Technical Report
LAX Master Plan EIS/EIR

14b. Health Effects of Noise Technical Report

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1. INTRODUCTION

This Technical Report presents additional information to support the assessment of potential health effects of noise associated with implementation of the Los Angeles International (LAX) Airport Master Plan. This report provides data and analysis in support of the Environmental Impact Statement/Environmental Impact Report (EIS/EIR) for the LAX Master Plan prepared pursuant to the National Environmental Policy Act (NEPA) and the California Environmental Quality Act (CEQA).

This report provides information that is supplemental to the material presented in Section 4.24.2, *Health Effects of Noise*, of the EIS/EIR. General approach and methodology and impacts associated with the information contained in this Technical Report are addressed in the EIS/EIR section. Noise impacts are also addressed in Section 4.1, *Noise*, of the EIS/EIR, Appendix D, *Aircraft Noise Technical Report*, and Section 4.2, *Land Use*, of the EIS/EIR and Technical Report 1, *Land Use*.

Noise is often described as unwanted sound. Factors that contribute to an individual's reaction to noise include the sound level, frequency, and duration, in addition to numerous non-acoustical factors, such as experience and personality. The level of noise can be represented in numerous ways.

Research on the health effects of aircraft noise has focused on the potential impact on physiological and psychological health, including speech communication, sleep disturbance, learning, and work performance. Publications pertaining to the long-term effects of noise on human health are often contradictory. Some studies suggest that there are clear indicators that noise, particularly aircraft noise, has a detrimental effect on the cardiovascular system, mortality rates, birth defects, achievement scores, psychiatric admissions, sleep disturbance, and overall psychological well being; other studies refute those conclusions and identify flaws in the methodology and analysis. With the exception of hearing damage, there are no quantifiable standards to be used as a basis for impact assessment with respect to the health effects of noise. However, the 65-decibel (dB) level of Community Noise Equivalent Level (CNEL) can be used in the assessment of aircraft noise in accordance with Federal Aviation Administration (FAA) guidelines. Numerous studies of human perception and annoyance have indicated that it is at this level that a substantial portion of the community will become "highly annoyed" by aircraft noise. The metric considers both the loudness and duration of exposure in the development of the average decibel level for all locations within the airport environs. FAA has developed compatibility criteria, which describe what land uses are acceptable within a certain noise level contour. These compatibility criteria are presented in Table 4.2-1, Land Use Compatibility Guidelines FAR Part 150, in Section 4.2, *Land Use*, of the EIS/EIR. These compatibility criteria consider the human response to noise, and have been established to prevent annoyance, which likely accrues at a lower noise level than health effects. It is, therefore, assumed that compliance with the compatibility criteria is sufficient to protect human health.

The following summarizes the findings of some of the existing studies and research on the physiological and psychological health effects of noise.

2. PHYSIOLOGICAL HEALTH

Potential physiological effects associated with noise include hearing loss, increased heart rate and blood pressure, and others. Hearing loss has been conclusively linked to noise exposure; however, research regarding other physiological effects is not conclusive. Details regarding existing research on each of these potential effects are provided below.

2.1 Hearing Loss

The most immediate and verifiable health effect presented by high sound levels is loss of hearing. Single-event noise levels from many aircraft that operate from runways at LAX commonly exceed 85 dB at neighboring residential land uses. However, on the basis of the single-event noise analysis and aircraft noise measurements, such levels are exceeded for less than one hour. Furthermore, aircraft noise levels of 115 dB are not experienced by residents around LAX. The baseline noise exposure analysis shows that the peak sound exposure level (SEL) affecting residents closest to LAX is 109 dB along Imperial Avenue in El Segundo. Due to the level and limited duration (a few seconds per operation) of baseline noise from aircraft at LAX, aircraft operations are not expected to cause permanent hearing damage to residents near LAX.

Employees of both LAWA and LAX tenants, particularly those who work on the airfield (e.g., baggage handlers, tug drivers, refueling workers) are exposed to aircraft noise during the course of their work.

Occupational Safety and Health Administration (OSHA) and California Occupational Safety and Health Administration (CalOSHA) noise standards, as shown in **Table 1**, OSHA and CalOSHA Permissible Noise Exposure Standards, regulate the exposure of all workers, including airport workers, to occupational noise. The noise levels are designed to prevent hearing damage in employees who work in loud environments. Airport employees use appropriate personal protective gear in order to reduce their noise exposure to the levels acceptable under OSHA and CalOSHA.

Table 1

OSHA and CalOSHA Permissible Noise Exposure Standards

Sound Level (dB)[1]	Duration Per Day (Hours)
90	8
92	6
95	4
97	3
100	2
102	1.5
105	1
110	0.5
115	<0.5[2] / <0.25[3]

1 When the daily exposure is composed of two or more periods of noise exposure of different levels, their combined effect should be considered, rather than the individual effect of each.
2 OSHA standard.
3 CalOSHA standard.

Source: OSHA, Code of Federal Regulations, Title 29, Chapter 27, Part 1910; CalOSHA, California Code of Regulations, Title 8, Article 105, Section 5096.

2.2 Physiological Effects Other Than Hearing Loss

Some studies on the physiological effects of noise have found that noise can cause physical reactions such as the release of adrenaline, a rise in blood pressure, and the tensing of muscles. For example, a study performed on schoolchildren in Munich indicated that children who live in high-noise areas near Munich International Airport have higher levels of stress hormones (adrenaline and norepinephrine) and elevated blood pressure. The researchers felt that their results confirm the link between chronic exposure to noise and elevation of stress hormones, elevation of resting blood pressure, and differential cardiovascular reactivity. Additionally, the authors interpreted the results of the study to indicate that chronic exposure to noise may deplete the coping capacity of children, directly affecting the cardiovascular system and indirectly affecting the immune system.[1] While such effects can be induced and observed, it is not known to what extent these physiological responses cause harm or signify that harm is occurring to the health of the individual.

A 1979 study performed near LAX identified a substantial increase in mortality rates in the area where noise was the highest. Specifically, the study claimed a 15 percent increase in deaths due to strokes and 100 percent increase in deaths due to cirrhosis of the liver as a result of jet noise.[2] However, a reanalysis of the data published in 1980 did not confirm the original results. Instead, the 1980 study indicated that "once the confounding effects of age, race, and sex were taken into account by direct and indirect methods of standardization, there was little difference in the mortality experience of the airport and control areas."[3]

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1 Evans, Gary W., Steffan Hygge, and Monika Bullinger, "Chronic Noise and Psychological Stress," Psychological Sciences, Volume 6, November 1995.

2 Meecham, W.C., and Neil Shaw, "Effects of Jet Noise on Mortality Rates," British Journal of Audiology, 1979.

3 Frerichs, Ralph R., Barbara L. Beeman, and Anne H. Coulson, "Los Angeles Airport Noise and Mortality -- Faulty Analysis and Public Policy," American Journal of Public Health, April 1980.

Although scientists have attempted to determine whether high noise levels can adversely affect human health beyond hearing damage, and the research efforts have covered a broad range of potential impacts, from cardiovascular response to fetal weight and mortality, a relationship between noise and health effects has yet to be convincingly demonstrated. Specifically, it has not yet been shown in a manner that can be repeated or replicated by other researchers while yielding similar results—an essential characteristic for acceptance by the scientific community.

In addition, physiological effects induced by noise can be associated with a wide variety of other environmental stressors. Isolating the effects of aircraft noise alone as a source of physiological change has not yet been convincingly proven. For example, socioeconomic factors can confound health effects of noise research. In a review of 30 studies conducted worldwide between 1993 and 1998,[4] a team of international researchers concluded that, while some findings suggest that noise can affect health, improved research concepts and methods are needed to verify this possible relationship. The team called for additional studies of the numerous environmental and behavioral factors that can confound, mediate, or moderate survey findings. Therefore, a direct link between aircraft noise exposure and physiological health effects, other than hearing loss, has not been demonstrated.

The U.S. Environmental Protection Agency (USEPA) has taken the following position: "Research implicates noise as one of several factors producing stress-related health effects such as heart disease, high blood pressure and stroke, ulcers and other digestive disorders. The relationship between noise and these effects has not yet been quantified."[5]

3. PSYCHOLOGICAL HEALTH

Potential psychological effects associated with noise include interference with speech communication, sleep disturbance, learning effects, and work performance effects. Many findings from survey reports show that there is little reliable evidence on the relationship between noise exposure and mental health.[6] Details about existing research on each of these potential effects are provided below.

3.1 Interference with Speech Communication

One of the most common effects of noise on human activities is the interference with speech communication. Speech communication interference may reduce understanding of conversations in classrooms and classroom teaching (as discussed in Section 3.3, *Learning Effects,* below) and the performance of work involving speech communication (as discussed in Section 3.4, *Work Performance Effects,* below). It also may affect a number of common daily activities and interactions.

Normal conversational speech is in the range of 60 to 65 dB and any noise in this range or louder may interfere with conversation. Scientific research has found that the maximum continuous sound level that will permit relaxed conversation with 100 percent intelligibility throughout a typical residential living room (talker/listener separation greater than approximately 3.5 feet) is 45 dB. A 95 percent intelligibility, considered to be "satisfactory conversation," can be obtained with a steady sound level of up to 64 dB. When the noise level approaches 80 dB, intelligibility drops to near zero even when a loud voice is used.[7] Speech communication interference may result from masking of the speaker's words or by causing the speaker to pause.

Outdoors, because of the absence of reflecting walls to provide the reverberation found indoors, the sound level of speech as it reaches the ear decreases comparatively more rapidly with increasing distance

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4 Lercher, P., S.A. Stansfield, and S.J. Thompson, "Non-Auditory Health Effects of Noise: Review of the 1993-1998 Period," Noise Effects - 98 Conference Proceedings, 1998.

5 U.S. Environmental Protection Agency, Guidelines for Noise Impact Analysis, EPA Report No. 550/9-82-105, 1982.

6 Taylor, S. Martin, and Peter A. Wilkins, Health Effects, Transportation Noise Reference Book, Butterworths, 1987.

7 U.S. Environmental Protection Agency, Office of Noise Abatement and Control, Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety, March 1974.

between the talker and listener. With steady background noise, there comes a point, as the talker and listener increase their separation, where the decreasing speech signal is masked by the noise.[8]

Almost all fluctuating sound levels found in the everyday environment will, if averaged over a long period of time, have less impact on speech intelligibility than a steady sound of the same Equivalent Sound Level (Leq). This occurs because, most of the time, the background noise level is less than the Equivalent Sound Level (because of the logarithmic base of sound intensity measurement, a loud sound need have only a relatively short duration to raise the Leq substantially).

The interference of speech associated with aircraft noise is a primary source of annoyance to individuals on the ground. The disruption of leisure activities, such as listening to the radio, television, music, and conversation, gives rise to frustration and irritation. Adequate speech communication is important in classroom, home, office, and industry settings. The degree to which noise interferes with indoor speech depends not only on physical factors such as noise levels, distance between the speaker and listener, and room acoustics, but also on non-physical factors such as the speaker's enunciation and the listener's interest in, and familiarity with, the topic.

The psychological effects of aircraft noise interference with speech communication have not been quantified, nor has there been a great deal of research widely accepted by the scientific community that deals specifically with the effects of speech communication interference. Research studies that address the relationship of speech communication interference with learning and work performance are discussed below.

3.2 Sleep Disturbance

Sleep disturbance is a major noise concern of residents near airports. Noise can make it difficult to fall asleep, create momentary disturbances of natural sleep patterns by causing shifts from deep to lighter stages, and awaken the sleeper. Sleep is essential for good physical and emotional health and noise can interfere with sleep even when the sleeper is not consciously awakened by noise.

The extent to which environmental noise affects human sleep patterns varies from individual to individual. Whether an individual is aroused by a noise depends upon the individual's sleep state and sleep habits, the loudness or suddenness of the noise, the information value of the noise, and other factors. When the noise source emanates from outdoors, as is the case with aircraft noise, additional factors affect the loudness of the noise as heard indoors. The noise level reduction provided by the type of structure is one of these determinants. A greater variable though, is whether windows are open or closed. Also, most people adapt over time to increased levels of noise during sleep.[9]

Recommended values for desired sound levels in residential bedroom space range from 25 to 45 dB with 35 dB being the norm. In 1981, the National Association of Noise Control Officials published data on the probability of sleep disturbance with various single event noise levels. Based on laboratory experiments conducted in the 1970s, this data indicated that noise exposure at a 75 dB interior noise level event will cause noise-induced awakening in 30 percent of cases. Like many earlier laboratory sleep studies, this study has been criticized because of the extremely small sample sizes and because the laboratory was not necessarily a representative environment.

Historical studies of sleep disturbance were conducted mainly in laboratories, using various indicators of response (e.g., electroencephalographic recordings, verbal response, button push). Field studies were also conducted, in which subjects were exposed to noise in their own homes, using real or simulated noise.[10, 11, 12] In a 1989 assessment of existing research, one study, cited by the Federal Interagency

8 California Department of Transportation, Division of Aeronautics, Airport Land Use Planning Handbook, December 1993.

9 California Department of Transportation, Division of Aeronautics, Airport Land Use Planning Handbook, December 1993.

10 Lukas, J., "Noise and Sleep: A Literature Review and a Proposed Criterion for Assessing Effect," Journal of the Acoustical Society of America, 58(6), 1975.

11 Griefahn, B., and A. Muzet, "Noise-Induced Sleep Disturbances and Their Effect on Health," Journal of Sound and Vibration, 59(1), 1978.

12 Pearsons, K.S., D.S. Barber, and B.G. Tabachnick, Analyses of the Predictability of Noise-Induced Sleep Disturbance, (HSD-TR-89-029), Brooks Air Force Base, 1989 (HSD/YA-NSBIT).

Committee on Aviation Noise (FICAN), indicated the need for substantially more research in this area, citing the large discrepancy between laboratory and field studies as a major concern.[13] For instance, data from studies since 1992 indicates that considerably fewer of the exposed population is expected to be awakened by noise than had been shown with laboratory studies.

Sleep disturbance studies may also involve the collection of cumulative data from subjects. Potential problems associated with the use of cumulative data include the potential influences of disturbance caused by non-noise sources and the difficulty of avoiding bias in test subjects when self-reporting. Additionally, a 1989 literature review conducted for the U.S. Air Force, indicated that no specific adverse health effects have been clearly associated with sleep disturbance either by awakening or by sleep-state changes.[14] Research has consistently shown that all subjective reactions to noise vary greatly from person to person and from time to time and deviations from the average can be very large. Details of specific sleep disturbance studies are provided below.

A research study from England has shown that the probability for sleep disturbance is less than what had been reported in earlier research. This study, conducted in the 1990s using new techniques, indicates that awakenings can be expected at a much lower rate. This research showed that once a person is asleep, it is unlikely that the individual will be awakened by single-event noise. The major difference between the British study and those performed earlier is that the British study used actual in-home sleep disturbance patterns as opposed to laboratory data. Some of this research was criticized because it was conducted in areas where subjects had become accustomed to aircraft noise. This study compared the various causes of sleep disturbance using in-home sleep studies. This field study assessed the effects of nighttime aircraft noise on sleep in 400 people (211 women and 189 men; 20 to 70 years of age; one per household) living at eight sites adjacent to four U.K. airports, with different levels of nighttiem aircraft activity. The main finding was that only a minority of aircraft events affected sleep and, for most subjects, domestic and other non-aircraft factors had much greater effects.[15]

The British study indicated that, once asleep, very few people living near airports are at risk of any substantial sleep disturbance due to aircraft noise, even at the high event levels. The study emphasized that its data represents average awakenings and that some individuals in any exposed population are likely to be more sensitive to nighttime noise than others. The study also showed that an average person has only a 1-in-75 chance of being awakened by aircraft noise in the outdoor range of 90 to 100 dB SEL. Allowing for the noise level reduction of the structure, this data indicates that indoor single-event sound levels of 70 to 80 dB will cause less than a 2 percent chance of sleep disturbance.[16]

In contrast to the British study, a U.S. Air Force study[17] found that approximately 20 percent of the population can be expected to awaken by indoor SEL of 70 dB. This percentage rises to nearly 50 percent at an SEL of 90 dB. Earlier studies documented by USEPA[18] indicate even higher percentages of people likely to be awakened by noise levels in this range. The USEPA report found that 60 percent of people are awakened by outdoor cumulative noise levels (DNL) of 65 dB. Some of the discrepancies among these studies can be accounted for by the differences in the way people sleep in their own homes versus in a laboratory setting and the difference between those likely to be awakened by noise in a laboratory setting than in a familiar, home environment. There is also an important distinction between individual noise events and ambient noise levels. When background noise levels are low, a single noise having a maximum level of as little as 45 dB may cause some individuals to awaken, particularly if they

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13 Federal Interagency Committee on Aviation Noise (FICAN), Effects of Aviation Noise on Awakenings from Sleep, June 1997.

14 Pearsons, K.S., D.S. Barber, and B.G. Tabachnick, Analyses of the Predictability of Noise-Induced Sleep Disturbance, (HSD-TR-89-029), Brooks Air Force Base, 1989 (HSD/YA-NSBIT).

15 Ollerhead, J.B., C.J. Jones, et al., Report of a Field Study of Aircraft Noise and Sleep Disturbance, A study commissioned by the U.K. Department of Transport, Department of Safety, Environment, and Engineering, 1992.

16 California Department of Transportation, Division of Aeronautics, Airport Land Use Planning Handbook, December 1993.

17 Finegold, 1992, as referenced in California Department of Transportation, Division of Aeronautics, Airport Land Use Planning Handbook, December 1993.

18 U.S. Environmental Protection Agency, Office of Noise Abatement and Control, Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety, March 1974.

have not become accustomed to such noises. However, a relatively constant noise of about the same level would likely cause less sleep disruption to surrounding residents.

A 1992 study conducted for the U.S. Air Force observed the effects of nighttime noise exposure on the in-home sleep of residents near Castle Air Force Base in California, near LAX, and in several suburban control households with negligible aircraft noise exposure. A statistically reliable relationship was observed between sound exposure levels of noise intrusions in sleeping quarters and behaviorally confirmed awakenings within five minutes of occurrence of noise intrusions. However, of a total of 4,452 awakening responses, only 326 could be associated with particular noise events. The authors also cautioned that the test subjects used in this study may not be representative of all residential situations and that generalizations of the data obtained in the study should be limited to long-term residents of areas with stable nighttime noise exposure.[19]

A large-scale field study of noise-induced sleep disturbance was conducted near Stapleton International Airport and Denver International Airport, both in Colorado. Sleep disturbance was measured by several methods, including button pushes upon awakening and body movements, as recorded by actimeters.[20] The results of this study indicated that statistically reliable relationships were observed between sound exposure levels of individual noise intrusions as measured inside sleeping quarters and several measures of sleep disturbance.[21] Although a statistically reliable relationship was observed, this study does not provide any guidance as to what level of sleep disturbance constitutes a significant impact.

In 1992, the Federal Interagency Committee on Noise (FICON), in a document titled *Federal Interagency Review of Selected Airport Noise Analysis Issues*, recommended an interim dose-response curve for sleep disturbance based on laboratory studies of sleep disturbance. In June 1997, FICAN updated the FICON recommendation with a curve based on the more recent in-home sleep disturbance studies which show lower rates of awakening compared to the laboratory studies. The study concluded that the FICON curve overestimated the extent of aircraft noise-related awakenings for a given noise exposure. The curve has some limitations. It is based on behavioral awakening as the indicator of sleep disturbance; relationships between aircraft noise and other potential sleep disturbance or related health effects responses have not been established by any of the recent studies. Additionally, the dose-response curve applies to long-term residents of areas near airports. Insufficient data is available to apply the dose-response curve to short-term or transient residents.[22] The dose response curve is presented as **Figure 1**, Recommended Sleep Disturbance Dose Response Relationship. As indicated by the curve, it is estimated that 10 percent of people are awakened by an 80 dB event.

A review of these existing studies and literature indicates that additional research is required to clarify the relationship between aircraft-related noise and sleep disturbance.

3.3 Learning Effects

Interference with classroom activities and learning from aircraft noise has been the subject of much recent research. Some interference with classroom activities can be expected from noise events that interfere with speech. As discussed previously, speech communication interference begins at 65 dB, which is the level of normal conversation. Typical classroom construction attenuates outdoor noise by 20 dB with windows closed and 12 dB with windows open. Therefore, some interference with classroom activities can be expected at outdoor levels of 77 to 85 dB. It is important to note that numerous schools, both public and private, within the existing 65 CNEL have been soundproofed so greater noise attenuation is likely at these schools.[23]

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[19] Fidell, S., K. Pearsons, R. Howe, B. Tabachnick, L. Silvati, and D.S. Barber, Noise Induced Sleep Disturbance in Residential Settings, Wright-Patterson Air Force Base, Armstrong Laboratory, 1994.

[20] Actimeters are activity monitors which record significant limb movements over a long period of time.

[21] Fidell, S., K. Pearsons, et al. "Field Study of Noise-Induced Sleep Disturbance," Journal of the Acoustical Society of America, 98(2), 1995.

[22] Federal Interagency Committee on Aviation Noise (FICAN), Effects of Aviation Noise on Awakenings from Sleep, June 1997.

[23] Soundproofing was performed as a result of a 1980 lawsuit that resulted in a settlement with several public school districts. Based on this judgment, easements have been granted to all schools within the 65 CNEL (64 schools at the time of the judgment and any schools constructed since that time). A similar settlement was reached for three private schools within the 65 CNEL.

A complicating factor in research regarding schools and aircraft noise is the extent to which background noise from within the classroom affects the results. Additionally, the quality of schools and socioeconomic factors are difficult to isolate and control for in the research. A brief summary of existing research regarding the learning effects of aircraft noise is provided below.

A study performed on children at the four elementary schools near LAX exposed to the greater level of aircraft-related noise suggests that exposure to aircraft noise affects the motivation and cognitive abilities of children. The study suggests that the exposure to high intensity noise can induce feelings of helplessness, which can occur when an individual cannot control or change a stressful event. This feeling of helplessness can decrease motivation to initiate new tasks or persist in ongoing tasks. The study also suggests that children who grow up in noisy environments become inattentive to sound by tuning it out. When this inattention leads to tuning out of speech, it may lead to reading and learning problems.[24]

A Cornell study also suggests that children who attend school in areas affected by aircraft noise have more difficulty with language acquisition. The researchers suspect that other factors at schools in neighborhoods exposed to aircraft noise may affect learning, including teacher and parent irritability and their reluctance to talk, due to interference with speech communication.[25]

A study performed with children near Munich International Airport indicates selective impairment in cognitive functioning among children from communities with high levels of aircraft noise. This study also indicates that children may cope with noise by developing cognitive strategies like tuning out noise, which may affect their language acquisition and speech processing.[26] Studies performed at Heathrow Airport in London, suggest that chronic exposure to aircraft noise is associated with school performance in reading and math, but that this association is influenced by socioeconomic factors.[27]

A review of these existing studies and literature indicates that additional research is required to clarify the relationship between aircraft-related noise and learning effects, particularly due to the confounding factors of background noise, school quality, and socioeconomic status. Additional research is being performed to try to account for these factors.

3.4 Work Performance Effects

Work performance can also be potentially affected by aircraft noise through speech communication interference, and increased fatigue; although a specific relationship between intermittent aircraft noise and decreased work performance has not been documented.

Epidemiological studies have shown that workers in noisy industries have significantly higher rates of cardiovascular problems than those in quiet industries. Other studies on metabolism, body steadiness, distance judgment, and many other activities show no evidence of any disturbance by noise. Many dose-response relationships have been studied on long-term exposure in residential areas that causes annoyance and complaints. While no dose-response relationship has been found relating noise and health effects, excluding hearing loss, there have been levels of sound identified that are considered safe. These levels typically apply to employees in noisy industries and would not apply to off-airport noise exposure. The exposure of LAX workers to noise is discussed in Section 2, *Physiological Health*, above.

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[24] Cohen, Sheldon, Gary W. Evans, David S. Krantz, and Daniel Stokols, "Physiological, Motivational, and Cognitive Effects of Aircraft Noise on Children: Moving from the Laboratory to the Field," American Psychologist, Vol. 35, March 1980.

[25] Evans, Gary, and Lorraine Maxwell, Environment and Behavior, 1997.

[26] Evans, Gary W., Staffan Hygge, and Monika Bullinger, "Chronic Noise and Psychological Stress," Psychological Sciences, Volume 6, November 1995.

[27] Stansfield, Stephen, and Mary Haines, Chronic Aircraft Noise Exposure and Children's Cognitive Performance and Health, FICAN Symposium, February 16, 2000.