same and other Districts.

	Percentage of Students Eligible for Free and Reduced Price Lunch	Percentage of Students who are African American, Hispanic, or Native American	Pupil Teacher Ratio	Enrollment per Grade
Airport Noise-Exposed (Target) Schools				
Mean	61%	66%	16.2	89.4
Standard deviation	31%	34%	4.0	52.9
Other Schools in Districts with Some Airport Noise-Exposed Schools				
Mean	61%	64%	16.6	87.1
Standard deviation	30%	33%	3.7	46.9
Schools in Other Districts in the same States				
Mean	45%	34%	16.2	79.1
Standard deviation	28%	32%	3.8	54.7

Since schools exposed to airport noise in this study existed in only a fraction of the school districts in each state, this meant excluding a large percentage of the "control" schools, but a very substantial, and more than adequate, sample of "control" schools remained. Instead of roughly

[3] Schools not in a district with airport noise-exposed schools were included in the analyses to estimate the relation between demographic and resource measures and test scores in each state, however.

50,000 control schools in the study, there were about 5,000 control schools to be compared to the roughly 1,000 schools exposed to airport noise. This has virtually no impact on the precision of the comparisons, which is largely determined by the smaller of the two sample sizes, that is, by the number of schools exposed to airport noise. Thus, there was no advantage to including control schools in other districts (away from large airports) and therefore no need for estimates of between-district variance components.

The main analyses compared schools exposed to airport noise to other schools in the same district in the same year. The analyses focused on non-insulated schools in school districts with at least two schools exposed to significant airport noise and two control schools. The database for these analyses consisted of adjusted test scores in 6,198 schools in 104 school districts, and of these schools 917 (= 905 + 12) were classified as exposed to significant airport noise, i.e. target schools, as shown in Table F3. A few schools were included as target schools some years and control schools in other years, due to changes in either school location or airport operations.

TABLE F-3 Total Number of Schools and Districts Included in the Test Score Database.

Schools in District	Districts	Exposed Schools	Control Schools	Both*
At least two exposed and two control schools	104	905	5281	12
1 exposed and at least two control schools	44	46	641	1
Fewer than two control schools	129	214	69	15
Total	277	1165	5991	28

*Schools exposed to airport noise some years and not in others.

The analysis sample could have been increased slightly to include 47 (= 46 + 1) more schools exposed to airport noise in districts with a single school exposed to airport noise, but there would be no independent estimate of within district variability of these schools. In fact, analyses were performed on this enlarged sample and yielded results very similar to the results presented in this report. The necessity of limiting the analyses to comparison of schools within the same district, to eliminate district effects, removed 229 (= 214 + 15) schools exposed to airport noise from the original sample: schools for which there were fewer than two control schools in the same district. To include those schools in the analyses would have required comparisons across district boundaries.

Each of the schools included in the analyses was open for one or more of the years from 2000 to 2008 and had reading and mathematics test scores for Grades 3, 4, and 5, as shown in Table F4. Test scores were, on average, available for five or six of the nine school years. The numbers of schools included in the main analyses for each grade and subject are shown in Table F4. These schools were in districts with at least two exposed and two control schools with the specified test scores. For Grade 3 Reading, for example, the comparisons were based on 703 (= 695 + 8) airport noise-exposed schools and 4481 (= 4473 + 8) control schools in 92 school districts.

TABLE F-4 Number of Schools and Districts Included in the Main Analyses for Each Grade and Subject.

Test Score	Districts	Exposed Schools	Control Schools	Both*
Reading Grade 3	92	695	4473	8
Reading Grade 4	97	851	4904	9
Reading Grade 5	89	670	4445	9
Math Grade 3	89	683	4451	8
Math Grade 4	99	857	4934	10
Math Grade 5	89	682	4466	8

F.4. Estimation of Design Effect

The database for the study included scores for up to nine years at each school, and although different students took each grade's test from year to year, the scores are correlated across years. Much of the correlation is due to demographics, but when the scores were adjusted for demographics, a year-to-year correlation averaging 0.47 remained.

The correlation across years causes standard analytical procedures, which assume uncorrelated scores, to overestimate the precision of statistical estimates.[4] The amount of overestimation is referred to as the "design effect." Measures of statistical significance obtained from standard analyses, such as Student's t, must be reduced by the design effect factor.

To estimate the design effects for this study, Monte Carlo simulations were analyzed. Data according to the parameters of the database were filled in randomly under the assumptions of the null hypothesis to create 1000 replicates of the data, with a cross-year correlation equal to the average cross-year correlation in each state. The SAS PROC GLM was executed for each replicate; and the standard deviation (over the 1000 replicates) of the estimated mean noise effects (i.e., the true standard errors) were compared to the standard error estimates produced by the package. The sizes of the design effects for the various test score types are shown in Table F.5. Student's t values for the effects of noise measures were adjusted by dividing by the corresponding design effect.

[4] The size and complexity of the database precluded carrying out the analyses using a repeated measures design that would explicitly incorporate the cross-year correlations.

TABLE F-5 Design Effects Resulting from Cross-Year Correlations of School-Level Test Scores.

Score Type	Design Effect
Reading Grade 3	1.665
Reading Grade 4	1.592
Reading Grade 5	1.546
Math Grade 3	1.600
Math Grade 4	1.625
Math Grade 5	1.595

APPENDIX G. Detailed Analysis Results

G.1. Single Decibel Noise Metrics

The first analyses performed to determine the estimated effects of aircraft noise, as measured by the L_{eq} metric, on average reading and math test scores in Grades 3, 4, and 5, are shown in Table G-1. The second and third columns in this table present the results of a two-predictor analysis (with two independent variables) relating change in test scores to aircraft noise and ambient noise. As would be expected, aircraft noise is negatively associated with school achievement scores; however, the effects are small, ranging from -0.0147 standard deviations per 10 dB for Grade 5 math to -0.0251 standard deviations per 10dB for Grade 4 math.

TABLE G-1 Estimates of the Effects of Aircraft Noise (Leq) on School Test Scores.

Achievement Test	Estimated Noise Effect*		
	2-Predictor Analysis		Aircraft + Ambient Noise Total, L_{tot}
	Aircraft Noise, L_{eq}	Ambient Noise, L_{eq}	
Reading Grade 3	-0.0160	-0.0491	-0.0726
Reading Grade 4	-0.0242	-0.0883	-0.1078
Reading Grade 5	-0.0148	-0.0369	-0.0560
Math Grade 3	-0.0173	-0.0480	-0.0700
Math Grade 4	-0.0251	-0.0882	-0.1092
Math Grade 5	-0.0147	-0.0020**	-0.0243

*Effect size estimates are in units of fractions of a standard deviation for a 10dB difference in noise level.
** Not statistically significantly different from zero

The effects for total noise, L_{tot}, the (logarithmic) sum of aircraft and ambient noise, shown in the fourth column, are three to four times larger, ranging from -0.0560 to -0.1092 respectively, but still small. Assuming that these relationships covers the range of L_{tot}, this translates to a 3 to 4 percent reduction in percentile rank in the state for a 10 dB increase in level for Grade 4 math and reading.

The analysis revealed that ambient noise also tends to negatively affect test scores (see the third column in Table G-1), more so than aircraft noise alone, although not as much as total noise. The effect for Grade 5 math, is not statistically significantly different from zero. In conclusion, the effects of aircraft noise on test scores is generally statistically significant but small for metrics L_{eq} and L_{tot}.

Two additional types of aircraft noise measure were considered, namely average SEL and L_{max} of the school day aircraft events, with the averages taken over events exceeding 70 and 80 dB for SEL, and 65 and 75 dB for L_{max}. In these comparisons, shown in Tables G-2 and G-3, data from schools not exposed to aircraft noise or only exposed to aircraft noise below the specified threshold are not included in the analysis.

TABLE G-2 Estimates of the Effects of SEL on School Test Scores Taking Ambient Noise into Account.

Test	Estimated Noise Effect*	
	SEL70	SEL80
Math Grade 3	-0.0256	-0.0920
Math Grade 4	-0.0262	-0.0027
Math Grade 5	-0.0183	-0.0220
Reading Grade 3	-0.0413	-0.0645
Reading Grade 4	-0.0037	0.0260
Reading Grade 5	-0.0144	-0.0509

*Effect size estimates are in units of fractions of a standard deviation for a 10dB difference in aircraft noise level.

TABLE G-3 Estimates of the Effects of L_{max} on School Test Scores Taking Ambient Noise into Account.

Test	Estimated Noise Effect*	
	L_{max65}	L_{max75}
Math Grade 3	-0.0130	-0.0117
Math Grade 4	-0.0193	-0.0170
Math Grade 5	-0.0105	-0.0094
Reading Grade 3	-0.0121	-0.0106
Reading Grade 4	-0.0187	-0.0164
Reading Grade 5	-0.0111	-0.0098

*Effect size estimates are in units of fractions of a standard deviation for a 10dB difference in aircraft noise level.

Generally, the results in Table G-2 yield no systematic patterns of effects on test scores, and in fact the estimates are not significantly different from zero. The estimated effects described with the L_{max} metric, shown in Table G-3, are statistically significant, but small, with the maximum decrement on the order of 1 percentile reduction in state rank for a difference of 10 dB. Although the metrics SEL and L_{max} describe the average maximum levels, they provide no information as to how many events occur.

G.2. Non-Decibel Metrics

Two non-decibel metrics were also analyzed. The effects of one set of these, the number of aircraft noise events above a selected threshold, NA(L), occurring in an average school day, are shown in Table G-4.[5] There is a definite pattern of increasing effects as the threshold level is increased from 55 to 80 dB. For example, for Grade 4 reading, the effect of 10 aircraft noise events above 60 dB would be a decrement of 0.0086 standard deviations (SD's) in average test scores, while the effect of 10 aircraft noise events above 70 dB would be 0.0185 standard deviations. Assuming that this relationship covers the range of NA, the decrement for 50 events greater than 70 dB is about 0.10 SD's, which translates to a 4 percentile reduction in rank in the state for Grade 4 math and reading. In the Year 2008 this number of exceedances occurred at eighty of the target schools in this study. Similarly, for 100 events greater than 70 dB the decrement would be 0.185, which roughly translates to an 8 percentile reduction in rank in the state, say from the 50th to 42nd percentile. More than 100 events per school day were noted at twenty-five of the target schools in the Year 2008.

TABLE G-4 Estimates of Effects of Number of Aircraft Noise Events On School Test Scores, Taking Ambient Noise into Account.

Test	Estimated Noise Effect*					
	NA55	NA60	NA65	NA70	NA75	NA80**
Math Grade 3	-0.0061	-0.0076	-0.0096	-0.0153	-0.0184	-0.0221
Math Grade 4	-0.0075	-0.0099	-0.0131	-0.0191	-0.0209	-0.0190
Math Grade 5	-0.0064	-0.0085	-0.0109	-0.0149	-0.0182	-0.0228
Reading Grade 3	-0.0048	-0.0064	-0.0088	-0.0148	-0.0196	-0.0187
Reading Grade 4	-0.0063	-0.0086	-0.0117	-0.0185	-0.0225	-0.0210
Reading Grade 5	-0.0047	-0.0061	-0.0083	-0.0138	-0.0194	-0.0244

*Effect size estimates are in units of fractions of a standard deviation for 10 noise events.
** Not statistically significantly different from zero

The effects of the number of aircraft noise events greater than 80 dB are not reliable or statistically significantly different from zero, due to the small sample size of schools experiencing aircraft noise at this level.

The small effect noted for the NA(L) metric is perhaps not surprising. Even though the number of disturbances from aircraft noise may be a factor in lowering of test scores, the metric contains no information on how high are the exceeding levels. For example, NA(65) = 10 may mean 10 events at 66 dB or 10 events at 80 dB.

As a second alternative noise metric, the total duration of aircraft noise above a threshold level, TA(L), in minutes per day, was estimated for each school exposed to aircraft noise. The results are shown in Table G-5. The pattern is similar to the pattern for number of noise events

[5] Results for the alternative metrics are all based on an analysis that assumes a linear combination of effects of ambient noise and of the particular aircraft noise metric.

per day, a small but statistically significant negative effect that increases with the noise level as would be expected. For example, for Grade 4 reading, 10 minutes per school day of aircraft noise above 60dB is associated with a decrement of 0.0231 standard deviations of average test scores, and for 10 minutes above 70dB per day, the decrement is 0.0641 standard deviations. Because few schools were exposed to noises above 75 dB or 80 dB, the effects for durations at these levels were not statistically significant from zero. In Tables G-4 and G-5, as well as in Table G-1, other schools in the same districts were included for comparison with airport noise measures of zero.

TABLE G-5 Estimates of Effects of Duration of Aircraft Noise Events on School Test Scores, Taking Ambient Noise into Account.

Test	Estimated Noise Effect*					
	TA55	TA60	TA65	TA70	TA75**	TA80**
Math Grade 3	-0.0118	-0.0205	-0.0355	-0.0639	-0.0923	-0.1352
Math Grade 4	-0.0140	-0.0248	-0.0407	-0.0600	-0.0648	-0.0612
Math Grade 5	-0.0134	-0.0236	-0.0402	-0.0657	-0.0871	-0.1326
Reading Grade 3	-0.0100	-0.0183	-0.0333	-0.0661	-0.0928	-0.1020
Reading Grade 4	-0.0126	-0.0231	-0.0394	-0.0641	-0.0764	-0.0744
Reading Grade 5	-0.0103	-0.0188	-0.0343	-0.0676	-0.0998	-0.1500

*Effect size estimates are in units of fractions of a standard deviation for 10 minutes above the threshold level.
** Not statistically significantly different from zero

The average decrement for a TA(70) of 10 minutes is 0.065 across all tests . Thus, the effect of exposure for 20 minutes a school day at a level greater than 70 dB is a 5 percentile change in state rank, say from the 50th to the 45th percentile. In the Year 2008, only twenty-two of the target schools in this study were exposed for this time above 70 dB. A similar reduction in state rank could be expected for 25 minutes in excess of 65 dB – a level exceeded by seventy-one target schools in 2008. The TA metric has the advantage over the NA metric in that it quantifies the time that aircraft noise can be a distraction, even though the absolute levels of the individual events are not known.

In conclusion, the effects of aircraft noise on test scores are generally statistically significant but small for the TA and NA noise metrics, but larger than for L_{eq} and L_{tot}.

G.3. Aircraft Noise Increment

In the evaluation of the L_{eq} metric for describing the effect of aircraft noise on test scores (Table G-1) it was noted that ambient noise, by itself, tends to negatively affect test scores more so than aircraft noise alone, at least according to the L_{eq} metric. The insensitivity of this metric in relating to student test scores can maybe be understood when it is realized that the aircraft L_{eq} for at least one-half of the target schools is less than the ambient noise level at those schools – see Figure 5-3 of Chapter 5. Thus, even though the aircraft noise peaks will nearly always exceed the ambient levels, there will be a certain degree of masking by the ambient noise for a large portion of the target schools.

Taking the approach that any decrement in test scores may be related to the amount by which the total (aircraft plus ambient) noise exceeds the ambient, the analysis was repeated with the noise increment, L_{tot}-L_{amb}, as the aircraft noise measure, where L_{tot} is the logarithmic addition of the aircraft L_{eq} and the ambient L_{eq}, and L_{amb} is the ambient L_{eq}.

The results shown in Table G-6 indicate aircraft noise effects based on the amount of noise, in decibels, added by the aircraft operations. The effects are more than seven times as large as for L_{eq} alone, and up to two times as large for L_{tot}, ranging from 0.1122 standard deviations per 10 dB for Grade 5 math to 0.1429 standard deviations per 10 dB for Grade 4 math. This corresponds to a 6 percentile reduction in rank in a state, and about a 9 percentile reduction for a difference of 15 dB. In 2008 there were about 103 and 30 of the target schools respectively with noise increments equal to or greater than 10 and 15 dB. Furthermore, there were about ten schools with an increment of 20 dB or greater, which translates to a 12 percentile reduction in state ranking.

The deficits reported in Table G-6 do not increase from Grade 3 to Grade 5. That is, they do not provide evidence for the hypothesis that the effects of aircraft noise might be cumulative over the elementary Grades.

TABLE G-6 Estimates of the Effects of Aircraft Noise Increment on School Test Scores.

Achievement Test	Estimated Noise Effect*	
	Aircraft Noise Increment	Ambient Noise, L_{eq}
Reading Grade 3	-0.1420	-0.0610
Reading Grade 4	-0.1360	-0.1031
Reading Grade 5	-0.1202	-0.0463
Math Grade 3	-0.1350	-0.0597
Math Grade 4	-0.1429	-0.1035
Math Grade 5	-0.1122	-0.0113

* Effect size estimates are in units of fractions of a standard deviation for a 10dB difference in increment noise level. Comparison schools have 0 dB increment.

This stronger relationship for the estimated aircraft noise effect raises the question of whether the incremental noise level is an appropriate metric for all values of ambient noise. Does an increment of 10 dB in aircraft noise level have the same effect on test scores at ambient levels of 50 dB as it does at ambient levels of 65 dB? In fact, when the results of the analysis are separated into categories of ambient noise, the estimated effects are very similar in the ambient ranges of

50 to 55 dB, 55 to 60 dB, and greater than 65 dB. At ambient levels less than 50 dB, the sample size is too small to draw definite conclusions. The distribution of incremental noise levels as a function of ambient levels for the target schools is shown in Figure G-1 where it can be seen that, with few exceptions, higher incremental levels are associated with lower ambient levels.

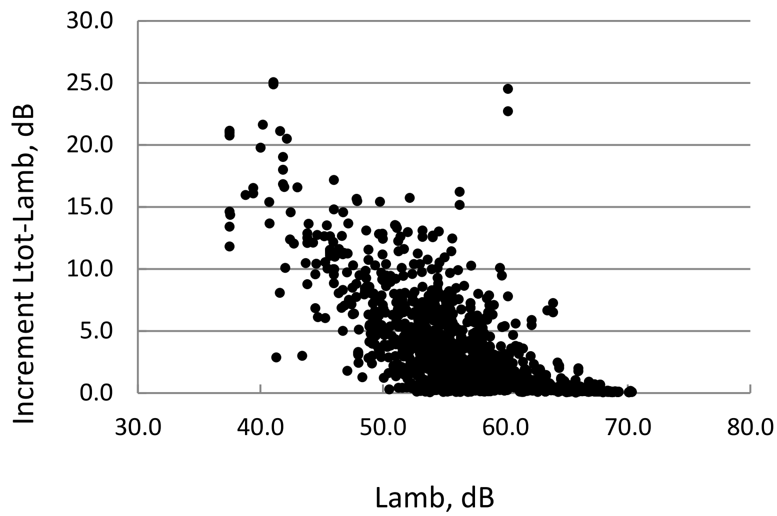


Figure G-1. Distribution of incremental noise levels as a function of ambient level.

G.4. Disadvantaged Students

Disadvantaged students are those whom family, social, or economic circumstances hinder their ability to learn at school. The term “disadvantaged” is a bureaucratic term stemming from the first large federal investment in public education, Title I of the Elementary and Secondary Education Act of 1965. That law provided for funds to go to schools based on the numbers of children in poverty enrolled in a school, to be used for the students in that school who were falling behind academically (often by hiring aides from the community). The staff in the school would determine which students were falling behind academically, often based on test scores.

To determine the extent to which disadvantaged student categories are affected differently by aircraft noise exposure, the analytical method was applied separately to test scores for two subgroups of students in each school, disadvantaged and non-disadvantaged, instead of to test scores for all students in the school.

The pre-adjustment for school-level demographic effects is much less for the analysis of the subgroups than it was for the analyses of the total set of students in the Grade at a school. In particular, the effect of the percentage of students in poverty (i.e., eligible for free or reduced price lunch) on the school average score is, logically, greater than its effect on the scores of disadvantaged students alone. In fact, one might expect that the effect on the average scores of disadvantaged students would be nil, that their numbers merely bring down the average of the total group. That is not quite the case – the concentration of poverty students in a school is correlated with somewhat lower scores for both disadvantaged and non-disadvantaged students in the school. Since the adjustment of scores for demographics is much less in these analyses than it is in the total group analyses, these subgroup comparison results cannot be directly compared with the total group results (i.e., to Table G-6).

There are two different designs for making the comparison:

(1) Same Schools - comparing adjusted scores of students in the two groups in each school, then averaging the differences over all target schools; or

(2) Separate Analysis - analyzing the adjusted scores of each group of students separately for all target schools, ignoring the scores of the other students.

For each school the first design weights the school the same for both subgroups, whereas the second design gives more weight to the school in the disadvantaged student analysis if it has a higher number of disadvantaged students, and more weight in the non-disadvantaged student analysis if it has a higher number of non-disadvantaged students. For both designs, only average scores based on five or more students were included in the analysis. Note that for the "same school" design, this excluded all schools in which either one of the subgroups had fewer than five students.

Table G-7 shows the effects of the aircraft noise increment on scores of disadvantaged and non-disadvantaged students. The results from the two sets of analyses are not the same. For example, the effects on disadvantaged student scores tend to be larger in the "Separate Analysis" than in the "Same Schools" comparison analysis. However, the "Same Schools" design probably addresses the comparison question better, in that it is a direct comparison between scores under identical noise and school conditions, i.e. teacher, teacher/pupil ratio, etc.

TABLE G-7 Comparison of the Effects of Aircraft Noise on Disadvantaged and Non-Disadvantaged Students.

Achievement Test	Estimated Noise Effect[1]			
	Same Schools		Separate Analysis	
	Disadvantaged	Non-Disadvantaged	Disadvantaged	Non-Disadvantaged
Reading Grade 3	-0.1172[2]	-0.1993	-0.2079	-0.2356
Reading Grade 4	-0.1094[2]	-0.2160	-0.1895	-0.2058
Reading Grade 5	-0.1394[2]	-0.2131	-0.1635	-0.2245
Math Grade 3	-0.1439[2]	-0.1874	-0.2009	-0.1785
Math Grade 4	-0.1989[2]	-0.2521	-0.2211	-0.1563
Math Grade 5	-0.1154[2]	-0.2368	-0.1421	-0.2341

[1] Effect size estimates are in units of fractions of a standard deviation for a 10dB difference in incremental level.

[2] Not significantly different from zero.

The results for the “Same Schools” analysis show that the effects of aircraft noise are significantly greater on non-disadvantaged than disadvantaged students, 71 percent more so for reading and 48 percent more for math. In fact, the effects for disadvantaged students in the “Same Schools” analysis, unlike the effects in the other three columns of Table G-7, are not statistically significantly different from zero.

In terms of percentile change, the effect size of -0.2 to -0.25 noted in the table for non-disadvantaged students corresponds to a 10 percentile reduction in state rank, (say from a 50th to almost a 40th percentile school in the state ranking) for an increment of 10 dB (103 target schools in 2008) in incremental aircraft noise. An increment of 15 dB (30 target schools in 2008), corresponds to a 15 percentile reduction in state ranking, and 20 percent for a 20 dB increase (10 target schools in 2008).

G.5. Effects of Sound Insulation on School Test Scores

The most obvious method for determining the effectiveness of sound insulation is to compare test scores in the years before and after the insulation was implemented. The achievement scores both before and after the intervention have similar levels of random measurement error. Therefore, the measurement of change must treat them similarly, for example by creating a change measure by subtracting the earlier score from the later score.

Of the target elementary schools analyzed in this study, there were twenty-nine insulated during the period between 2000 and 2008 that were both open for at least one year before and after being insulated and had test scores available. For these schools, it is possible to compare average test scores in years after sound insulation with scores in the same school before sound insulation. The results are shown in Table G-8. Based on changes in demographics of student bodies over the period, the demographically predicted changes in test scores in these schools were generally negative, and the apparent effects of insulation, as shown in the unadjusted results, were not sufficiently positive to overcome the demographic trend. None of the unadjusted changes were either noticeably or statistically significantly different from zero. After adjusting for the demographic trend, the effects were somewhat more positive, at Reading Grades 4 and 5, but not statistically significantly so. The sample size of schools undergoing sound insulation during the period of this study was insufficient to obtain a reliable estimate of the effects of that insulation.

Estimating the benefits of sound insulation by comparing test scores before and after the insulation is introduced is fraught with uncertainties. Even in the absence of noise, test scores vary from year to year in a given grade, as well as from grade to grade, and these variations are superimposed on any changes resulting from insulation. A larger sample of schools with test scores recorded before and after sound insulation is needed for a definitive result.

All of the analyses described in previous sections that were conducted to identify a relationship between test scores and aircraft noise (i.e., Tables G1- G7) had omitted records for insulated schools. In an attempt to overcome the limitations in the number of schools available for evaluating the effects of sound insulation, these previous regression analyses were repeated, but this time separately estimating aircraft noise effects on insulated and non-insulated schools.

TABLE G-8 Average Changes in Test Scores Associated with School Sound Insulation.

	Math Grade 3	Math Grade 4	Math Grade 5	Reading Grade 3	Reading Grade 4	Reading Grade 5
Unadjusted Change	-0.1635	0.0406	-0.0067	-0.1600	0.0198	0.0199
Students t	-1.65	0.41	-0.07	-1.68	0.22	0.21
Demographically Predicted Change	-0.1287	-0.0391	-0.1086	-0.0774	-0.1199	-0.1421
Students t	-3.14	-0.89	-2.43	-2.07	-1.96	-3.06
Adjusted Change	-0.0348	0.0797	0.1020	-0.0826	0.1397	0.1620
Students t	-0.30	0.88	1.00	-0.75	1.56	1.59
Number of Schools	22	19	23	23	20	21

Note: Differences are in standard deviations of school average test scores

The models posited three noise effects, namely (1) Ambient Noise, (2) Aircraft Noise Increment for insulated schools (Y), and (3) Aircraft Noise Increment for non-insulated schools (N). Between the years 2000 and 2008 the sample of open target insulated schools (those within the DNL 55 noise contour) ranged from 98 to 119. The results of the analysis are shown in Table G-9 where it is noticeable that the slope for the estimated noise effect is statistically significantly negative for non-insulated schools, similar to the results in Table G-6. For insulated schools, on the other hand, the aircraft noise effects did not differ significantly from zero.

Thus, it would appear that the act of sound insulating a school exposed to aircraft noise is to return student test scores to what they would be if the aircraft noise were removed.

TABLE G-9 Effect of Sound Insulation on Test Scores.

Test	Insulation Y/N	Estimated Noise Effect*	Adjusted t-Value**
Reading Grade 3	N	-0.134	-3.66
	Y	0.048	0.53***
Reading Grade 4	N	-0.128	-3.88
	Y	-0.093	-1.01
Reading Grade 5	N	-0.111	-3.04
	Y	0.033	0.36***
Math Grade 3	N	-0.118	-2.86
	Y	0.127	1.26
Math Grade 4	N	-0.134	-3.74
	Y	-0.016	-0.17***
Math Grade 5	N	-0.102	-2.50
	Y	0.132	1.31

* Effect size estimates are in fractions of a standard deviation for a 10dB difference in incremental noise level.

**Student's t-value adjusted by the deign effect – see Appendix F.4.

*** Not significantly different from zero.