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Nonauditory Effects of Noise on Behavior and Health

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This article presents an overview of research and theory on the nonauditory effects of noise on human behavior and health. Laboratory and naturalistic research on the effects of noise on human performance, interpersonal behavior, annoyance, cognitive development, and mental and physical health are reviewed. The review includes studies of children as well as adults, and the discussion emphasizes the relevance of this research for predicting the effect of noise in community and industrial settings. Noise effects are viewed as determined by variations in psychological characteristics of a situation as well as the physical parameters of the sound. Predictability and controllability of a noise, its meaning for the respondent and its degree of interference with auditory communication are factors that mediate the effects of noise across a variety of outcome measures.

Noise pollution is rapidly growing as a major environmental concern. Sources of noise in communities, residential dwellings, offices and factories are numerous. They range from the moderately intrusive sounds of our neighbors, children, pets, and televisions to the high-intensity sounds of aircraft, automobiles, trucks and construction equipment. Although some recent federal, state and local regulations specify permissible noise levels, noise exposure in the United States may still be growing (cf. Bragdon, 1971).

Is noise harmful to our health and well-being? Does it interfere with human performance in work settings, distort and degrade interpersonal interactions and cause physiological disturbances? This paper provides partial answers to these questions by presenting an overview of research and theory on the effects of noise on human behavior and health. The discussion is restricted to the nonauditory effects of noise. There is no discussion of the effects of noise on hearing acuity or of the role of noise in disrupting verbal communication (see Kryter, 1970; Miller, 1974). Moreover, we generally limit ourselves to studies of noises likely to impact large numbers of people, excluding discussion of infrasonic and ultrasonic sound and of sounds loud enough to cause physical pain or vestibular disturbances (see A. Cohen, 1977; Kryter, 1970, for reviews of this literature).

Noise Versus Sound

Noise researchers have long made a distinction between sound and noise. Sound is changes in air pressure that are detected by the ear. These pressure changes are created by wave-like motions of air molecules in response to object vibration. Frequency, the number of times per second a wave motion completes a cycle, is perceived by the listener as pitch. Variations in wave height or amplitude are determined by the amount of energy or pressure and are experienced as differences in loudness.

The intensity of sound is commonly expressed in decibels (abbreviated dB). Zero dB is about the level of the weakest sound that can be heard by a person with very good ears in an extremely quiet environment. Fifty-five decibels is roughly equivalent to light traffic, 70 dB to a vacuum cleaner at 10 feet, 110 dB to a riveting machine and 120 dB to a jet takeoff at 200 feet. The decibel scale is logarithmic with an increment of three decibels reflecting a doubling of the intensity (energy) of the sound. An increment of about 10 dB is required, however, for a perceived doubling of loudness.

Most behavioral studies of sound use the A decibel scale (dBA) that is designed to closely approximate *perceived* loudness. Since people perceive high frequency sounds as louder than low frequency sounds of equal sound pressure, this scale assigns lesser weights to low frequency than high frequency sounds in calculating total sound level.

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Noise is a psychological concept and is defined as sound that is unwanted by the listener because it is unpleasant, bothersome, interferes with important activities or is believed to be physiologically harmful (Kryter, 1970). Sounds can be unwanted because of their physical properties, e.g., intensity, frequency, and intermittency, or because of their signal properties, i.e., their meaning. Unwanted effects of sound that are related to its physical properties include the masking of wanted sound, auditory fatigue and hearing damage, excessive loudness, bothersomeness and startle (Kryter, 1970). Recent data also suggest that the meaning of a sound plays an important role in determining its effects on annoyance, performance and possibly health (Borsky, 1980; S. Cohen, 1980a; S. Cohen, Glass & Phillips, 1979). Thus, even fairly loud sounds may sometimes be viewed as desirable, while relatively soft sounds can be viewed as noisy. For example, while your neighbor might enjoy listening to an album of rock music at 110 decibels, you might find the same physical stimulus quite aversive, and while the sound of a couple whispering during a theater performance may be barely audible, it may also be reacted to as an intruding noise.

Noise and Human Performance

How does noise influence performance? Existing theory and data on the relationship between noise and performance suggest that effects depend on the kind of noise and the type of performance (Loeb, 1980). Moreover, a recent analysis suggests that accurate prediction of noise-performance relationships also requires an emphasis on the meaning of the sound and the social context of the setting for the person(s) performing in noise (cf. S. Cohen, 1980a).

It is important to note that even with the myriad of existing studies, we are unable to predict with much confidence the effects of noise on performance in a particular situation (cf. Loeb, 1980). The noise-performance literature is complex, often at least seemingly inconsistent, and subject to a number of different interpretations. While a thorough review of this literature is beyond the scope of this paper (see Broadbent, 1979; Loeb, 1980 for recent reviews), short summaries of several theoretical approaches and an overview of existing data are provided. This selective review emphasizes deleterious as opposed to positive effects of noise.

Theories

People in management or otherwise concerned with human efficiency are often interested in the possible effect of a specific source or type of noise on a particular task. While psychologists have studied the impact of high-intensity sound on a wide range of tasks, the probability is small that there is reliable evidence associating a specific noise with the task of interest. Thus judgments of whether noise will have a deleterious effect in a setting are usually made by interpreting the situation in the context of an established theoretical framework that relates noise to task performance.

Theories about the relationship of noise and performance have undergone substantial changes in the last 25 years. In order to provide some theoretical structure to this section, we will provide short summaries of three recent approaches: those of Broadbent, Cohen and Poulton. The descriptions of these theories are limited and the interested reader is directed to Broadbent (1971, 1978), S. Cohen (1978) and Poulton (1977, 1978, 1979) for more elaboration. The relation of existing evidence to these theories is still considered controversial.

Broadbent (1971) has argued that exposure to moderate and high-intensity noise causes an elevation in arousal. Heightened arousal, in turn, is said to lead to a narrowing of one's attention. The first inputs to be ignored are those that are irrelevant or only partially relevant to task performance. As arousal increases, attention is further restricted and task relevant cues may also be neglected. In some tasks, proficiency demands the use of only a restricted range of cues. Such tasks improve with moderate narrowing of attentional focus to the extent that competing cues are no longer noticed. In other tasks, proficiency demands the use of a wide range of cues (e.g., dual-task performance or single tasks requiring the integration of information from many sources). Any narrowing of attention during such tasks is likely to affect performance adversely. It follows that the optimal level of arousal (and thus attentional focus) varies with the complexity (number of cues required) of the task. Optimal levels of arousal for complex tasks are lower than those for simple tasks. Thus high levels of arousal like those that are presumably elicited by laboratory noise manipulations, are usually assumed to have detrimental effects on complex but not on simple tasks.

S. Cohen (1978) similarly predicts attentional focusing will often occur under high-intensity noise but explains the focusing as a strategy commonly used to decrease the amount of information processed when one's processing capacity is overloaded by the combined demands of the stressor (the noise) and the ongoing task. Cohen also argues that the information load imposed under noise exposure is affected more by the meaning of the noise and the situation than by the intensity of the sound. Specifically, he suggests that predictability and controllability of the noise and one's expectancies about its effects are important factors to consider. S. Cohen (1980a) also emphasizes that even if one accepts Broadbent's argument that attentional focusing occurs because of heightened arousal, it is likely that the level of arousal is determined by the meaning of the noise and situation, not merely by the physical parameters of the sound.

Poulton (1978, 1979) argues that there is an increase in arousal when continuous noise is first switched on, but that the arousal gradually lessens over time. He asserts that this initial increase in arousal often results in improved performance. Poulton also suggests that reported deficits in task performance under *continuous* noise occur because of subjects' inability to hear acoustic cues (including hearing one's own internal speech) that aid performance when the task is performed in quiet. Deleterious effects of *intermittent* noise are attributed to the distraction that occurs at the onset of the noise.

Decrements in task performance that *follow* exposure to unpredictable, uncontrollable high-intensity noise (e.g., Glass & Singer, 1972) are variously attributed by these theorists to learned helplessness (Broadbent, 1978), to cognitive fatigue and consequent loss of information processing capacity (S. Cohen, 1978), and to decreased level of arousal following the termination of the noise (Poulton, 1978).

Tasks that are Unaffected by Noise

Although there is little agreement on the nature of situations in which noise will affect performance, there are a number of tasks that most investigators agree will not be affected detrimentally. In a recent review, Broadbent (1979) suggests a simple rule for classifying such tasks. "Almost any task in which a person has to react only at certain definite times, receives a clear warning of the need for reaction, and receives an easily visible stimulus will show no effect in continuous loud noise" (p. 17–4). One category of tasks that generally fit Broadbent's rule is tests of visual functioning. Examples of visual tasks unaffected by quite intense noise levels include visual acuity for lines and discs (Krauskopf & Coleman, 1979), the ability to detect contrasts

(Broussard, 1979), to judge distance, dark vision, speed of moving the eyes to a visual angle, and speed of changing focus (Stevens, 1972). The ability to make practiced and repetitive dexterous and coordinated movements are similarly unlikely to show noise induced impairment. For example, the squeezing of a dynameter (Miles, Note 1) and the dexterity with which nuts and bolts can be undone and retightened (Harris, 1973) are relatively unaffected by high-intensity noise. A task requiring the repetitive printing of the same sequence of letters (McBain, 1961) actually shows fewer errors during noise exposure.

Tasks Affected by Noise

It is well established that *novel or unusual* noise will interfere with efficiency on most tasks (cf. Broadbent, 1979). This effect occurs during the first few presentations of the noise then disappears. Similar effects occur with cessation of noise. Hence, task interference seems to be due to a change in stimulation and may not be peculiar to intense noise.

There has also been some consistency in reports of effects of familiar noise on multiple source tasks and vigilance tasks. These effects are thought to occur with noise levels of 95 dBA or more. They are less likely to occur under fixed-intermittent than continuous noise, and most likely to occur under unpredictable-intermittent exposure.

Multiple source tasks require subjects to perform two tasks simultaneously or to process multiple inputs from the same task. Subjects are generally instructed that some sources (e.g., one of the two tasks in the dual-task paradigm) are more important than others. In general, the results of these studies show that noise increases the amount of effort applied to the primary task cues (or task) at the expense of the less important cues (cf. Broadbent, 1971, 1979). Examples of tasks used in these studies include the watch keeping of multiple signal lights with different probabilities of occurrence (e.g., Hamilton, 1969), simultaneous visual tasks (e.g., Hockey, 1970a, 1970b), various visual monitoring tasks with auditory secondary tasks (e.g., Boggs & Simon, 1968; Finkleman & Glass, 1970), and tasks in which subjects are instructed to memorize particular stimuli and then are asked to recall some incidental feature of the stimulus display (e.g., Hockey & Hamilton, 1970; O'Malley & Poplawsky, 1971). It should be noted that the reliability of some of these effects has been questioned (e.g., Forster & Grierson, 1978; Loeb & Jones, 1978; Smith & Broadbent, 1980).

Vigilance tasks require continuous monitoring for faint, infrequent signals. These tasks have been employed in noise studies because of their presumed similarity to certain kinds of industrial quality control tasks and to military requirements for radar monitoring. In a recent review, Broadbent (1979) concludes that vigilance performance seems to improve under relatively low levels of noise, especially varied noise. Decrements in performance occur, however, in levels of noise higher than 95 dBA under certain conditions. Task deficits are most likely to occur when (1) the signals are hard to see, (2) the situation is not one that encourages caution, i.e., one in which even the most doubted judgment should be reported, (3) the length of the watch is long, and (4) there are a number of sources from which the signal may come. The fact that the multiple source vigilance tasks are more likely to be affected is consistent with the attentional focusing phenomenon predicted by both Broadbent and Cohen.

The most reliable finding in studies of vigilance performance under high-intensity noise seems to be that noise reduces the frequency of doubtful and uncertain judgments and increases the frequency of confident ones (Broadbent, 1979). Thus tasks that require one to report even the least confident judgments are detrimentally affected, while those requiring one to report only those signals that one is absolutely sure of improve under noise.

Variability of Performance

While the average efficiency on many tasks appears to be unaffected by exposure to high-intensity noise, there is evidence that noise sometimes produces highly variable performance—moments of inefficiency interspersed with normal and compensating spurts of efficient performance. Highly variable performance in industrial settings can mean poor product reliability and can result in increased accident potential in some work settings (A. Cohen, Note 2).

As pointed out earlier, performance can be disturbed by both the onset and offset of the noise. With *random-intermittent* noise, even experienced subjects seem to show recurrent momentary deteriorations of performance at noise onset and offset that are compensated by increased efficiency between the bursts of noise (cf. Broadbent, 1979). Examples of tasks showing this variability effect include: clerical tests (e.g., Sanders, 1961), continuous serial-reaction time tasks (Fisher, 1972), and mental arithmetic (Woodhead, 1964). There is also some evidence that exposure to *continuous* noise similarly results in performance variability. It seems to occur on tasks that involve tracking targets whose rate of movement is set by the subject and on some forms of serial reaction-time tasks, for example, those in which lights are widely separated from the response board (cf. Broadbent, 1979; Hartley, 1973; Wilkinson, 1963). Additional studies of intra-subject variability under both intermittent and continuous noise are needed to clarify the role of noise in the distribution of effort over time.

Aftereffects of Noise on Human Performance

Recent studies indicate that there are effects of noise on human performance that occur *after* noise exposure is terminated (see S. Cohen, 1980b for review). For example, Glass and Singer (1972) found that in comparison with a control group not previously exposed to noise, subjects exposed to unpredictable (random-intermittent), 108 dBA or 56 dBA noise showed less tolerance for frustration and performed more poorly on both proofreading and a competitive response (Stroop color word) task. Similar effects following exposure to unpredictable-intermittent noises (varying from 80 to 100 dBA) have been reported by a number of investigators (e.g., Rotton, Olszewski, Charleton & Soler, 1978; Gardner, 1978). Moreover, studies of the impact of variable intensity *continuous* noise, where there are unpredictable components of the noise, (e.g., aperiodic bursts of static or office noise), report similar post-stimulation effects (e.g., Wohlwill, Nasar, DeJoy & Foruzani, 1976; Sherrod, Hage, Halpern & Moore, 1977).

It is important to note that the same post-stimulation effects on performance also occur after exposure to a number of other unpredictable and uncontrollable stressors including electric shock, high density, bureaucratic stress and cold pressor (see review by S. Cohen, 1980b). Thus, this effect is not specific to high intensity noise. Moreover, the noise aftereffects (as well as the deleterious effects of the other stressors) can be ameliorated by providing the subject with accurate expectancies of when the stressor will begin and end (increased predictability) and/or providing the subject with the perception that they can terminate the stressor at will (increased control). Thus, noise aftereffects are principally related to cognitive factors—predictability and controllability of the sound—rather than to acoustic parameters. Finally, S. Cohen (1980b) has noted that this research has employed a limited number of aftereffects tasks whose common characteristics are not clear. It is thus difficult to predict whether similar effects will occur on any specific task.

Field Research

Industrial and office performance during noise. Results of studies on the impact of noise on performance conducted in factories and offices have produced mixed results that often are difficult to interpret (see reviews by Ahrlin & Öhrström, 1978, Broadbent, 1979; Moos, 1976). Most of these studies compare a group of workers in a noise impacted part of a factory or office to a second group working on the same task in an area recently made quieter through some sort of noise abatement technique. A problem in many of these studies is that the mere fact that someone cared enough to introduce the intervention or to assess the effects of noise on the workers affects the morale and production of both those working in noise and in quiet. An example of this problem is reported by Broadbent and Little (1960). The same workers were moved back and forth from noise-treated (89 dB) to untreated (99 dB) parts of a plant over the course of the year. The rate of threading rolls of film onto a machine showed improvement after the noise abatement work was completed, but the improvement was equally large both during quiet and noise exposure.

A study of weavers reported over 30 years ago (Weston & Adams, Note 3) uses a design that provides a better test of the hypothesis that noise deleteriously effects performance. In this case, the efficiency of weavers was examined during a six month period of alternative weeks of wearing and not wearing ear plugs. The looms had a sound level of 95 dB and the ear plugs attenuated the noise by 10 to 15 dB. Worker efficiency was up about 12% during the period that ear plugs were worn.

Recent reviews of field studies conducted in offices and factories (e.g., Broadbent, 1979; Moos, 1976) generally conclude that there is no conclusive evidence that noise affects the average rate of work. Broadbent (1979) points out, however, if accidents or errors caused by momentary inefficiency are important, it is likely that noise increases these hazards.

Scholastic performance during noise. Two field studies have artificially increased classroom noise levels and assessed the effects on student behavior and performance. These studies should be distinguished from those that follow in that they are the only studies of school performance during noise that randomly assign students to the noise and quiet treatments. Ward and Suedfeld (1973) broadcast traffic noise outside a large university classroom

building. Less student participation and attention were observed under induced sound, compared to a no noise control group. McCroskey and Devens (Note 4) similarly induced a 4 dB increase in the ambient noise level of several fifth and sixth grade classrooms by adding a white noise background. Children tested in the classrooms with the additional noise showed impaired auditory discrimination, visual motor skills, and visual discrimination as compared with children tested in classrooms without the additional noise.

Several recent studies compare the scholastic achievement of children attending schools near urban airports to that of children attending schools in quieter areas. Such groups are usually matched on important variables (e.g., demographic makeup of enrollment). For example, a study contracted by a school board to support its lawsuit against the Seattle-Tacoma airport (Maser, Sorensen & Kryter, Note 5) found that children *with low aptitudes* attending noisy (in flight path) schools showed a cumulative deficit in tested achievement compared to children in quiet control schools. Differences between noise and quiet groups were not significant, however, until the 10th grade. A recent dissertation by Green (Note 6) reports a positive correlation between school noise level (as determined by a noise contour map) and the percentage of second-through-sixth-grade children scoring one or more years below grade level. The effect was found after controlling for various racial and socioeconomic characteristics of the schools. Bronzaft and McCarthy (1975) similarly found that second-through-fourth-grade children in classrooms on the side of a school facing train tracks performed more poorly on a reading achievement test that children in classrooms on the quiet side of the building.

In a study of the effectiveness of aircraft noise abatement, S. Cohen, Evans, Krantz, Stokols and Kelly (in press) report that after controlling for possible socioeconomic and racial differences, third grade children who spent the year in noise abated classrooms had better math scores than children in nonabated rooms. A similar, although nonsignificant, pattern was found for reading scores. It should be noted that experimental studies of the effects of noise on both adults (cf. Broadbent, 1979) and children (e.g., Slater, 1968; Weinstein & Weinstein, 1979) generally suggest that intellectual tasks performance is not impaired during short-term noise exposure. Thus although these studies are concerned with tests taken during noise, the effects may actually occur because of the cumulative effects of the noise on the learning process.

Scholastic performance outside of noise. A number of recent studies have investigated the impact of living and/or attending school in noisy conditions on task performance *outside* of the stressful environment. For example, S. Cohen, Glass and 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, S. Cohen, Evans, Krantz and Stokols (1980) studied third and fourth grade children attending school under the air corridor of a busy metropolitan airport. When tested in *quiet*, children attending noisy schools were poorer on both a simple and difficult puzzle solving task and were more likely to "give up" on the task than their counterparts from quiet schools. Again, race, social class and hearing damage were ruled out as possible explanations.

A recent study (Moch-Sibony, in press) comparing children from a quiet (soundproofed) elementary school in the air corridor of Orly (Paris) Airport to children from a nearby noisy (without soundproofing) school matched on socioeconomic variables found poorer auditory discrimination among children from the noisy school. There were, however, no differences between schools in reading achievement. Moch-Sibony also reported that children from the noisy school showed less tolerance for frustration than their counterparts from the quiet school.

Finally, a study of 4-1/2 to 6-1/2 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 an 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 (cf. Kryter, 1970) and thus limit the generality of Heft's findings.

In sum, there is increasing evidence of noise effects on human performance that persist (or possibly occur only) outside of the noisy environment. It should be noted, however, that all of these studies involve *children* and all are *correlational.* One explanation for deficits in achievement scores of children attending noisy schools is that the noise interferes with the teaching-learning process, thus resulting in a cumulative and progressive deficit. For example, noise may decrease teaching time by forcing teachers to continuously pause or by making it difficult for the student and teacher to hear one another (Crook & Langdon, 1974). Other possible explanations include noise-produced influence on children's information processing strategies (cf. S. Cohen et al., 1973; S. Cohen et al., 1980; Heft, 1979), on their feelings of personal control (cf. S. Cohen et al., 1980; S. Cohen et al., 1979) and on their level of arousal (S. Cohen et al., 1980).

Noise and Social Behavior

While psychologists have studied the relationship between noise and human performance for over a half a century, there has been little interest in the impact of noise on interpersonal behavior until very recently. The experimental work in this area has dealt primarily with the relationship between noise and one's sensitivity to others, especially the willingness to give aid both during and immediately following noise exposure. For example, in a laboratory study, Mathews and Canon (1975) examined the effects of various noise levels on the percentage of subjects willing to help someone pick up accidentally dropped materials. Those exposed to 85 dB noise were less likely to help than those exposed to 65 dB or lower, ambient noise levels. Similar results were found in a field experiment reported in the same paper. Subjects were less likely to aid a person who had dropped a pile of books when a loud lawnmower was running than when it was quiet. Moreover, a subtle cue suggesting the legitimacy and degree of need for assistance—a cast on the victim's arm—increased helping under ambient conditions but did not affect the frequency of helping under noise.

In a study conducted in the Netherlands, Korte, Ypma and Toppen (1975) used sound level, traffic count, pedestrian count, and the number of visible "public" buildings to specify areas that they characterized as either high or low on environmental inputs. They report that regardless of whether the area is in a city or small town, people in low-input areas were more likely to assist a lost person and to grant a street interview than people in high-input area. Page (1977) similarly reported that construction noise decreased the granting of small favors. Page also found that noise was more likely to reduce compliance to requests for verbal aid than for physical assistance.

A similar noise-induced lack of sensitivity to others is reported by Sauser, Arauz and Chambers (1978). Subjects were asked to work on a simulated management task in 70–80 dBA office noise or in quiet (50–57 dBA). Those working in noise recommended lower starting salaries for new employees than recommended by their counterparts in quiet offices.

Other effects of noise on interpersonal behavior were found in two studies of traffic noise in natural settings. Appleyard and Lintell (1972) studied the relative effects of traffic noise on three residential streets in a San Francisco neighborhood of "moderate" income. The streets differed in the amount of traffic (light, moderate, heavy) and in associated noise levels. There was substantially more casual social interaction on the street with light traffic than on the other two. There was virtually no sidewalk activity on the street with heavy traffic. People on the noisy street also reported that the street was a rather lonely place to live, while those on the street with light traffic perceived their street as a rather friendly, sociable area. These patterns of social behavior may have been affected by the type of people who live on the street as well as by the level of traffic noise.

Damon (1977) studied the effects of traffic noise on a residential project in a lower income neighborhood. Noise intensities varied from low levels around the interior buildings to very high levels (averaging 80 dB during the day time) along one border exposed to heavy traffic. Residents in the noisy area were arrested more often, were less likely to take care of their entry ways, and were more likely to be truant from school than their counterparts from quieter areas. Unfortunately, there were differences between the noisy and quiet areas in family size, density and age that make the results difficult to interpret.

A study finding decreased helping *after* noise exposure has been reported by Sherrod and Downs (1974). Their subjects worked on a demanding task which was presented with a "soothing-simulated-seashore" background or with a distracting recording of Dixieland jazz plus a voice reading nonrelevant prose. In a third condition, subjects were exposed to the distracting recording but were told that they could terminate the distracting stimulation if they found it necessary (perceived control). After completion of the experiment, subjects were confronted by a second experimenter who asked for voluntary help in pretesting some experimental materials. Those exposed to the seashore sounds were most helpful, followed by those with perceived control

over the distracting tape, with the least assistance offered by those who were exposed to the distracting tape without the option of terminating the noise. A similar study of post-noise aggression (Donnerstein & Wilson, 1976) found that angered subjects who were exposed to noise without perceived control administered more shock to a confederate than subjects with perceived control over the termination of the noise. These findings are similar to work on the aftereffects of noise on performance, discussed earlier, indicating that perceived control over the termination of the noise lessens or completely eliminates noise aftereffects.

Two other laboratory studies suggest that noise may cause people to over-simplify and distort perceptions of complex social relationships. Siegel and Steele (1979) report that subjects exposed to 92 dB random intermittent white noise are less able to discriminate between behaviors and make attributions of responsibility than those working in quiet. Similarly, Rotton et al. (1978) found that both loud (80 dBA) speech and the combination of 80 dBA noise with a difficult task reduced subject's ability to differentiate the characteristics of people occupying different roles (e.g., self, best friend) *after* the noise is terminated.

As mentioned earlier, both Broadbent's and Cohen's theoretical approaches to the effects of noise on performance suggest that unpredictable, uncontrollable high-intensity noise causes a focusing of one's attention on the most important aspects of a situation to the neglect of other cues. S. Cohen (1978; S. Cohen & Lezak, 1977) has pointed out that this restriction of attention affects the processing of less relevant *social* as well as nonsocial cues. Thus, many of the studies reviewed above can be interpreted as noise causing the subject to focus his or her attention on the most salient aspects of a situation to the neglect of subtle interpersonal cues. For example, Mathews and Canon's (1975) finding that an arm cast increased the proportion of people helping a confederate in quiet but not in noise can be interpreted as a neglect of a subtle cue (the arm cast) under noise but not under quiet.

There are alternative explanations for the decreased sensitivity to others that occurs in noise. For example, decreases in helping may be attributable to a negative affective state induced by the noise (cf. Isen, 1970; Moore, Underwood & Rosenhan, 1973). Further research is necessary to clarify the roles of attentional and affective mechanisms in response to noise and their implications for interpersonal behavior.

COMMUNITY ANNOYANCE

Excessive noise is mentioned more frequently by community residents than any other neighborhood problem (U.S. Bureau of Census, 1973). In examining the effects of community noise problems, it is important to distinguish between public complaint behavior and annoyance. Although annoyance often leads to public action, many variables may intervene. Complainants, for example, are better educated and hold higher status jobs than noncomplainants (McKennell, 1973). This is not because people with more education and higher occupational status tend to be more annoyed, but, apparently, because such people are more likely to feel that their complaints will be listened to.

Since complaint behavior is not an accurate measure of public sentiment, most community noise research has focused on individual annoyance, assessed through interviews. A major goal of community noise surveys has been to generate response curves that indicate the degree of annoyance to be expected at different sound levels. Such curves can be used to predict noise impact and to set community standards for permissible noise exposures.

Smooth and nearly linear response curves are produced when the mean annoyance or the proportion deemed "highly annoyed" is plotted against noise levels, (Alexandre, 1973; McKennell, 1973) and it is likely that these curves are relatively stable across different settings (Schultz, 1978). These data are misleading, however, because they give the impression that subjective reactions to noise are a simple function of the exposure. In fact, the physical stimulus—the sound level itself—accounts for a relatively small percentage of the variability in self-reported annoyance, usually 10% to 25% (e.g., Griffiths & Langdon, 1968; McKennell, 1963). At any particular sound level, such dose-response curves do not tell whether a given individual will be highly annoyed or unconcerned.

In attempting to explain individual differences, researchers have searched for measures of noise exposure that will correlate more closely with the subjective reports. Dozens of noise indices are now in existence. While some of these are more highly correlated with annoyance than others (cf. U.S. Environmental Protection Agency, 1974), it is questionable whether significant improvements in predictive accuracy can be produced by further refinement of the indices. Furthermore, the limited predictive ability of noise indices cannot be attributed to unreliable annoyance measures. The multi-item scales employed generally have quite

satisfactory internal reliability (e.g., McKennell, 1963) although the stability of annoyance measures is not so clearly established (Griffiths & Delauzun, 1977; Leonard & Borsky, 1973).

Intervening Variables

From many surveys it has become apparent that age, sex, income, education, and occupational status are not significantly related to annoyance (Weinstein, 1976). Attempts to relate annoyance to the personality scales of the MMPI and Rorschach Inkblot Test (Moreira & Bryan, 1972), the Eysenck Personality Inventory (Griffiths & Delauzun, 1977; Moreira & Bryan, 1972), and Cattell's 16 PF (Griffiths & Delauzun, 1977) have been inconclusive. On the other hand, several studies have demonstrated that people do differ in their general sensitivity to noise and that this attribute is responsible for part of the variability in reported annoyance (e.g., Griffiths & Delauzun, 1977; Weinstein, 1978). Among college students, greater self-reported sensitivity to noise is associated with lower intellectual ability and less confidence during interpersonal interactions (Weinstein, 1978). It has also been observed (Weinstein, 1979) that people are consistent in their tendency to be critical or uncritical about many aspects of their surroundings, including judgments of noise, privacy, air pollution, neighborhood services, and other neighborhood characteristics (cf. Broadbent, 1972; Griffiths & Delauzun, 1977). It is not yet known, however, whether this consistency in environmental judgments represents a response style—a variation in the willingness to *express* dissatisfaction—or whether highly critical people are genuinely less satisfied with their surroundings.

Much of the research on intervening variables has examined the meanings people attach to noise situations. For example, people who are afraid of airplane crashes report greater aircraft noise disturbance than people who are not. Presumably, the former interpret each passing plane as a signal of possible danger (Borsky, 1973). Other studies (e.g., Tracor, 1970) have shown that people who have a positive attitude toward the source of the noise are less annoyed than people who think the noise source serves no useful purpose or who believe that the authorities are not making a genuine effort to control the noise. A field experiment in Sweden, for instance, demonstrated that reports of annoyance by people living near an air force base were reduced by propaganda that produced a more positive attitude toward the air force (Sörensen, 1970). Similarly, laboratory studies have shown that a sound is rated as noisier if it is attributed to a teenager's hot rod than if it is attributed to a taxi (Cederlöf, Friberg, Hammarfous, Holmquist & Kajland, 1961).

Although many beliefs are correlated with annoyance, there is no accepted theory of annoyance to bring order to the data. In some cases "annoyance" may represent fear or simply aversiveness, but many of the correlates of annoyance are predictable if one views annoyance as a mild form of anger. According to cognitive theories of emotion, anger is produced when people believe that they have been harmed and believe that the harm was both avoidable and undeserved (Brown & Herrnstein, 1975; Crosby, 1976). The harm produced in noisy situations may include threats to health and to property values, blocking of behavioral goals or simply exposure to an aversive stimulus.

Coping and Adaptation

Although many noise effects decrease rapidly in the laboratory (Glass & Singer, 1972; Kryter, 1970), community noise research provides little evidence that people adapt to noise in residential settings. Surveys find consistently that longtime neighborhood residents are at least as bothered by noise as more recent arrivals. Longitudinal studies, which avoid some of the self-selection problems inherent in the usual surveys, also find more disturbance at the end of the study period than at the beginning (Jonsson & Sörensen, 1973; Weinstein, 1978).

It is possible that the data are misleading and that people do adapt to noise. After a while, they may pay less attention to the noise and fall asleep more quickly, but their survey responses may continue to reflect their original feelings about the noise rather than their current reactions. Nevertheless, it is worth emphasizing that people appear to have much more difficulty in adjusting to noise than is commonly believed.

Some studies (e.g., Appleyard & Lintell, 1972; Grandjean, Graf, Lauber, Meier & Müller, 1973) have described the overt actions people take to cope with noise, including such responses as changing bedrooms, planting trees, installing doublepane windows, and taking sleeping pills. There is considerably less work, however, examining cognitive coping mechanisms—attention deployment strategies, self-coaching about how not to react—that might facilitate adaptation or account for individual differences. Only attentional deployment in children has received any attention (S. Cohen et al., 1980; Heft, 1979).

New Directions

There is considerable room for progress in community noise research. Investigators have not distinguished carefully between behavioral interference, emotional distress, judgments of aversiveness, or opinions about the acceptability of the noise (cf. Jonsson, Arvidsson, Berglund & Kajland, 1973). The noise levels in many communities clearly interfere with communication and sleep, and certainly evoke strong emotional reactions. But behavioral interference does not necessarily produce an emotional response. Furthermore, noise can be aversive without producing other behavioral interruptions or emotional reactions, as when subjects are asked to rate loud noises in the laboratory.

The answers given in community surveys probably reflect a mixture of all these reactions. Even if investigators deliberately formulate questions in attempts to separate these components of dissatisfaction, respondents may be unable to make the discriminations requested. Nevertheless, a clear conception of the kinds of noise reactions that can occur should help to develop more precise models of the noise response process.

Since almost all community noise research has used a cross-sectional survey design, most conclusions about the psychological variables that influence annoyance have been based on correlational data. An association between the belief that the noise is a health threat and annoyance, for example, is generally interpreted to mean that this belief is a cause of annoyance. On the other hand, respondents may conclude that the noise is harmful *because* they find that they are upset and sleeping poorly. To classify such beliefs as *either* causes *or* effects is to oversimplify the issue. Noise appraisals are likely to influence noise reactions *and* be altered by those reactions (Alexandre, 1973). Field experiments and longitudinal studies are needed to provide a more realistic model of noise reactions. Progress in community noise research will also require less reliance on self-report measures and more direct observations of the physiological, behavioral, and interpersonal consequences of noise exposure.

Noise, Mental Health & Cognitive Development

If noise causes annoyance and frustration, it seems plausible that prolonged exposure could cause or aggravate mental illness. Existing studies suggest the possibility of a relationship between noise and symptoms of serious mental distress, but the evidence is mixed and rather weak.

Industrial surveys, for example, report that noise exposure results in increased anxiety and emotional stress. Workers habitually exposed to high-intensity noise (usually 110 dB or above) show increased incidence of nervous complaints, nausea, headaches, instability, argumentativeness, sexual impotency, changes in general mood, and anxiety (cf. A. Cohen, 1969; Granati, Angelepi & Lenzi, 1959; Miller, 1974). Jansen (1961) reports that workers in the noisiest parts of a steel factory have a greater frequency of social conflicts both at home and in the plant. These results are difficult to interpret, however, since the same workers are often subject to other work stresses (e.g., task demands and risks) that may precipitate or contribute to the reported symptoms.

Studies of the impact of community noise exposure on self-reported neurotic symptoms provide inconsistent evidence for a link between noise and pathology. Thus in a recent review, McLean and Tarnopolsky (1977) report that while a number of community surveys indicate an association between noise and various symptoms—being tense and edgy (Office of Population Census and Survey, Note 7), irritability (Finke, Guski, Martin, Rohrman, Schümer, & Schümer-Kohrs, 1974), nervousness, sleep difficulties and headaches (Kokokusha, 1973)—the questions in these studies were worded in a way that seemed to invite one to blame noise for one's ailments. In a study by Grandjean (Note 8), where aircraft noise was not mentioned as a possible cause, there were no correlations between symptoms and exposure. A survey of general practitioners in high and low noise areas around Amsterdam's airport (Knipschild, Note 9) did, however, find a high proportion of psychological and psychosomatic complaints in the high noise area. Differences in social class of the noise and quiet areas, however, provide a possible alternative explanation.

Hospital Admissions

Work on community response to aircraft noise suggests a possible relationship between noise level and admission rates to community mental health facilities (cf. reviews by Arhlin & Öhrström, 1978; McLean & Tarnopolsky, 1977). Several studies relating sound level and mental-hospital admissions have been conducted in the vicinity of London's Heathrow Airport. Abbey-Wickrama, a'Brook, Gattoni, and Herridge (1969; Herridge & Chir, 1972) compared the psychiatric-hospital admission rates of those residing in noisy and less noisy parts of the same borough.

Admission rates were higher for the noisy area; persons most at risk were older single, widowed, or separated women suffering from neurotic or organic mental illness. These results have been challenged by Chowns (1970), who argues that the noise index used was inappropriate and that noisy and less noisy (control) neighborhoods were poorly matched on demographic factors. A replication of this work (Gattoni & Tarnopolsky, 1973), using a different technique of indexing noise and carefully matching the noise and control groups on a number of socioeconomic variables, found similar but small (nonsignificant) differences between noise and quiet areas. Recent work on mental hospital admissions around Heathrow (Hand, Tarnopolsky, Barker & Jenkins, 1980) has looked at the admission rates of several different community facilities, rather than studying the single hospital examined in the studies described above. This work has resulted in mixed (different for each hospital) results.

A recent comparison of noise and control populations around Los Angeles International Airport (Meecham & Smith, 1977) indicates a marginal increase in mental-hospital admissions among those living in maximum noise areas. Poor matching of quiet and noise areas on race and socio-economic status, however, severely limit confidence in these results.

In sum, existing studies suggest that there may be a small difference between mental hospital admission rates of quiet neighborhoods and neighborhoods subjected to aircraft noise. However, the studies are all retrospective and involve differences between the admission rates of noise and quiet groups that are so small (between .001 and .003%) as to be considered by many as trivial. It should be noted, however, that admission to community mental-hospitals represent only the severest cases of mental distress. It is likely that many sufferers would see their general practitioner rather than visiting a community mental health facility (e.g., Knipschild, Note 9). Moreover, what may be considered a serious deviation from normality in one social class or ethnic group may be an acceptable deviation in another. Thus depending on the background of the population, the sensitivity of these admission rates to mental distress could vary substantially. Prospective studies of community mental health that include a wider range of psychiatric care would help clarify this issue. It is also important to note that these data do not indicate whether noise causes severe mental distress in otherwise healthy individuals or whether it merely aggravates existing problems (cf. McLean & Tarnopolsky, 1977).

Cognitive Development

Recent studies by Wachs and his colleauges suggest that noise in the home may interfere with normal psychological development. For example, Wachs, Uzgiris and Hunt (1971) administered a Piagetian test of intellectual development to 102 infants between 7 and 22 months of age. There was a negative relationship between scores on the test and mothers' reports of home noise levels. Moreover, infants whose homes did not have a place where the infants could be isolated from the noise performed more poorly on the developmental test than those who had opportunities to escape. Similar effects have been found for slightly older infants although these effects may be sex specific (Wachs, 1978, 1979). It is important to note that self-reports of noise do not necessarily correlate well with objective sound levels (cf. Kryter, 1970) and that these studies are correlational and open to alternative explanations. While not allowing any conclusions about the relationship between home noise level and psychological development, this work does suggest the necessity for further research in this area.

Noise and Health

Does noise hurt the human body? Most would argue that outside of the effects of high-intensity sound on hearing (see Kryter, 1970; Miller, 1974), there is little convincing evidence for a causal-link between noise and physical disorders. However, noise can alter physiological processes including the functioning of the cardiovascular, endocrine, respiratory and digestive systems (see review by McLean & Tarnopolsky, 1977). Since such changes, if extreme, are often considered potentially hazardous to health, many feel that pathogenic effects of prolonged noise exposure are likely. Physiological changes produced by noise consist of nonspecific responses typically associated with stress reactions (Glorig, 1971; Selye, 1956). These include increases in electrodermal activity, catacholamine secretions, vasoconstriction of the peripheral blood vessels, and increases in diastolic and systolic blood pressure. Most of these reactions have been documented in laboratory studies involving short-term exposure to relatively high sound levels (cf. A. Cohen, 1977).

Do such physiological effects constitute evidence that noise is detrimental to health? The question is difficult to answer. On the one hand, there is mixed evidence that a number of physiological responses *do not* habituate to repeated exposure (cf. Jansen, 1969; McLean & Tarnopolsky, 1977) and thus could constitute the physiological bases for long-term harmful effects of noise. On the other hand, others report that habituation of these responses occurs after only short exposure to noise (e.g., Glass & Singer, 1972), thus prolonged exposure might not necessarily produce continuous elevation of physiological processes inimical to normal bodily function. Kryter's (1970) conclusion that "the exact course and degree of adaptation of all these responses has not been very thoroughly studied" (p. 491) probably represents the state of our knowledge in this area.

Industrial Studies

A recent review of the industrial noise literature (Welch, Note 10) concludes that there is elevated morbidity among people who have been exposed at work to sound of 85 dBA or greater for at least 3–5 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. Morbidity also tends to be greater under unpredictable-intermittent, impulse sound than under periodic, continuous or relatively steady sound; and it affects those whose work involves mental concentration more than those who do mainly manual work.

Welch argues that the strongest case for industrial noise impacting health derives from the research on cardiovascular problems. He interprets the data (over 40 different studies) to indicate that long-term work under high-intensity sound is associated with at least a 60 percent increase in risk of cardiovascular disease. Impaired regulation of blood pressure (including hypertension) is the best documented of these effects (e.g., Parvizpoor, 1976; Pokroviskii, 1966). Other concomitants of prolonged routine exposure to intense industrial sound include cardiac morbidity (e.g., Capellini & Moroni, 1974; Raytheon Service Company, Note 11), poor peripheral circulation (e.g., Jansen, 1959), and elevated cholesterol levels (e.g., Khomulo, Rodinova & Rusinova, 1967).

Although there is an impressive amount of data suggesting that cardiovascular morbidity is greater among workers exposed to high noise levels, there are a number of reasons to be critical (or at least cautious) about Welch's conclusions. All of these studies suffer from the methodological problems associated with correlational field research and as many as half of the existing studies are either poorly designed (inadequate control groups) or do not report sufficient information to allow a critical analysis of the work (see critique in Peterson, Note 12). Our confidence in the relationship between prolonged exposure to high-intensity noise and cardiovascular problems would be significantly increased if similar effects were found in prospective research. Cardiovascular response could be monitored over time in a new work group entering a particular noisy environment and compared with similar workers not so exposed (cf. A. Cohen, Note 2; Peterson, Note 12).

Besides cardiovascular changes, reports have linked industrial noise to a number of other health problems. The data in all of these cases is suggestive but as yet inconclusive (cf. Welch, Note 10). For example, there are a number of studies reporting increased gastrointestinal complaints for noise exposed workers. Reported problems include gastrointestinal ulcers (e.g., Kangelari, Abramovich-Polyakov & Ruolenko, 1966), chronic gastritis (e.g., Dokukina, Koberts & Lyubomudrav, 1972) and general digestive problems (Raytheon Service Company, Note 11).

Although there has been a lot of speculation about the effect of prolonged exposure to noise on resistance to infectious disease, the small number of existing studies are mixed and inconclusive (cf. Welch, Note 10). Similarly, predictions about the impact of high-intensity sound on the reproductive system is virtually unstudied. An interesting investigation by Carosi and Calabro (1968) did, however, indicate that Italian families in which either husband or wife worked in a noisy job had a smaller number of sons born than non-noise families matched for age. Factory noise has also been associated with increased reports of sore throats and laryngitis (cf. A. Cohen, 1969) and increased job related injuries (e.g., A. Cohen, 1973, 1976). It is likely that the former is attributable to workers raising their voices in order to be heard, and the latter, to some degree, to not hearing warning signals. However, A. Cohen's (1976) finding that there are fewer accidents among workers wearing hearing protections then those without protection suggests that the masking of warning signals is not entirely responsible for increased injuries. Finally, a small number of studies suggest that prolonged exposure to high-intensity industrial noise is implicated in functional neural change, with the most convincing data suggesting impaired control of circulation (Welch, Note 10).

It is also important to note that several industrial surveys failed to find a relationship between noise and ill health. For example, Finkle and Poppen (1948) report that men working in turbojet noise of 120 dB showed complete adaptation to noise. Results for renal function tests, electroencephalography, and hematological examinations were all negative. Glorig (1971) also reports no increase in cardiovascular problems, ulcers, or fatigue for those working in noisy industries.

In sum, while several years of exposure to industrial noise has been associated with a number of specific nonauditory diseases, only cardiovascular problems have received enough attention and enough consistent support to allow a convincing argument that they are noise induced. This argument is to some extent corroborated by both short-term laboratory studies of humans (see review by McLean & Tarnopolsky, 1977) and animal studies of long-term exposure (cf. Peterson, Note 12) showing similar effects on the cardiovascular system. More research will be required before even tentative conclusions can be made about the relation of industrial noise to other diseases.

It should also be noted that noise may not be etiologically specific to any given disease (cf. Cassel, 1974) but may enhance susceptibility to disease in general and thus cause a wide variety of symptoms of physical and psychiatric disorder. This perspective suggests that studies of the relationship of noise to any specific disease (or even just somatic or just psychiatric diseases) may be insensitive to noise-induced effects and that a broader definition of health that encompasses both mental and physical aspects may be more productive.

Community Studies

A number of recent studies have examined the effects of community noise on cardiovascular problems and physiological risk factors related to cardiovascular disease. In a series of these studies conducted in the neighborhoods adjacent to Schiphol (Amsterdam) airport, Knipschild (1977) reports that residents in areas with high levels of aircraft noise are more likely to be under medical treatment for heart trouble and hypertension, more likely (especially women) to be taking drugs for cardiovascular problems, and more likely to have high blood pressure and pathologically shaped hearts than an unexposed population. While these differences could not be explained by age, sex, smoking habits or obesity, the noisy and quiet areas did differ in socio-economic 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.

A recent study of elementary school children in Los Angeles (S. Cohen et al., 1980) indicates that children living and attending elementary school under the air corridor to Los Angeles International Airport have higher systolic and diastolic blood pressure than matched counterparts living in quieter neighborhoods. These differences, while small in magnitude, were obtained with a conservative statistical analysis that controlled for race, grade, social class, length of residence in the neighborhood, height and obesity. 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 lability of pulse, 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, while 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 an increased incidence of cardiovascular disease and some factors related to the risk of cardiovascular pathology. One striking aspect of these data is the evidence that children as well as adults (and possibly even more than adults) show noise associated cardiovascular effects (cf. Cohen et al., 1979).

There are a number of other studies investigating the impact of aircraft noise on various health problems. For example, increased noise has been associated with pregnancy complications and decreases in the health and survival of newborn infants (e.g., Ando & Hattori, 1973; 1977; Edmonds, Layde & Erickson, 1979; Jones & Tauscher, 1978; Knipschild, Meijer & Salle, Note 13). This data is somewhat inconsistent, however, and as yet inconclusive (see review by Knipschild et al., note 13). It has also been reported that increased noise levels due to aircraft overflights are associated with increased *death* rates due to strokes and cirrhosis of the liver (Meecham & Shaw, 1979), although a reanalysis of the same data, carefully controlling for the confounding effects of age, race and sex, found no difference in the mortality rates of the airport and control areas (Freirchs, Beeman & Coulson, 1980). Other studies report noise associated increases in nervous

and gastrointestinal diseases (Karagodina et al., 1969), consumption of sleeping pills and visits to doctors (Grandjean et al., 1973), and self-reported incidence of a variety of chronic illnesses (Cameron, Robertson & Zaks, 1972). In isolation, this work (some of which suffers from serious methodological flaws) can only be viewed as suggestive of possible pathogenic effects of community noise exposure. Replications of these studies would greatly increase our confidence in their findings.

Conclusion

Two themes recur throughout this article and deserve some additional emphasis. The first theme has to do with the importance of psychological factors, particularly the predictability, controllability and meaning of the noise, in mediating the relationship between noise and human response. The second theme involves the possibility that the masking of auditory communication is responsible for a number of what we have presented as nonauditory effects.

The preceeding review suggests that the ability to predict and control the occurrence of the noise mediates both psychological and physiological response. Hence, unpredictable noise is more likely to disrupt performance, to lead to variable performance, to be reported as annoying, and to be linked with pathological response, than predictable noise. One's perception that a noise is controllable, i.e., that it can be escaped or avoided, can eliminate post-exposure deficits in task performance and interpersonal sensitivity. Perceptions of control also play a role in reported annoyance and may be an ameliorative factor in noise-induced disease.

The respondents perception of the role of noise in a particular context is also important in mediating the relationship between noise and human response. Noise that is perceived as disruptive of an important goal, unnecessary, representative of something that is feared or loathed and is produced without concern for the respondent is more likely to elicit stress-related responses than noise without these characteristics. Although the strongest data for this conclusion are those collected in noise annoyance surveys, there is reason to believe that these factors are also important in predicting the impact of noise on performance and pathological response.

Although we limited this article to the discussion of nonauditory effects of noise, the masking of auditory communication provides a possible explanation for a number of reported effects, particularly the deleterious effects of noise on human performance. It is obvious that a task whose performance requires auditory communications will suffer under high-intensity noise. As mentioned earlier, Poulton (1977) has also argued that even in situations in which masking is not obvious, noise may interfere with the reception of subtle auditory feedback cues or with hearing one's own internal speech. Noise masking of parent-child and teacher-child communication may also be responsible for the poorer scholastic performance among children living and/or attending school in noisy neighborhoods and masking of supervisor-worker or worker-worker communication may be partly responsible for increased incidence of accidents for those working in noisy industrial settings. It also seems likely that decreased social interactions under noise (e.g., Appleyard & Lintell, 1972) may be wholly or partly due to one's expectancy that communication would be awkward and difficult under noisy conditions.

In sum, it is clear that the mere existance of unwanted sound, even at relatively high intensities, is often not sufficient to cause a deleterious effect of noise. Our response to any particular noise is determined to some degree by its physical properties, its meaning (including its significance), and various characteristics of the respondent. Even so, an overall view of the existing research suggests that prolonged exposure to high-intensity noise in community or work settings is often harmful to the health and behavior of large segments of the exposed populations.

REFERENCE NOTES

1. Miles, W. A. *In the Benox Report*, Chicago University, 1953.
2. Cohen, A. *Remarks as discussant at symposium: Research needs with regards to the non-auditory effects of noise.* Presented at the Annual Meeting of the American Psychological Association, New York, September, 1979.
3. Weston, H. C., & Adams, S. *Part II, Report no. 65, Industrial Health Research Board.* London: Her Majesty's Stationary Office, 1932. Also cited in Broadbent, 1979.
4. McCroskey, R. L., & Devens, J. S. *Effects of noise upon student performance in public school classrooms.* Proceedings of the Technical Program, National Noise and Vibration Control Conference. Chicago, Illinois, 1977.
5. Maser, A. L., Sorensen, P. H. & Kryter, K. D. *Effects of intrusive sound on classroom behavior: Data from a successful lawsuit.* Paper presented at the Annual Meeting of the Western Psychological Association, San Francisco, 1978.
6. Green, K. B. *The effects of community noise exposure on the reading and hearing ability of Brooklyn and Queens school children.* Dissertation submitted to the Program in Environmental Health Sciences, New York University, 1979.

7. Office of Population Census and Survey. *Second survey of airport noise annoyance around London (Heathrow) Airport.* London: Her Majesty's Stationary Office, 1970.
8. Grandjean, E. *Sozio-psychologische Untersuchungen vor den Fluglarms.* Bern, 1974.
9. Knipschild, P. G. *Medische Gevolgen van Vliegtuilawaai* (Doctoral thesis with English summary, pp. 127–129.) Amsterdam Coronel Laboratorium, 1976.
10. Welch, B. L. *Extra-auditory health effects of industrial noise: Survey of foreign literature.* Aerospace Medical Research Laboratory, Aerospace Medical Division, Air Force Systems Command, Wright-Patterson, June, 1979.
11. Raytheon Service Company, Industrial Noise and Worker Medical, Absence and Accident Records. National Institute of Occupational Safety and Health Contract Report TRL-NIOSH RR-17, 1972.
12. Peterson, E. A. *Some issues and investigations concerning extra auditory effects of noise.* Paper presented at annual meeting of the American Psychological Association, New York, September, 1979.
13. Knipschild, P., Meijer, H., Salle, H. *Aircraft noise and birth weight.* Coronel Laboratory, University of Amsterdam, 1054 BW Amsterdam, The Netherlands.

REFERENCES

Abbey-Wickrama, I., a'Brook, M. F., Gattoni, F. W. G., & Herridge, C. F. Mental hospital admissions and aircraft noise. *Lancet*, 1969, *2*, 1275–1277.

Ahrlin, U., & Öhrström, E. Medical effects of environmental noise on humans. *Journal of Sound and Vibration*, 1978, *59*, 79–87.

Alexandre, A. Decision criteria based on spatio-temporal comparisons of surveys of an aircraft noise. In W. D. Ward (Ed.), *Proceedings of the International Conference on Noise as a Public Health Problem* (EPA 550/9-73-008). Washington, D.C.: U.S. Government Printing Office, 1973.

Ando, Y. & Hattori, H. Statistical studies on the effects of intense noise during human fetal life. *Sound and Vibration*, 1973, *27*, 101–110.

Ando, Y. & Hattori, H. Effects of noise on human placental lactogen, (HPL) levels in maternal plasma. *British Journal of Obstetrics and Gynaecology*, 1977, *84*, 115–118.

Appleyard, D. & Lintell, M. The environmental quality of city streets: The residents' viewpoint. *Journal of the American Institute of Planners*, 1972, *38*, 84–101.

Boggs, D. H. & Simon, J. R. Differential effects of noise on tasks of varying complexity. *Journal of Applied Psychology*, 1968, *52*, 148–153.

Borsky, P. N. *A new field-laboratory methodology for assessing human response to noise* (NASA CR-221). Washington, D.C.: National Aeronautics and Space Administration, 1973.

Borsky, P. N. Research on community response to noise since 1973. In J. V. Tobias (Ed.), *The proceedings of the Third International Congress on Noise as a Public Health Problem.* Washington, D.C.: American Speech and Hearing Association, 1980.

Bragdon, C. R. *Noise pollution: The unquiet crisis.* Philadelphia, PA: University of Pennsylvania Press, 1971.

Broadbent, D. E. *Decision and stress.* New York: Academic Press, 1971.
Broadbent, D. E. Individual differences in annoyance by noise. *Sound,* 1972, *6,* 56-61.
Broadbent, D. E. The current state of noise research: Reply to Poulton. *Psychological Bulletin,* 1978, *85,* 1052-1067.
Broadbent, D. E. Human performance and noise. In C. M. Harris (Ed.), *Handbook of noise control.* New York: McGraw-Hill, 1979.
Broadbent, D. E. & Little, F. A. J. Effects of noise reduction in a work situation. *Occupational Psychology,* 1960, *34,* 133-140.
Bronzaft, A. L. & McCarthy D. P. The effects of elevated train noise on reading ability. *Environment & Behavior,* 1975, *7,* 517-527.
Broussard, I. G. Cited in Broadbent, D. E. Human performance and noise. In C. M. Harris (Ed.), *Handbook of noise control.* New York: McGraw-Hill, 1979.
Brown, R. & Herrnstein, R. J. *Psychology.* Boston, MA: Little, Brown & Co., 1975.
Cameron, P., Robertson, D., & Zaks, J. Sound pollution, noise pollution, and health: Community parameters. *Journal of Applied Psychology,* 1972, *56,* 67-74.
Capellini, A. & Maroni, M. Clinical survey on hypertension and coronary disease and their possible relations with the environment in workers of a chemical plant (Italian). *Medicina del Lavoro,* 1974, *65,* 297-305.
Carosi, L. & Calabro, F. Fertility of couples working in noisy factories. *Folia Medica,* 1968, *51,* 264-268.
Cassel, J. Psychosocial processes and "stress": Theoretical formulation. *International Journal of Health Services,* 1974, *4,* 471-482.
Cederlöf, R., Friberg, L., Hammarfors, P., Holmquist, S. E., & Kajland, A. Studier över ljudnivaer och hygieniska olägenheter av trafikbuller samt förslag till atgärder, *Nordisk Hygienisk Tidskrift,* 1961, *42,* 101-192.
Chowns, R. H. Mental-hospital admissions and aircraft noise. *Lancet,* 1970, *1,* 467.
Cohen, A. Effects of noise on psychological state. In W. Ward & J. Fricke (Eds.), *Noise as a public health hazard.* Washington D.C.: American Speech and Hearing Association, 1969.
Cohen, A. Industrial noise and medical, absence, and accident record data on exposed workers. In W. D. Ward (Ed.), *Proceedings of the International Congress on Noise as a Public Health Problem.* Washington, D.C.: U.S. Government Printing Office, 1973.
Cohen, A. The influence of a company hearing conservation program on extra-auditory problems in workers. *Journal of Safety Research,* 1976, *8,* 146-162.
Cohen, A. Extraauditory effects of acoustic stimulation. In D. K. Lee, H. L. Falk, S. D. Murphy, & S. R. Geiger (Eds.), *Handbook of physiology: Reactions to environmental agents, Section 9.* Baltimore, MD: Williams & Wilkins, 1977.
Cohen, S. Environmental load and the allocation of attention. In A. Baum, J. E. Singer & S. Valins (Eds.), *Advances in environmental psychology, Vol. 1.* Hillsdale, N.J.: Erlbaum, 1978.
Cohen, S. Cognitive processes as determinants of environmental stress. In I. Sarason & C. Speilberger (Eds.), *Stress and anxiety, Vol. VII.* Washington,

D.C.: Hemisphere Press, 1980. (a)
Cohen, S. The aftereffects of stress on human performance and social behavior: A review of research and theory. *Psychological Bulletin,* 1980, *88,* 82-108. (b)
Cohen, S., Evans, G. W., Krantz, D. S., & Stokols, D. Physiological, motivational and cognitive effects of aircraft noise on children: Moving from the laboratory to the field. *American Psychologist,* 1980, *35,* 231-243.
Cohen, S., Evans, G. W., Krantz, D. S., Stokols, D., & Kelly, S. Aircraft noise and children: Longitudinal and cross-sectional evidence on adaptation to noise and the effectiveness of noise abatement. *Journal of Personality and Social Psychology,* in press.
Cohen, S., Glass, D. C., & Phillips, S. Environment and health. In H. E. Freeman, S. Levine, and L. G. Reeder (Eds.), *Handbook of medical sociology.* Englewood Cliffs, N.J.: Prentice-Hall Inc., 1979.
Cohen, S., Glass, D. C., & Singer, J. E. Apartment noise, auditory discrimination, and reading ability in children. *Journal of Experimental Social Psychology,* 1973, *9,* 407-422.
Cohen, S. & Lezak, A. Noise and inattentiveness to social cues. *Environment and Behavior,* 1977, *9,* 559-572.
Crook, M. A. & Langdon, F. J. The effects of aircraft noise in schools around London Airport. *Sound and Vibration,* 1974, *34,* 221-232.
Crosby, F. A model of egoistical relative deprivation. *Psychological Review,* 1976, *83,* 85-113.
Damon, A. The residential environment, health, and behavior: Simple research opportunities, strategies, and some findings in the Solomon Islands and Boston, Massachusetts. In L. E. Hinkle, Jr., & W. C. Loring (Eds.), *The effect of the man-made environment on health and behavior.* Atlanta, GA: Center for Disease Control, Public Health Service, 1977.
Dokukina, G. A., Koberts, G. P., & Lyubomudrov, V. Y. On the nonspecific effect of noise and vibration (Russian). *Vrachneboe Delo,* 1972, *2,* 134-136.
Donnerstein, E. & Wilson, D. W. Effects of noise and perceived control on ongoing and subsequent aggressive behavior. *Journal of Personality and Social Psychology,* 1976, *34,* 774-781.
Edmonds, L. D., Layde, P. M., & Erickson, J. D. Airport noise and teratogensis. *Archives of Environmental Health,* 1979, *34,* 243-247.
Finke, H. O., Guski, R., Martin, R., Rohrmann, B., Schümer, R., & Schümer-Kohrs, A. Effects of aircraft noise on man. *Proceedings of the Symposium on Noise in Transportation, Section III, paper 1.* Southampton: Institute of Sound and Vibration Research, 1974.
Finkelman, J. M. & Glass, D. C. Reappraisal of the relationship between noise and human performance by means of a subsidiary task measure. *Journal of Applied Psychology,* 1970, *54,* 211-213.
Finkle, A. L. & Poppen, J. R. Clinical effects of noise and mechanical vibrations of a turbo-jet engine on man. *Journal of Applied Physiology,* 1948, *1,* 183-204.
Fisher, S. A "distraction effect" of noise bursts. *Perception,* 1972, *1,* 223-236.
Forster, P. M., & Grierson, A. T. Noise and attentional selectivity: A reproducible phenomenon? *British Journal of Psychology,* 1978, *69,* 489-498.
Frerichs, R. R., Beeman, B. L., & Coulson, A. H. Los Angeles Airport

Noise and Mortality-Fault Analysis and Public Policy. *American Journal of Public Health*, 1980, *70*, 357–362.

Gardner, G. T. Effects of federal human subjects regulations on data obtained in environmental stressor research. *Journal of Personality and Social Psychology*, 1978, *36*, 628–634.

Gattoni, F. & Tarnopolsky, A. Aircraft noise and psychiatric morbidity. *Psychological Medicine*, 1973, *3*, 516–520.

Glass, D. C. & Singer, J. E. *Urban stress: Experiments on noise and social stressors*. New York: Academic Press, 1972.

Glorig, A. Non-auditory effects of noise exposure. *Sound and Vibration*, 1971, *5*, 28–29.

Granati, A., Angelepi, F., & Lenzi, R. L'influenza dei rumori sul sistema nervoso. *Folia Medica*, 1959, *42*, 1313–1325.

Grandjean, E., Graf, P., Lauber, A., Meier, H. P., & Müller, R. A survey on aircraft noise in Switzerland. In W. D. Ward (Ed.), *Proceedings of the International Congress on Noise as a Public Health Problem*. Washington, D.C.: U.S. Government Printing Office, 1973.

Griffiths, I. D. & Delauzun, F. R. Individual differences in sensitivity to traffic noise: An empirical study. *Journal of Sound and Vibration*, 1977, *55*, 93–107.

Griffiths, I. D. & Langdon, F. J. Subjective response to road traffic noise. *Journal of Sound and Vibration*, 1968, *8*, 16–32.

Hamilton, P. Selective attention in multisource monitoring tasks. *Journal of Experimental Psychology*, 1969, *82*, 34–37.

Hand, D. J., Tarnopolsky, A., Barker, S. M., & Jenkins, L. M. Relationships between psychiatric hospital admissions and aircraft noise: A new study. In J. V. Tobias (Ed.), *The proceedings of the Third International Congress on Noise as a Public Health Problem*. Washington, D.C.: American Speech and Hearing Association, 1980.

Harris, C. S. The effects of different types of acoustic stimulation on performance. In W. D. Ward (Ed.), *Proceedings of the International Congress on Noise as a Public Health Problem*. Washington, D.C.: U.S. Environmental Protection Agency, 1973.

Hartley, L. R. Effect of prior noise or prior performance on serial reaction. *Journal of Experimental Psychology*, 1973, *101*, 255–261.

Heft, H. Background and focal environmental conditions of the home and attention in young children. *Journal of Applied Social Psychology*, 1979, *9*, 47–69.

Herridge, C. F. & Chir, B. Aircraft noise and mental hospital admissions. *Sound*, 1972. *6*, 32–36.

Hockey, G. R. J. Effect of loud noise on attentional selectivity. *Quarterly Journal of Experimental Psychology*, 1970, *22*, 28–36. (a)

Hockey, G. R. J. Signal probability and spatial location as possible bases for increased selectivity in noise. *Quarterly Journal of Experimental Psychology*, 1970, *22*, 37–42. (b)

Hockey, G. R. J., & Hamilton, P. Arousal and information selection in short-term memory. *Nature*, 1970, *226*, 866–867.

Isen, A. M. Success, failure, attention, and reaction to others: The warm glow of success. *Journal of Personality and Social Psychology*, 1970, *15*, 294–301.

Jansen, G. On the origin of functional vegetative change due to working under noise (German). *Archiv für Gewerbepathologie und Gewerbehygiene*, 1959, *17*, 238–261.

Jansen, G. Adverse effects of noise in iron and steel workers. *Stahl und Eisen*, 1961, *81*, 217–220.

Jansen, G. Effects of noise on physiological state. In W. D. Ward & J. E. Fricke (Eds.), *Noise as a public health problem*. Washington, D.C.: American Speech and Hearing Association, 1969.

Jones, F. N. & Tauscher, J. Residence under an airport landing pattern as a factor in teratism. *Archives of Environmental Health*, 1978, *33*, 10–12.

Jonsson, E. & Sorensen, S. Adaptation to community noise—A case study. *Journal of Sound and Vibration*, 1973, *26*, 571–575.

Jonsson, E., Arvidsson, O., Berglund, K., & Kajland, A. Methodological aspects of studies of community response to noise. In W. D. Ward (Ed.), *Proceedings of the International Conference on Noise as a Public Health Problem* (EPA 550/9-73-008). Washington, D.C.: U.S. Government Printing Office, 1973.

Kangelari, S. S., Abramovich-Polyakov, D. K., & Rudenko, V. F. The effects of noise and vibration on morbidity rates (Russian). *Gigiena Truda i Professional 'nye Zabolevaniya*, 1966, *6*, 47–49.

Karagodina, I. L., Soldatkina, S. A., Vinokur, I. L., & Klimukhin, A. A. Effect of aircraft noise on the population near airports. *Hygiene and Sanitation*, 1969, *34*, 182–187.

Karsdorf, G. & Klappach, H. Einflüsse des Verkehrslärms auf Gesundheit und Leistung bei Oberschülern einer Grofzstadt. *Zeitschrift fur die Gefamte Hygiene*, 1968, *14*, 52–54.

Khomulo, L. P., Rodinova, L. P., & Rusinova, A. P. Changes in the blood lipid metabolism of man owing to the prolonged effects of industrial noise on the central nervous system (Russian). *Kardologia*, 1967, *7*, 35–38.

Knipschild, P. Medical effects of aircraft noise. *International Archives of Occupational and Environmental Health*, 1977, *40*, 185–204.

Knipschild, P. & Salle, H. Road traffic noise and cardiovascular disease: A population study in the Netherlands. *International Archives of Occupational and Environmental Health*, 1979, *44*, 55–99.

Kokokusha, D. *Report on Investigation of Living Environment around Osaka International Airport*. Japan: Association for the prevention of Aircraft Nuisance, 1973.

Korte, C., Ypma, A., & Toppen, C. Helpfulness in Dutch society as a function of urbanization and environmental input level. *Journal of Personality and Social Psychology*, 1975, *32*, 996–1003.

Krauskopf, J. & Coleman, P. D. Cited in Broadbent, D. E. Human performance and noise. In C. M. Harris (Ed.), *Handbook of noise control*. New York: McGraw-Hill, 1979.

Kryter, K. D. *The effects of noise on man*. New York: Academic Press, 1970.

Leonard, S. & Borsky, P. N. A causal model for relating noise exposure, psychological variables and aircraft noise annoyance. In W. D. Ward (Ed.), *Proceedings of the International Conference on Noise as a Public Health Problem* (EPA 550/9-73-008). Washington, D.C.: U.S. Government Printing Office, 1973.

Loeb, M. Noise and performance: Do we know more? In J. V. Tobias

(Ed.), *The Proceedings of the Third International Congress on Noise as a Public Health Problem.* Washington, D.C.: American Speech and Hearing Association, 1980.

Loeb, M. & Jones, P. D. Noise exposure, monitoring, and tracking performance as a function of signal bias and task priority. *Ergonomics*, 1978, *21*, 265–279.

Mathews, K. E., Jr. & Canon, L. K. Environmental noise level as a determinant of helping behavior. *Journal of Personality and Social Psychology*, 1975, *32*, 571–577.

McBain, W. N. Noise, the "arousal hypothesis," and monotonous work. *Journal of Applied Psychology*, 1961, *45*, 309–317.

McKennell, A. C. *Aircraft noise annoyance around London (Heathrow) Airport* (Central Office of Information, U.K. Government Social Survey S S. 337). London: Her Majesty's Stationary Office, 1963.

McKennell, A. C. Psycho-social factors in aircraft noise annoyance. In W. D. Ward (Ed.), *Proceedings of the International Conference on Noise as a Public Health Problem* (EPA 550/9-73-008). Washington, D.C.: U.S. Government Printing Office, 1973.

McLean, E. K. & Tarnopolsky, A. Noise, discomfort and mental health: A review of the socio-medical implications of disturbance by noise. *Psychological Medicine*, 1977, *7*, 19–62.

Meecham, W. C. & Shaw, N. Effects of jet noise on mortality rates. *British Journal of Audiology*, 1979, *13*, 77–80.

Meecham, W. C. & Smith, H. G. Effects of jet aircraft noise on mental hospital admissions. *British Journal of Audiology*, 1977, *11*, 81–85.

Miller, J. D. Effects of noise on people. *Journal of the Acoustical Society of America*, 1974, *56*, 729–764.

Moch-Sibony, A. Study of the effects of noise on the personality and certain psychomotor and intellectual aspects of children, after a prolonged exposure. (French). *Travail Humain*, in press.

Moore, B., Underwood, B., & Rosenhan, D. L. Affect and altruism. *Developmental Psychology*, 1973, *8*, 99–104.

Moreira, M. N. & Bryan, M. E. Noise annoyance susceptibility. *Journal of Sound and Vibration*, 1972, *21*, 449–462.

Moos, R. H. *The human context.* New York: John Wiley & Sons, Inc., 1976.

O'Malley, J. J. & Poplawsky, A. Noise induced arousal and breadth of attention. *Perceptual and motor skills*, 1971, *33*, 887–890.

Page, R. A. Noise and helping behavior. *Environment and Behavior*, 1977, *9*, 311–334.

Parvizpoor, D. Noise exposure and prevalence of high blood pressure among weavers in Iran. *Journal of Occupational Medicine*, 1976, *18*, 730–731.

Pokrovskii, N. N. On the effect of industrial noise on the blood pressure level in workers in machine building plants (Russian). *Gigiena Truda i Professional 'nye Zabolevaniya*, 1966, *10*, 44–46.

Poulton, E. C. Continuous intense noise masks auditory feedback and inner speech. *Psychological Bulletin*, 1977, *84*, 977–1001.

Poulton, E. C. A new look at the effects of noise: A rejoinder. *Psychological Bulletin*, 1978, *85*, 1068–1079.

Poulton, E. C. Composite model for human performance in continuous

noise. *Psychological Review*, 1979, *86*, 361–375.

Rotton, J., Olszewski, D., Charleton, M., & Soler, E. Loud speech, conglomerate noise, and behavioral aftereffects. *Journal of Applied Psychology*, 1978, *63*, 360–365.

Sanders, A. F. The influence of noise on two discrimination tasks. *Ergonomics*, 1961, *4*, 253–258.

Sauser, W. I., Jr., Arauz, C. G., & Chambers, R. M. Exploring the relationship between level of office noise and salary recommendations: A preliminary research note. *Journal of Management*, 1978, *4*, 57–63.

Schultz, T. J. Synthesis of social surveys on noise annoyance. *Journal of the Acoustical Society of America*, 1978, *64*, 377–405.

Selye, H. *The stress of life.* New York: McGraw-Hill, 1956.

Sherrod, D. R. & Downs, R. Environmental determinants of altruism: The effects of stimulus overload and perceived control on helping. *Journal of Experimental Social Psychology*, 1974, *10*, 468–479.

Sherrod, D. R., Hage, J. N., Halpern, P. L., & Moore, B. S. Effects of personal causation and perceived control on responses to an aversive environment: The more control, the better. *Journal of Experimental Social Psychology*, 1977, *13*, 14–27.

Siegel, J. M. & Steele, C. M. Noise level and social discrimination. *Personality and Social Psychology Bulletin*, 1979, *5*, 95–99.

Slater, B. R. Effects of noise on pupil performance. *Journal of Educational Psychology*, 1968, *59*, 239–243.

Smith, A. P. & Broadbent, D. E. The effects of noise on performance on embedded figures tasks. *Journal of Applied Psychology*, 1980, *65*, 246–248.

Sörensen, S. On the possibilities of changing the annoyance reaction to noise by changing the attitude to the source of annoyance. *Nordisk Hygienisk Tidskrift, Supplementum 1*, 1970, 1–76.

Stevens, S. S. Stability of human performance under intense noise. *Journal of Sound and Vibration*, 1972, *21*, 35–36.

Tracor, Inc. *Community reactions to airport noise, Volume I* (NASA CR-1761). Washington, D.C.: National Aeronautics and Space Administration, 1970.

U.S. Bureau of Census, *Annual housing survey: 1973 U.S. and regions: Part B, Indicators of housing and neighborhood quality.* Current Housing Report Series H-150-73-B. Washington, D.C.: U.S. Government Printing Office, 1973.

U.S. Environmental Protection Agency. *Information on levels of environmental noise requisite to protect public health and welfare with an adequate margin for safety* (EPA 550/9-74004). Washington, D.C.: U.S. Government Printing Office, 1974.

Wachs, T. D. The relationship of infants' physical environment to their Binet performance at 2-1/2 years. *International Journal of Behavioral Development*, 1978, *1*, 51–65.

Wachs, T. D. Proximal experience and early cognitive-intellectual development: The physical environment. *Merrill-Palmer Quarterly of Behavior and Development*, 1979, *25*, 3–41.

Wachs, T. D., Uzgiris, I. C., & Hunt, J. McV. Cognitive development in infants of different age levels and from different environmental backgrounds: An exploratory investigation. *Merrill-Palmer Quarterly of Behav-*

ior and Development, 1971, *17*, 288–317.
Ward, L. M. & Suedfeld, P. Human response to highway noise. *Environmental Research*, 1973, *6*, 306–326.
Weinstein, C. S. & Weinstein, N. D. Noise and reading performance in an open space school. *Journal of Educational Research*, 1979, *72*, 210–213.
Weinstein, N. D. Human evaluations of environmental noise. In K. Craik & E. H. Zube (Eds.), *Perceiving environmental quality*, New York: Plenum, 1976.
Weinstein, N. D. Individual differences in reactions to noise: A longitudinal study in a college dormitory. *Journal of Applied Psychology*, 1978, *63*, 458–466.
Weinstein, N. D. Individual differences in critical tendencies and noise annoyance. *Journal of Sound and Vibration*, 1979, *67*, 241–248.
Wilkinson, R. T. Interaction of noise, with knowledge of results and sleep deprivation. *Journal of Experimental Psychology*, 1963, *66*, 332–337.
Wohlwill, J. F., Naser, J. L., DeJoy, D. M., & Foruzani, H. H. Behavioral effects of a noisy environment: Task involvement versus passive exposure. *Journal of Applied Psychology*, 1976, *61*, 67–74.
Woodhead, M. M. The effect of bursts of noise on an arithmetic task. *American Journal of Psychology*, 1964, *77*, 627–633.

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Physiological, Comfort, Performance, and Social Effects of Heat Stress

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This paper reviews research on the relationship of high ambient temperatures to physiological adaptation, performance, and the social behaviors of attraction, aggression, and helping. In general, very high temperatures reduce performance, attraction, aggression and helping behavior. Moderately warm temperatures, however, have less predictable effects, sometimes facilitating a given behavior and at other times reducing it. High temperatures may either increase or decrease arousal, narrow attention, and cause discomfort. The mediators of arousal, adaptive capacity, and negative affect are employed to explain the empirical data, and to suggest directions for future research.

Human cultures have adapted to climatic extremes ranging from frigid arctic cold to debilitating tropical heat. Even within a culture, circumstances may require that humans encounter wide variation in temperatures. There is little question about the capability of humans to tolerate thermal extremes. There is concern, however, about the cost of such tolerance, for there are demonstrable effects of exposure to abnormally high or low ambient temperatures. These effects include physiological adaptation, changes in performance, and influences on social behavior. Concern about a number of circumstances under which humans encounter these physiological and behavioral consequences of thermal stress has prompted considerable research, much of which is of interest to psychologists and others studying social issues.

First, there is concern about consequences of naturally changing temperatures, as typified by studies relating crime and violence to seasonal fluctuations in temperature. Second, industry has studied worker safety and productivity in temperature extremes,

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