11 Community Noise, Behavior, and Health: The Los Angeles Noise Project

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Over 70 million Americans live in neighborhoods with noise levels sufficient to interfere with communication and cause annoyance and dissatisfaction (U. S. Environmental Protection Agency, 1974). Sources of noise in these neighborhoods include aircraft overflights, traffic, construction and industrial machinery, as well as the sounds of neighbors, children, and pets. Are high levels of community noise detrimental to residents' health and well-being? This is a question we are only beginning to answer.

The potentially deleterious impact of high-intensity noise on hearing has been widely accepted by scientists and policy makers alike. Acceptable noise standards used in both national and local statutes are based on data that establishes the relationship between the intensity and duration of noise and temporary or permanent losses of hearing (Kryter, 1970). Research completed during the last 10 years also indicates that noise can affect nonauditory systems as well as auditory ones. For example, accumulating evidence suggests that prolonged exposure to high-intensity noise is associated with increased risk of cardiovascular pathology and disturbing psychological symptoms (Cohen & Weinstein, 1981). Moreover, increased levels of community noise have been repeatedly associated with greater dissatisfaction and annoyance by community residents (Borsky, 1980). Despite numerous studies of the possible deleterious effects of routine noise exposure on aspects of behavior and health other than hearing loss and annoyance, inferences concerning these other effects are generally considered tenuous.

It is difficult to reach firm conclusions based on naturalistic studies of the effects of community noise. Invariably, the possibility exists that people who choose (or are forced) to work or live in a noise-impacted area are somehow different from those who work or live elsewhere. Moreover, environments that suffer from serious levels of noise often have other characteristics (e.g., pollution, poor housing, high levels of population density) that may also affect health and behavior.

Laboratory research provides another source of data from which to speculate about the effects of routine noise exposure. This research suggests that high-intensity noise can affect at least three types of nonauditory processes. Firstly, exposure to noise can lead to a *narrowed focus of attention*. This decrease in one's breadth of attention presumably occurs either as a reaction to a noise-induced increase in arousal (Broadbent, 1971) or as a strategy to decrease the amount of information being processed when the presence of noise taxes processing capacity (Cohen, 1978). A narrowed focus of attention during noise exposure is assumed to have detrimental effects on performance of complex tasks (i.e., those requiring a wide range of attention), but not on tasks that are simple or intermediate in complexity.

A second effect of exposure to noise—at least noise that is unpredictable and uncontrollable (cannot be escaped or avoided)—is a reduction in one's perception of control over the environment (Glass & Singer, 1972; Krantz, Glass, & Snyder, 1974). This loss of control is often accompanied by a depressed mood and a decrease in one's motivation to initiate new responses (Seligman, 1975). Loss of control has also been associated with aftereffects, that is, deficits in performance that occur after the noise stimulus is terminated.

A third effect of exposure to noise suggested by experimental evidence is an alteration in physiological arousal characteristic of a generalized stress reaction (Kryter, 1970; Welch & Welch, 1970). This effect includes increased blood pressure, elevated skin conductance levels, and increased excretion of hormones indicative of sympathetic nervous system activity. There is also convincing evidence that prolonged exposure to noise can produce long-term changes in cardiovascular function in animal subjects (Peterson, 1979; Peterson, Augenstein, Tanis, & Augenstein, 1981). Most of these reactions in humans have been documented in laboratory studies involving short-term exposure to relatively high sound levels; thus, the implications of this research for those suffering prolonged exposure at home or at work are questionable.

The respective shortcomings of laboratory and field research on nonauditory effects of noise can be overcome by a strategy that combines experimental and naturalistic studies. Such a strategy examines whether effects of short-term noise exposure found in well-controlled laboratory studies generalize to settings where people are routinely exposed to high-intensity noise. Laboratory studies serve to

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direct our attention to categories of behavior and health that may be affected by noise, and to establish a causal link between noise and these behaviors. Naturalistic research helps to establish whether particular effects found in the laboratory also occur in real-life settings. Accordingly, this chapter reviews research on the cardiovascular and behavioral effects of community and industrial noise on humans with particular emphasis placed on health-related cardiovascular responses, noise-induced shifts in attention, and feelings of personal control. In conjunction with this review, we report results of a collaborative longitudinal study, the Los Angeles Noise Project, designed to examine the course of adaptation to noise, and the impact of a noise-abatement intervention on a variety of physiological and psychological measures (Cohen, Evans, Krantz, & Stokols, 1980; Cohen, Evans, Krantz, Stokols, & Kelly, 1981).

NOISE AND PHYSICAL HEALTH

Is noise harmful to the human body? Many would argue that outside of the effects of high-intensity sound on hearing (Kryter, 1970; Miller, 1974) there is little convincing evidence for a causal link between noise and physical disorders. As mentioned earlier, several noise-induced physiological changes have been reported in laboratory research. Such changes, if extreme, are often considered potentially hazardous to health. These studies are usually of short duration, making it tenuous to generalize these results to situations where people are routinely exposed to noise. However, epidemiological research in industrial and community settings provides some suggestive evidence of deleterious health effects.

A recent review of the foreign industrial-noise literature by Welch (1979) concludes that there is increased prevalence of a variety of specific nonauditory diseases (e.g., cardiovascular disorders, gastrointestinal complaints, infectious disease) among people who have been exposed at work to sound levels of 85 db(A) or greater for at least 3 to 5 years. Moreover, the morbidity associated with exposure to relatively high intensities of sound increases with advancing age and years of employment for both men and women. Disease prevalence tends to be greater among those exposed to sound that is unpredictable or intermittent, compared to periodic or continuous noise. Both absenteeism and accident rates are higher for those working in intense noise as compared with unexposed workers or workers wearing ear protection (A. Cohen, 1976). Many of the aforementioned studies unfortunately do not control for relevant confounding factors such as education, income, and job demands. It is also important to note that several industrial surveys failed to find a relationship between noise and ill health (Finkle & Poppen, 1948; Glorig, 1971).

The strongest case for routine industrial noise impacting health derives from research on cardiovascular problems (Cohen & Weinstein, 1981; Welch, 1979).

Impaired regulation of blood pressure (including especially hypertension) is the best documented of these effects. Other concomitants of prolonged exposure to intense industrial sound include additional clinical cardiac symptoms (e.g., arrhythmia) and vascular disorders. The impressive amount of data linking cardiovascular disorders to exposure to high noise levels at work must, nevertheless, be viewed with caution. All these studies suffer from the methodological problems associated with correlational field research, and many do not include adequate control groups. Our confidence in the relationship between prolonged exposure to high-intensity industrial noise and cardiovascular problems would be significantly increased if similar effects were obtained in well-designed prospective research.

The effects of community noise on cardiovascular problems and physiological risk factors for cardiovascular disease have also been examined. In a series of studies conducted in the neighborhoods adjacent to an airport in Amsterdam, Knipschild (1977) reports that residents in areas with high levels of aircraft noise were more likely to be under medical treatment for heart trouble and hypertension, more likely (especially among women) to be taking drugs for cardiovascular problems, and also more likely to have high blood pressure and other cardiac abnormalities than an unexposed population. Whereas these differences could not be explained by age, sex, smoking habits, or obesity, the noisy and quiet areas did differ in socioeconomic status. A final study, not subject to this alternative explanation, reports that increases in the purchase of cardiovascular drugs were positively correlated with the number of aircraft overflights at night. Similarly, a Russian study (Karagodina, Soldatkina, Vinokur, & Klimukhin, 1969) suggests that children (9–13 years old) in noise-impacted areas around nine airports show blood pressure abnormalities, higher pulse-rate lability, cardiac insufficiency, and local and general vascular changes. Unfortunately, the report does not provide any information on the nature of the quiet-control population or any details of the measurement procedures.

Studies of the effects of traffic noise on cardiovascular measures are less consistent. A German study of children in the seventh through tenth grades (Karsdorf & Klappach, 1968) reports higher systolic and diastolic pressure for children from noisy schools, whereas a Dutch study (Knipschild & Salle, 1979) found no evidence for increased risk of cardiovascular disease in middle-aged housewives living on streets with high levels of traffic noise as compared with their neighbors living on quieter streets. Overall, like the industrial studies, the studies of community noise suggest that such noise is associated with increases in the incidence of cardiovascular disease and factors related to risk of cardiovascular pathology.

One striking aspect of these data is the evidence that children as well as adults show noise-associated cardiovascular effects. In fact, based on existing theory and evidence, there is reason to expect that exposure to high-intensity noise is a greater threat to children than to adults. Physiological development may be

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disrupted by unusual demands of external stressors. As we describe later, children may also be psychologically less able to deal with a continuous stressor, because of a limited repertoire of coping strategies, or because they lack the opportunity to control or manipulate their own outcomes (Cohen, Glass, & Phillips, 1979). During the formative years of childhood, noise may also have a particularly detrimental effect on learning or cognitive development.

EFFECTS OF CHRONIC NOISE EXPOSURE ON ATTENTIONAL PROCESSES

A number of years ago, it was proposed that young children continuously exposed to noise adopt an attentional strategy to help them cope with their acoustic environment (Deutsch, 1964). Moreover, it was suggested that this strategy, although successful in the sense of helping the children cope with the noise, has the adverse effect of causing children reared in noisy environments to become inattentive to acoustic cues; that is, they "tune out" their acoustic environment. Children who tune out noisy environments are not likely to distinguish between speech-relevant and speech-irrelevant sounds. Thus, they will lack experience with appropriate speech cues and generally show an inability to recognize relevant sounds and their referents. The inability to discriminate sound is presumed to account, in part, for subsequent problems in learning to read.

Recent research suggests that children living and attending school in noisy neighborhoods are poorer at making auditory discriminations even when tested in quiet settings. For example, S. Cohen, Glass, & Singer (1973) studied third- through fifth-grade children living in apartment buildings built on bridges spanning a busy expressway. When tested in a *quiet* setting, children living in noisier apartments showed greater impairment of auditory discrimination and reading ability than those living in quieter apartments. The magnitude of the correlation between noise and auditory discrimination increased with the length of residence. Race, social-class variables, and hearing losses were ruled out as possible alternative explanations. Similarly, Moch-Sibony (in press) compared children from a quiet (soundproofed) elementary school in the air corridor of Orly (Paris) Airport to a nearby noisy (without soundproofing) school population matched on socioeconomic variables. Results indicated that children from the noisy school showed poorer auditory discrimination, but there were no differences between schools in reading achievement.

A third study of 4½- to 6½-year-old children from homes described by their parents as either noisy or quiet (Heft, 1979) indicates that when tested in *quiet*, children from noisy homes performed more poorly on both a matching and incidental memory task than those from quieter homes. Analyses controlled for age, preschool experience and income level of parents. It should be noted, however, that self-reports of noise level do not usually correlate highly with objective noise measures (Kryter, 1970) and thus limit the generality of these findings.

The results obtained in the aforementioned studies may be termed *aftereffects*, because task performance was measured outside the stressful environment. In contrast to the previous research, Bronzaft & McCarthy (1975) tested children *in* their respective noisy and quiet classrooms. Children in classrooms on the side of a school facing train tracks performed more poorly on a reading achievement test than children in classrooms on the quiet side of the building.

Although the evidence suggests that children living and attending school in noisy environments are poorer at making auditory discriminations and in reading performance, there is no direct evidence for the selective inattention mechanism as a mediator of these effects. Another equally plausible explanation for the auditory discrimination and school achievement results is that noise masks parent and teacher speech, similarly resulting in the child's lack of experience with appropriate speech cues and, as a consequence, reading deficits. It has also been suggested that attentional strategies employed to tune out noise stimuli may be persistently employed after termination of the stimulus (Cohen, 1980). Clearly, more research is needed to choose among these various hypotheses.

NOISE, PERSONAL CONTROL, AND HELPLESSNESS

Laboratory research on personal control over aversive stimuli (Glass & Singer, 1972) also suggests some possible long-term effects of noise exposure. The great majority of this work deals with the role of control in mediating physiological and behavioral reactivity during short-term exposure to laboratory stress (Krantz, Glass, & Snyder, 1974). Seligman (1975) suggests that motivational, cognitive, and emotional disturbances result when individuals continually encounter environmental events (especially aversive events) that they can do nothing about. This psychological state, called *learned helplessness*, results because individuals perceive themselves as incapable of exerting control over the environment.

Closely related to the work on learned helplessness is Glass and Singer's (1972) research on the effects of noise on poststimulation performance. These and other authors (Rotton, Olszewski, Charleton, & Soler, 1978; Sherrod, Hage, Halpern, & Moore, 1977) report that subjects exposed to uncontrollable noise that is unrelated to an ongoing task do more poorly on poststimulation tasks compared to subjects who perceive that they can terminate the noise at will. These effects were observed on poststimulation tasks as diverse as proofreading and measures of tolerance for frustration. Although a variety of plausible explanations for these aftereffects have been suggested (Cohen, 1980, for review), both Seligman (1975) and Glass and Singer (1972) assert that subjects unable to control or predict noise learn that there is little they can do to affect the stressor. This presumably results in lowered motivation and poorer performance on subsequent poststimulation tasks.

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There is inferential data to suggest that those experiencing chronic exposure to noise in real life settings often perceive the noise as uncontrollable and show helplessness-like effects. Consider, for example, data reported by Herridge (1974) indicating that those living in "noise slums" were more likely to be admitted to a mental hospital than those living in less-noisy areas. Herridge suggests that the mental distress of those experiencing prolonged exposure to noise was largely attributable to feelings of helplessness rather than to noise per se. This assertion is supported by data indicating that residents of the noisy areas were less likely to complain about aircraft noise than residents of control areas. In other words, even though they are apparently disturbed by noise, they appear to exert minimal effort to modify or escape the unwanted stimulation. Unfortunately, the questionable demographic comparability of noisy and less-noisy areas in this study, and the low base rate of complaints from both areas restricts our confidence in this interpretation.

Although these data on the relationship between noise and helplessness are only suggestive, at least two studies supply direct evidence that, at least for children, environmental stress (noise or high levels of residential density) can result in behavioral deficits (e.g., poor performance on tasks measuring persistence). In one case these performance deficits were associated with lowered perceptions of personal control.

A study by Moch-Sibony (1979), described earlier, reported that children from a noisy school in an airport corridor also showed less tolerance for frustration than their quiet-school counterparts. Research from the crowding literature also supports the notion that chronic environmental stress can induce helplessness. A well-controlled set of studies by Rodin (1976), demonstrated that children living in presumably stressful high-density apartments were more adversely affected by a learned-helplessness pretreatment—unsolvable puzzles—than children from low-density apartments. The high-density children were also less likely to exercise their own choices when given the opportunity to do so. Thus, high chronic density can result in feelings of helplessness among children. Our understanding of the cognitive and motivational processes affected by chronic noise exposure would be advanced by a longitudinal study examining similar effects of noise stress on performance on standard helplessness measures (response to failure).

THE LOS ANGELES NOISE PROJECT

The evidence reviewed previously suggests that laboratory work on health-related cardiovascular responses, noise-induced shifts in attention, and feelings of personal control may have some generality to situations of chronic noise exposure. Whereas investigators have begun to take a closer look at the nonauditory effects of noise in naturalistic settings, methodologically tight studies are rare. This research also tends to be atheoretical and thus difficult to compare to existing laboratory work. Moreover, there are few *longitudinal* studies of people living and/or working under noise. Thus, it is unknown whether prolonged noise exposure results in increasingly deleterious effects, or whether those exposed for prolonged periods adapt to noise with effects disappearing after a while. Studies comparing measures of health and behavior of the same person before exposure, immediately after exposure begins, and at set intervals for one to several years would allow us to determine the long-term course of stress and adaptation. In addition, longitudinal studies in situations where the environmental stressor is removed or attenuated would make it possible to determine whether there are long-term aftereffects of prolonged noise exposure.

Accordingly, we conducted a controlled longitudinal study of the impact of aircraft noise on elementary school children (The Los Angeles Noise Project or LANP) The study examined the course of adaptation and the impact of a noise-abatement intervention on blood pressure, attentional processes, and feelings of personal control. (Cohen et al., 1980; 1981, for a fuller report of this study).

The subjects were children (initially third and fourth graders) living and attending schools in the air corridor of Los Angeles International Airport, and children of similar socioeconomic, age, and racial composition living and attending schools in quiet Los Angeles neighborhoods.[1] Peak sound-level readings in the noise schools were as high as 95db (A), and the schools were located in an air corridor that has approximately one flight every 2½ minutes during school hours (Lane & Meecham, 1974)

As part of a settlement of a lawsuit brought by the school systems against the airport, the interior sound levels of many of the schools in the landing corridor were lowered following the collection of data for the first testing phase of the study (T1). Thus, a large number of noise-affected children spent the following year in quieter classrooms, whereas others remained in noisy classrooms. One year after original testing, children who were still enrolled in their schools were retested (T2) on the original measures to determine whether effects of noise that occurred during the first year of the study would persist after the child was assigned to a quieter classroom. The study focused on effects occurring outside of noise exposure; thus, all measures, except school achievement tests given in classrooms, were administered in a quiet setting (a soundproof van).

Longitudinal data from subjects who were tested at both sessions (T1 and T2), and who remained in noise classrooms, were compared to children in quiet classrooms at both testing sessions These data were used to determine if noise effects adapted—decreased or disappeared—over the 1-year interval between

[1]Children with hearing losses were excluded from the study. In all analyses of data, a regression analysis procedure enabled precise statistical control for number of children in the child's family, the number of years the child had lived in the neighborhood, grade in school, and race Additional controls and multivariate analyses were used for selected dependent measures where appropriate (Cohen et al , 1980, Cohen et al , 1981)

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Overview of the Analyses

	Title of Analysis	*San*
I.	Cross-sectional, T1	T1
II.	Longitudinal	Subjec at bot
III	Noise Abatement: Cross-sectional Analyses	T1
IV.	Noise Abatement: Longitudinal Analyses	Noise s tested a T1 & T

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TABLE 11.1
Overview of the Analyses in the Los Angeles Noise Project

	Title of Analysis	*Sample*	*Classroom noise conditions during: 1977 (T1) 1978 (T2)*
I.	Cross-sectional, T1	T1	noise vs. quiet
II.	Longitudinal	Subjects tested at both T1 & T2	noise[a] — noise vs. quiet — quiet
III.	Noise Abatement: Cross-sectional Analyses	T1	noise vs. abated vs. quiet
IV.	Noise Abatement: Longitudinal Analyses	Noise subjects tested at both T1 & T2	noise — noise vs. noise — abated

[a]The few classrooms that had had noise abatement work completed prior to T1 are included as noise classrooms in these analyses. This was done in order to make these analyses comparable to those reported in Cohen et al. (1980) and is justified by the findings reported in this paper suggesting little if any effect of abatement.

sessions. Several years before the first testing session, a number of classrooms had been treated with noise-reducing materials. Thus, because some abatement work was introduced both prior to T1 and between T1 and T2, separate analyses (both cross-sectional and longitudinal) were conducted in order to evaluate the effectiveness of the noise-abatement interventions. Four types of analyses are, therefore, discussed in this chapter: *cross-sectional* and *longitudinal* analyses to evaluate the effects of *noise* and *noise abatement*. Table 11.1 presents an overview of these analyses. In our discussion following we first consider the nature and persistence of noise effects and then discuss the effects of abatement.

AIRCRAFT NOISE AND BLOOD PRESSURE

Because chronic noise exposure might affect the cardiovascular system, a measure of cardiovascular function, resting blood pressure, was included in the LANP. The effects of noise exposure on blood pressure were decisively clear in the cross-sectional analysis of T1 data (see Fig. 11.1) Children attending noisy schools had higher systolic and diastolic pressures than their quiet-school counterparts. Moreover, the pattern of means for systolic and diastolic pressures suggest that this effect was greatest during the first 2 years of exposure, with the differences remaining consistently smaller after that point. It should be noted, however, that although these blood pressure differences were statistically reli-

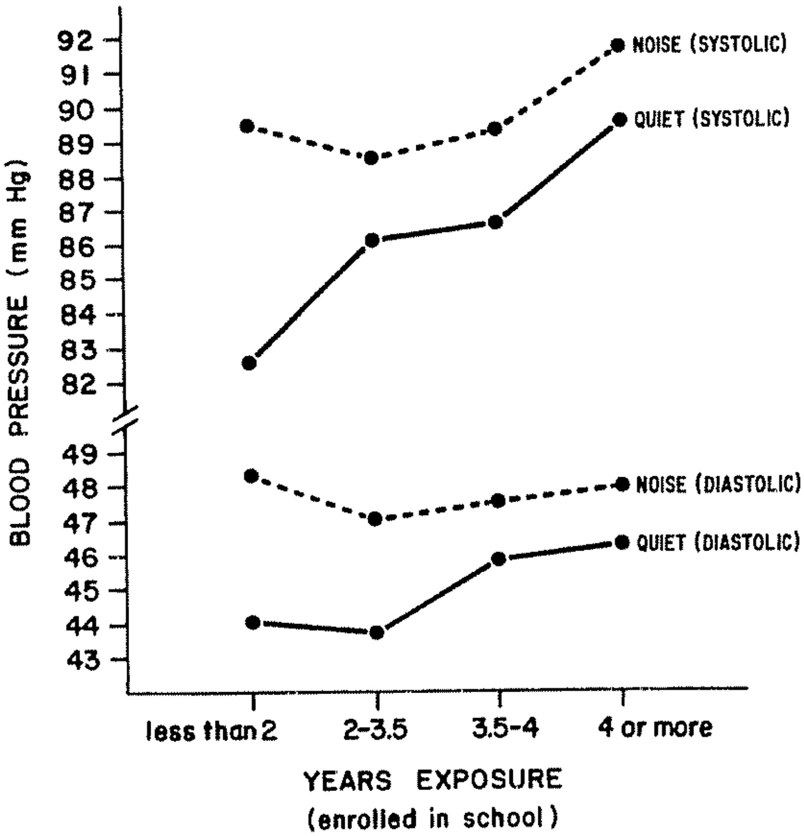

FIG. 11.1. Systolic and diastolic blood pressure as a function of school noise level and duration of exposure for T1 sample. Each period on the years exposure coordinate represents one quarter of the sample. For example, 25% of the sample were enrolled in school less than 2 years (from Cohen, S., Evans, G. W., Krantz, D. S., & Stokols, D. 1980. Copyright 1980 by the American Psychological Association. Reprinted by permission).

able, the mean levels for children attending noisy schools do not as a group exceed normative levels for children of similar ages (Voors, Foster, Frerichs, Weber, & Berenson, 1976). The long-term health consequences, if any, of these blood pressure elevations remain unknown.

The greater difference during the first few years of school enrollment found in this cross-sectional analysis could be due to noise children habituating to the stressor as the duration of exposure increased. On the other hand, the effect could be due to some kind of subject selection bias; that is, children with noise-induced blood pressure elevations may have quickly moved out of the noise-impacted

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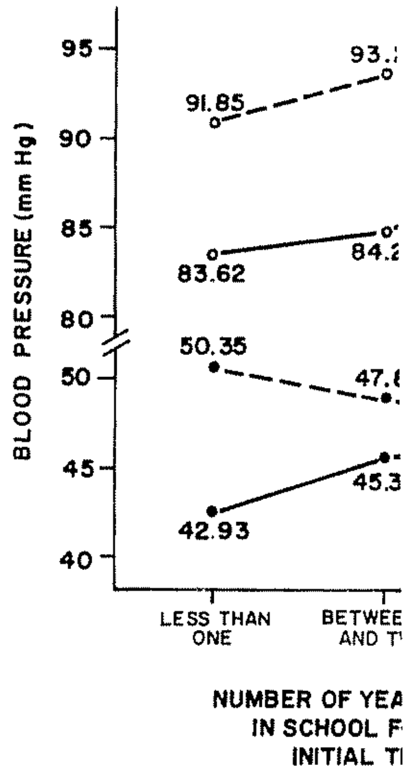

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neighborhood and thus lowered the mean blood pressure for noise-school children who remained exposed for 2 or more years.

Available longitudinal data on *how long* specific noise and quiet-school children remain enrolled in their schools helped distinguish between these two explanations. Another analysis of T1 blood pressure data revealed that some form of subject selection bias was indeed operative. As depicted in Fig. 11.2, noise-school students with the highest blood pressures move out of the noise area soon (within 2 years) after the initial testing, and a reverse trend appears for the quiet children. Thus, it appears that selective attrition, *not* adaptation, is responsible for the decrease of the difference between the blood pressure of noise- and quiet-school children.

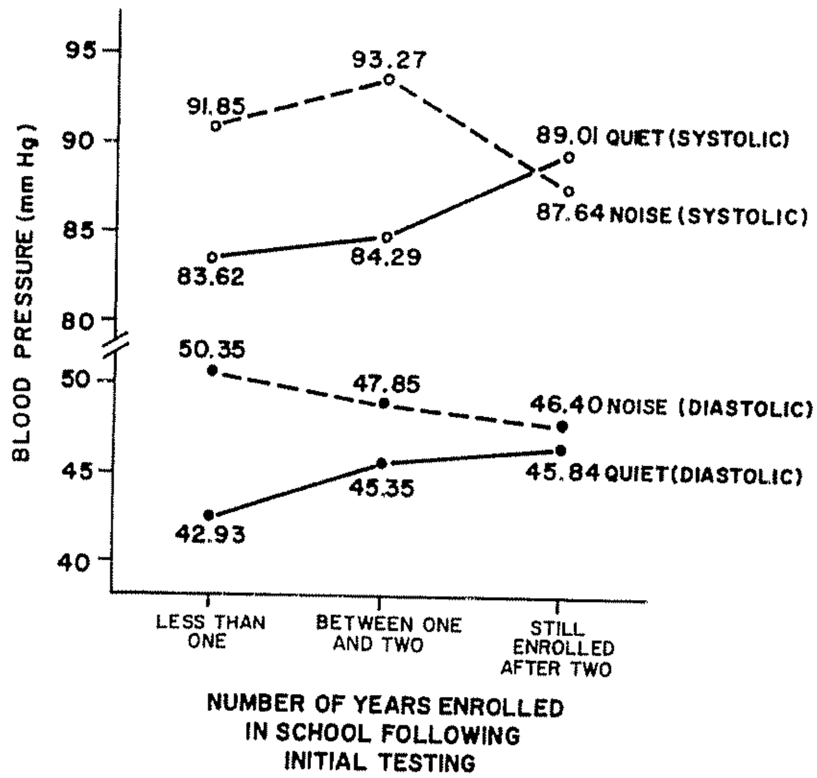

FIG. 11.2. Systolic and diastolic blood pressure measured at T1 as a function of school noise level and the number of years enrolled in school following T1. Each period on the years exposure coordinate represents number of years students remained enrolled (from Cohen, S., Evans, G. W., Krantz, D. S., Stokols, D., & Kelly, S., 1981. Copyright 1981 by the American Psychological Association. Reprinted by permission)

It is important to emphasize that these effects occurred with race and social class partialed out of the analyses. Some possible (and admittedly speculative) explanations for the selective attrition effect among noise children are: (1) Parents of children with elevated blood pressure were sensitive to their children's experience of stress and as a consequence moved to a less-noisy neighborhood; (2) because of a familial bias (either genetic or environmentally determined), parents of children with noise-induced blood pressure elevations experienced similar stress-related reactions that motivated them to move from the neighborhood; (3) the children's elevated blood pressures were a response, not to the noise itself, but to their parents' own noise-induced stress, which motivated the parents to move from the neighborhood; and (4) some unknown third factor is related to mobility, higher blood pressure, and living in a noisy neighborhood. Although we cannot select among these possible explanations, there is recent related evidence that children of hypertensive parents show elevated cardiovascular response to stress (Baer, Collins, & Bourianoff, 1980; Obrist, Grignolo, Hastrup, Koepke, Langer, Light, McCubbin, & Pollak, in press). This reinforces the notion that parents of children with elevated blood pressure may be suffering from cardiovascular disorder. We have no ready explanation for the opposite trend for blood pressure and attrition obtained among the quiet children.

Although the analysis of the complete T1 sample indicated higher systolic and diastolic blood pressures for noise-school children, there were no effects on either systolic or diastolic blood pressure in the longitudinal analyses, which include both T1 and T2 data. Longitudinal blood pressure effects were not expected, however, because a relatively high proportion of noise-school children with higher blood pressures were lost to attrition (see earlier) and thus not included in the longitudinal analyses. Because of this attrition effect, our data do not enable us to make a definitive determination about whether the increased blood pressure levels of noise-affected children found in the initial complete cross-sectional sample habituate over time.

Figure 11.3 presents cross-sectional blood pressure data from an independent replication sample of third graders. Noise-school children had higher blood pressure levels among those exposed 2 years or less, but not among those attending noise schools for longer periods. In sum, the data from both the longitudinal study and the cross-sectional replication clearly indicate that children attending school in the air corridor have elevated blood pressures during their first few years of exposure. Although this elevation does not occur for those who have lived in the neighborhood and attended their schools for longer periods of time, data from the various longitudinal analyses argue that this is due to a bias in who moves out of the neighborhood rather than to habituation to the noise. This data is consistent with previous studies of both adults and children cited earlier, which suggest that those undergoing prolonged noise exposure show persistent elevations in cardiovascular response.

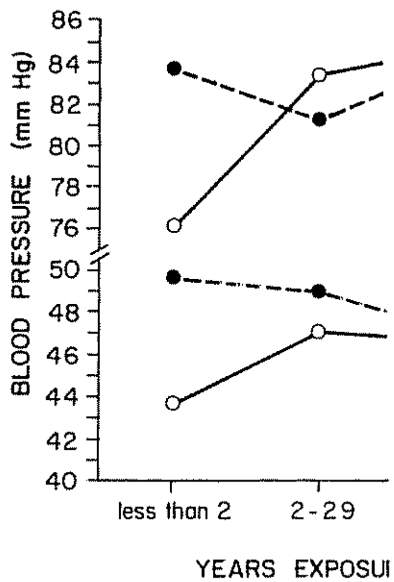

FIG. 11.3. Systolic and diastolic blood pressur
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learned helplessness.

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Whether or not the puzzle was solved,
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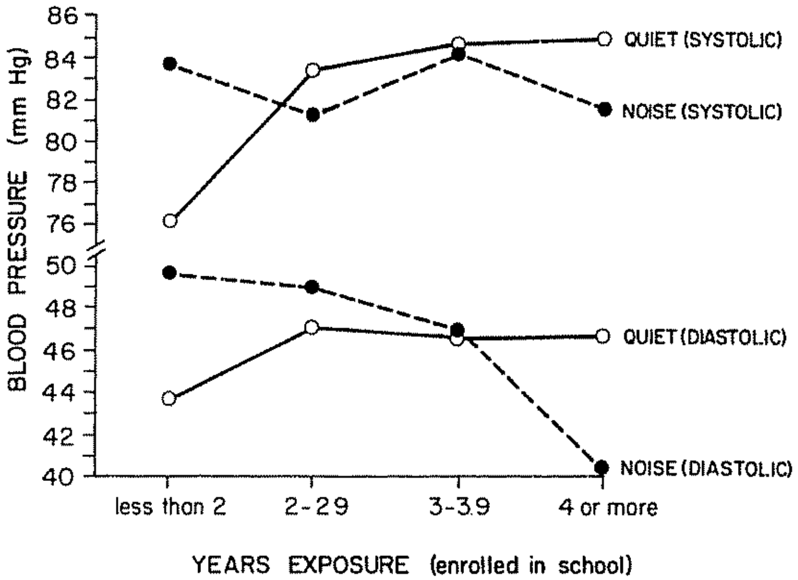

FIG. 11.3 Systolic and diastolic blood pressure as a function of school noise level and duration of exposure for cross-sectional third grade replication study Each period on the years exposure coordinate represents one quarter of the sample (copyright in the public domain)

AIRCRAFT NOISE AND HELPLESSNESS

To determine if noise-school children behave as if they have less control over their environment, the Los Angeles Noise Project tested students on a cognitive task after a manipulated experience of success or failure. A lack of persistence after failure (''giving up'' syndrome) is considered a direct manifestation of learned helplessness.

During the initial testing (T1), each child was given a treatment puzzle to assemble after the tester demonstrated the task with another puzzle. Half the children received an insoluble (failure) puzzle and half a soluable (success) puzzle. After time was up on the first puzzle, the child was given a second, moderately difficult puzzle to solve. The second (test) puzzle was the same for all (success and failure) children, and the child was allowed 4 minutes to solve it. Whether or not the puzzle was solved, time to solution, and whether the child ''gave up'' before the 4 minutes had elapsed were used as measures of helplessness.

Unexpectedly, during T1 a large proportion of the children receiving a soluble treatment puzzle failed to solve the treatment puzzle within the time allowed Therefore, many children self-selected themselves into a failure condition; thus we were obliged to confine ourselves to a comparison of children from noise schools versus quiet schools, irrespective of whether they received success or failure puzzles.

Among children assigned to the success treatment condition, children from noise schools were more likely to fail to solve the first (treatment) puzzle than children from quiet schools. Secondly, there were similar effects of noise on the test (second) puzzle that occurred irrespective of whether the child received a success (solved or not) or failure treatment. Noise children were again more likely to fail the test puzzle than quiet-school children and more likely to give up than their quiet-school counterparts Moreover, as apparent in Fig. 11.4, the

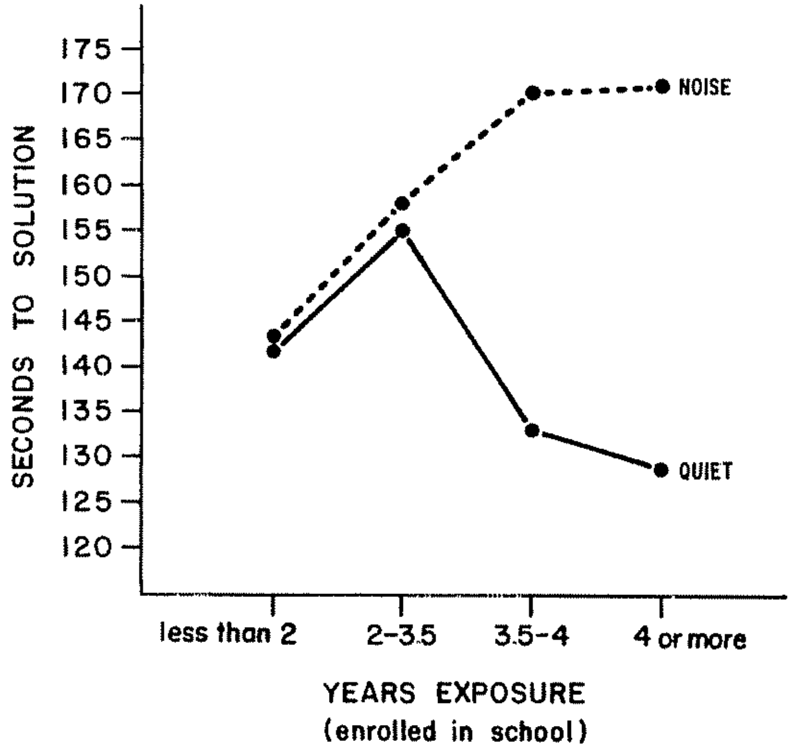

FIG. 11.4. Performance on the second (test) puzzle as a function of school noise level and duration of exposure for T1 cross-sectional sample Each period on the years exposure coordinate represents one quarter of the sample (from Cohen, S , Evans, G W , Krantz, D S , & Stokols, D , 1980 Copyright 1980 by the American Psychological Association Reprinted by permission)

longer the child attended a noise schc puzzle.

The preceding analyses indicate that less capable of performing a cogniti schools. The strongest indication that f children is related to helplessness pe were more likely than quiet children elapsed. Therefore, a final analysis wa who failed the second puzzle. This in were associated with giving up more (dren. Thus, even though all these ch school children were less likely to per

A year later at the second session (' zles were *not* readministered. Each chi to solve. As previously, the child was with the same measures of helplessness As in the analysis of the entire T1 sa puzzle performance that occurred irre success (solved or not) or failure treat likely to fail the test puzzle than quiet- longer solving the puzzle.

Although these analyses suggested poorer than quiet-school children at so sions, the increased "giving up" of n did not appear in the repeated measures in the longitudinal analysis may have oc because the children had had a previo because the effect disappears (i.e., adap the cross-sectional analysis of the entire giving up with increased years of sch giving-up effect does not adapt out o performance deficits among noise-scho However, it is unclear whether the poo interpreted as learned helplessness.

AIRCRAFT NOISE, DISTRA ACHIEV

Earlier it was proposed that selective in exposure. Because children who are rela be less affected by an auditory distractor selective inattention in the LANP Sub longer the child attended a noise school, the slower she/he was in solving the puzzle.

The preceding analyses indicate that children from noise schools are generally less capable of performing a cognitive puzzle task than children from quiet schools. The strongest indication that failure on these puzzles on the part of noise children is related to helplessness *per se* would be data indicating that they were more likely than quiet children to *give up* before their alloted time had elapsed. Therefore, a final analysis was conducted including only those children who failed the second puzzle. This indicated that the failures of noise children were associated with giving up more often than were the failures of quiet children. Thus, even though all these children failed to solve the puzzle, noise-school children were less likely to persist than their quiet-school counterparts.

A year later at the second session (T2) pretreatment success and failure puzzles were *not* readministered. Each child was given only the test (square) puzzle to solve. As previously, the child was allowed 4 minutes to solve the test puzzle with the same measures of helplessness assessed as in the earlier testing session. As in the analysis of the entire T1 sample, there were effects of noise on test puzzle performance that occurred irrespective of whether the child received a success (solved or not) or failure treatment. Noise children were reliably more likely to fail the test puzzle than quiet-school children, and more likely to take longer solving the puzzle.

Although these analyses suggested that noise-school children were again poorer than quiet-school children at solving the test puzzle at both testing sessions, the increased "giving up" of noise, compared to quiet-school children, did not appear in the repeated measures analysis. The disappearance of this effect in the longitudinal analysis may have occurred because of a subject attrition bias, because the children had had a previous experience with the same puzzle, or because the effect disappears (i.e., adapts out over time). It should be noted that the cross-sectional analysis of the entire T1 sample did not indicate a lessening of giving up with increased years of school enrollment; thus suggesting that the giving-up effect does not adapt out over time. In sum, the data indicate that performance deficits among noise-school children persist over a 1-year period. However, it is unclear whether the poorer performance of noise children can be interpreted as learned helplessness.

AIRCRAFT NOISE, DISTRACTABILITY, AND SCHOOL ACHIEVEMENT

Earlier it was proposed that selective inattention may result from chronic noise exposure. Because children who are relatively inattentive to acoustic cues should be less affected by an auditory distractor, distractability was used as a measure of selective inattention in the LANP. Subjects performed a crossing-out E's task under both ambient and distracting conditions. The subject's task was to cross out the E's in a two-page passage from a sixth grade reader. In a distraction condition, the child worked on one of the versions of the task while a tape recording of a male voice read a story at a moderate volume. In the no-distraction condition, the alternative form of the task was completed under ambient sound conditions. The criterion measure was performance (percent E's found) on the distraction task after these scores were adjusted for no-distraction performance. It was expected that children from noise schools would be less affected by distraction. Because selective inattention is a strategy that develops over time, it was also predicted that this "tuning out" strategy would increase with exposure (Cohen, Glass, & Singer, 1973).

It can be seen in the cross-sectional (T1) data presented in Fig. 11.5 that children in noise schools did better than the quiet group on the distraction task

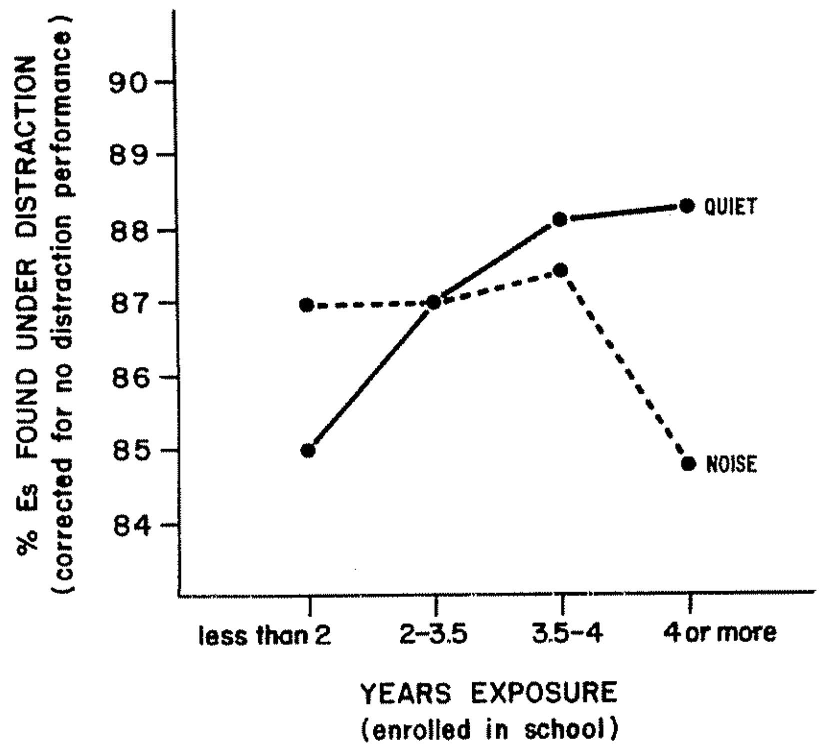

FIG. 11.5. Distraction as a function of school noise level and duration of exposure for T1 cross-sectional sample. Each period on the years exposure coordinate represents one quarter of the sample (from Cohen, S. Evans, G. W., Krantz, D. S., & Stokols, D., 1980. Copyright 1980 by the American Psychological Association. Reprinted by permission).

during the first 2 years of exposure
trary to earlier evidence, this finding
increases, children are *more*, rather
One possible explanation for this
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as they find that the strategy is not ad
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Figure 11.6 presents longitudina
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Auditory discrimination and readir
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It should be noted that the failure
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and had different teachers. It is likel
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difficult.

during the first 2 years of exposure and unexpectedly worse after 4 years. Contrary to earlier evidence, this finding suggests that as the length of noise exposure increases, children are *more*, rather than less, disturbed by auditory distractors. One possible explanation for this effect is that at first, the children attempt (somewhat successfully) to cope with the noise by tuning it out. Later, however, as they find that the strategy is not adequate, they give it up. This interpretation is consistent with the helplessness data. Alternatively, it is possible that as the duration of exposure increases, the children become more discriminating in terms of the kinds of sounds that they tune out; that is, initially they tune out a wide range of acoustic stimuli (including the distractor used in the present study) but later tune out only aircraft sounds.

Figure 11.6 presents longitudinal data based only on those subjects who returned for testing at both T1 and T2. It can be seen that there was a pattern similar to the T1 data reported previously, except that noise children enrolled for 2–4 years also appear to be less distractable than their quiet counterparts. Furthermore, the T2 noise sample continues to show the pattern of better performance which becomes equivalent to the quiet group after 4 years of enrollment.

Auditory discrimination and reading achievement were assessed in an attempt to replicate previous work and to establish if there is an association between these measures and the children's attentional strategies. Standardized reading and math tests (administered during the second and third grades by the school system) were gathered from school files, and an auditory discrimination test (Wepman, 1958) was administered individually to children in the soundproof van. Results indicated that math, reading, and auditory discrimination were all unrelated to noise or duration of noise exposure.

Further correlational analyses, however, did suggest that those children who were better at auditory discriminations were also better on both the reading ($r = .19$) and math ($r = .18$) tests. However, there were no significant relationships between these variables and the selective inattention measure. In sum, there was no evidence in the initial analysis of the T1 data that aircraft noise affected reading and math skills, nor that these skills are related to a selective inattention strategy.

It should be noted that the failure of this study to replicate the previously reported relationship between community noise and reading ability (Bronzaft & McCarthy, 1975; Cohen, Glass, & Singer, 1973) may be attributable to an experimental design insensitive to noise-induced differences in school achievement. In both the earlier studies, all students attended the same school. Moreover, in the Cohen et al. (1973) study, students from both noisy and quiet apartments were taught in the same classrooms by the same teachers. In the present study, noise and quiet children attended different schools, were in different classrooms, and had different teachers. It is likely that these factors add substantial error variance to the equation making the detection of a small effect of noise quite difficult.

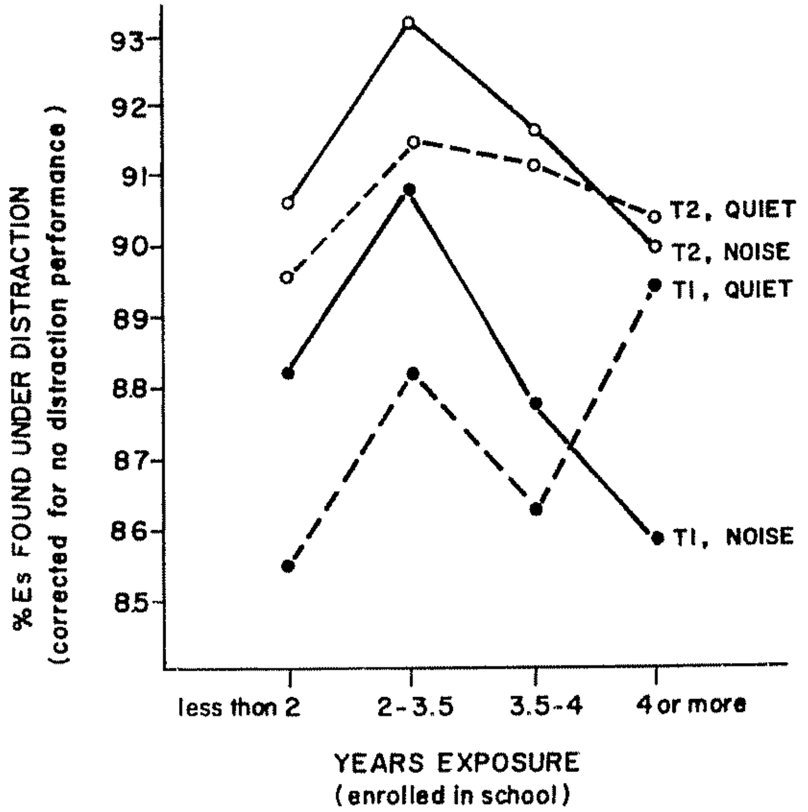

FIG 11 6 Distractibility at T1 and T2 as a function of school noise level and duration of exposure for the longitudinal study Sample includes only those subjects present for both sessions (from Cohen, S., Evans, G W, Krantz, D S. Stokols, D, & Kelly, S, 1981. Copyright 1981 by the American Psychological Association Reprinted by permission).

NOISE ABATEMENT AND NOISE-STRESS REDUCTION

Do noise abatement interventions (and the resulting reduction in classroom noise levels) decrease or ameliorate the effects of noise in impacted classrooms? Both cross-sectional data collected during the first testing session and longitudinal data looking at changes in response of children moved from noisy to quiet classrooms are relevant to this question. T1 cross-sectional abatement analyses, based on the entire sample, were collected during the first testing session and compare children who were in noise-abated classrooms to those in noisy (nonabated) rooms and those from quiet schools. (Recall that prior to T1, a number of noise-

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testing session, and thus there was no
effects of noise abatement on school
analyses.

In sum, the evidence for ameliorat
were neither substantial nor did they co
the classroom, however, was affected

impacted schools had been treated with sound-reducing materials). Longitudinal abatement analyses look at the changes in response of children who moved from a noise to noise-abated classroom in contrast to those children who spent both years in noise-impacted rooms. As outlined in Table 11.1, longitudinal data are based only on those subjects available for retesting at T2.

To examine effects of abatement, data from T1 were reanalyzed with classrooms categorized as noisy, abated, and quiet. The mean peak noise level for noise classrooms was 79 dB(A); for abated, 63 dB(A); and for quiet classrooms, 57 dB(A). Analyses suggested only a minimal impact of the abatement intervention. Childrens' perceptions of noise and noise interference, blood pressure, and the auditory distraction measure were apparently *unaffected* by abatement.

On the other hand, abatement seemed to provide at least slight improvement on two factors. Firstly, abatement had a marginal effect of increasing the number of children who were able to solve the moderately difficult test puzzle in the helplessness task irrespective of whether they received a soluble or insoluble first puzzle. It is noteworthy, however, that giving up, the measure designed to provide a direct assessment of feelings of helplessness, was affected only by the noise-school versus quiet-school distinction. Secondly, although reading achievement and auditory discrimination ability were unaffected by abatement, there was evidence that math achievement was higher for children in abated than for those in noise classrooms. It is important to consider, however, that unlike all other measures that were administered in a relatively quiet setting, the achievement tests were actually taken in the classroom. Thus, the relative deficit in math performance of the children from the noise as opposed to noise-abated classrooms may be attributable to noise interfering with test performance, rather than to an aftereffect of noise that we would expect to occur even outside of the noise-impacted environment.

The longitudinal data similarly provides little evidence that children who had been enrolled in a noise impacted school show improvement in their performance and/or health following a 1 (school)-year experience in a noise-abated classroom (even though sound attenuation had a substantial effect on interior sound levels). In contrast to the cross-sectional analysis, the longitudinal data did not even indicate improvement in ability to solve the moderately difficult puzzle on the part of children in noise-abated rooms. This failure to mimic the cross-sectional findings may be due to an attrition bias or to the marginality of the effect itself. Unfortunately, school achievement data were not available during the second testing session, and thus there was no opportunity to reevaluate the ameliorative effects of noise abatement on school achievement found in the cross-sectional analyses.

In sum, the evidence for ameliorative effects of classroom-noise abatement were neither substantial nor did they cover a wide range of measures. Behavior in the classroom, however, was affected by the sound attenuation as was school achievement test performance. Both of these measures likely reflect a remediation of the effects that occur during noise, rather than after exposure.

IMPLICATIONS AND FUTURE DIRECTIONS

The data from our study of aircraft noise indicated that the noise resulting from chronic exposure to aircraft overflights affects a variety of cognitive, motivational, and physiological processes in a manner generally consistent with previous laboratory findings on the nonauditory effects of noise and other stressors. Blood pressure was relatively higher in noise-impacted children, there was evidence for poorer cognitive functioning in the form of lowered puzzle-solving performance and math achievement, and noise children were less distractable during the early, but not later, years of exposure. With the exception of math achievement scores, all these effects occurred outside of noise exposure and may therefore be termed aftereffects. Moreover, these effects cannot be attributed to confounding economic or social variables or to hearing loss. Because the effects were also stable over a 1-year period, there was very little evidence that children habituated or adapted to the noise stressor over time.

Although this chapter has concerned the physical intensity of sound as it might affect health and behavior, it is also important to note that noise is a psychological concept. The meaning of noise to the individual (termed *cognitive appraisal*) and the context in which noise occurs play important roles in determining effects on annoyance, performance, and health (Cohen & Weinstein, 1981; Lazarus, 1966). In accord with these principles, recently completed analyses of LANP data have revealed that after controlling for the physical intensity of noise, the *child's ratings* of noise annoyance predict a variety of dependent measures. For example, diastolic blood pressure is relatively higher among children who rate classroom noise as more bothersome. In addition, noise levels at home and school have an interactive effect, with school noise abatement making less of a difference on blood pressures of children from noisier than quieter homes.

Pending further replications of these results in other settings, it is difficult to draw definitive conclusions about the clinical or policy significance of these data, and we favor a cautious approach toward interpreting our findings. To this end, our own research program is longitudinal in design and includes an ongoing replication of this study with a population exposed to traffic noise. However, from a policy point of view these data do support the need for noise-abatement work in noise-impacted settings, but they also suggest that short-term protection by sound insulation in the classroom may not be enough. Although there was evidence that abatement affects behavior in the classroom, the ameliorative effects of noise insulation were neither substantial nor did they cover a wide range of measures. This relative ineffectiveness may have occurred because the effects of previous noise exposure are relatively long lasting; that is, it takes more than a 1-year reprieve from the noise for a return to more normal levels of behavior and

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ACKNOW

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grants from the National Science Found
National Institute of Environmental Hea
Psychological Study of Social Issues, the
Uniformed Services School of Medicine
Kelly and the staff, children and parents

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health. Secondly, because the children are all exposed to the noise outside the school—in their homes, on the playground, etc.—a quieter classroom may not have been a sufficient intervention. Finally, in evaluating the abatement results, it is also important to remember that most of the children attending noise schools spent previous years in nonabated classrooms. Thus, although abatement interventions were not entirely effective for this population, it is possible that children who start to attend school after the entire school has undergone noise abatement (and are thus always in relatively quiet classrooms) would benefit from the interventions. Therefore, it is likely that a more effective noise abatement in schools (bringing overall levels closer to those in quiet schools) and decreased noise exposure *outside of school* would have an increased ameliorative impact. Decreasing overall community noise levels by creating buffer zones between airports and other sources of high-intensity noise and the surrounding communities would be one way of providing more adequate protection for community residents.

A research strategy of studying effects that are closely linked to laboratory findings, together with the use of both cross-sectional and longitudinal approaches in the field, has important benefits. In particular, it helps establish the scientific validity and practical value of work with potential implications for social issues. The research reviewed in this chapter clearly suggests lending additional weight to the possible impact of aircraft noise on psychological adjustment and on nonauditory aspects (particularly cardiovascular) of health. As converging laboratory and naturalistic approaches eliminate alternative explanations for noise-associated effects, the potential for increasing scientific knowledge and for affecting the formation of public policy increases.

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