Chapter 15

ENVIRONMENTAL STRESS

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15.1. INTRODUCTION

One way to understand the relationship between the environment and human behavior is to analyze environmental conditions that are capable of interfering with optimal human functioning. In this chapter we examine how the concept of stress has been used to specify environmental characteristics that may lead to physiological or psychological discomfort and, in some cases, ill health.

Individual appraisals of the potential threat or harm of an environmental array plus the extent of available, efficacious coping resources largely determine how environmental conditions affect human health and well-being. This chapter can be distinguished from most other writings on stress in that our focus is on the physical characteristics of settings that are likely to evoke the stress and coping process. We contend that this aspect of the transactional process between environment and human behavior has largely been overshadowed by psychological and sociological investigations of personal, organizational, and societal factors that influence the stress and coping process.

Physical environments have enduring characteristics that can influence whether or not stress is produced. All biological systems must self-regulate in the context of changing environmental demands. To understand our responses to such demands, we require knowledge of both individual processes and environmental features of the ecological niches we inhabit (Sells, 1963, 1969). Situations are the source of many stress-provoking stimuli that influence both psychological and physiological responses as we learn cognitive coping strategies. Stress emanates from individual appraisals of and reactions to actual environmental conditions (Baum, Singer, & Baum, 1982; Magnusson, 1982). The conditions of the physical environment weigh significantly in the stress and coping process. Certain environmental conditions are more

capable than others of straining the adaptive resources of human beings. A strict focus on individual differences in people's reactions to environmental conditions overlooks the fact that human beings, as all other organisms, have some general requirements. We can examine whether settings support or hinder some of these requirements (S. Kaplan, 1983). We also know that individual differences in reactivity to some stressors can be systematically comprehended when certain features of settings are held constant rather than allowed to vary. Better understanding of some of the situational variation as it interacts with individual vulnerability to stressors may provide more insight into the stress and coping process (Forsman, 1983; Magnusson, 1982).

To emphasize a point made throughout this chapter, we are not claiming that stress is inevitably or even predominantly a function of variation in environmental quality. Stress is inevitably a person-based concept. Nevertheless, many stress researchers have overlooked properties of physical situations most likely to place greater adaptive demands on human coping resources.

15.2. FOCUS AND ORGANIZATION

In this chapter we restrict our view to environmental conditions typically experienced in daily life. Furthermore, we will focus on physical characteristics of environments. Thus our review focuses on crowding, noise, heat, and air pollution. Water pollution is not discussed because of the paucity of behavioral research on this topic (Coughlin, 1976). Housing and other aspects of the influence of special settings on human satisfaction and health are covered in Chapters 17, 22, 24, and 25 of this volume.

Environmental stressors are typically aversive, primarily uncontrollable, and of variable duration and periodicity and require low to moderate adjustments. One of the unfortunate consequences of the neglect of physical characteristics of stressors in the study of stress and coping has been the relative absence of theoretical or empirical work on how such characteristics as duration, intensity, and so forth affect human health and functioning. A related consequence of the emphasis on interpersonal coping processes and psychosocial mediating variables between stressors and outcome has been the lack of research on single and multiple stressor interactions. It is instructive to reread early books on stress and note the high value placed on systematic evaluation of varying stressor intensity across a large range as well as measuring multiple stressor effects (cf. Appley & Trumbull, 1967; McGrath, 1970b).

The chapter is organized into four major sections following a brief introduction. The first section describes the focus and organization of the chapter. Section 15.2 gives an overview of the stress paradigm including definitions of stress, characteristics of stressors, and general theoretical perspectives in the stress field as well as hypothetical mechanisms for the actions of environmental stressors and a brief summary of the effects of stressors on human health and behavior. The next section summarizes the effects of the four major environmental stressors reviewed in this chapter: noise, crowding, heat, and air pollution. The stress paradigm is then evaluated as an explanatory heuristic for these four stressors. The last major section of the chapter discusses several theoretical and methodological problems with the stress paradigm and its application to noise, crowding, heat, and air pollution.

15.3. OVERVIEW OF THE STRESS PARADIGM

15.3.1. Definitions of Stress

Stress is a difficult concept to define. Early definitions varied in the extent to which they emphasized the responses of the individual, or the situations that caused disruptions of ongoing behavior and functioning. Appley and Trumbull (1967), McGrath (1970a), and Mason (1975) have summarized several objections to each of these approaches to defining stress. Response-based definitions are often insensitive to critical temporal parameters in stress. The duration and periodicity of stressors have important influences on human health and well-being. Furthermore, a focus on outcomes ignores the fact that highly variable situations (e.g., negative, positive, ambiguous) can lead to similar response outcomes. For example, exercise as well as threat of personal injury heightens blood pressure. Other factors apart from the individual also have an impact on responses and may be obscured by a strict focus on response outcomes. Other sources of stress, cultural norms, or the resources provided by other people may all mediate responses to stressors (H. B. Kaplan, 1983; Levine & Scotch, 1970; Mechanic, 1978; Pearlin, 1982). Finally, there is a noteworthy lack of correspondence among measures of stress. It has proven difficult to

isolate a set of responses that invariably occur when adaptive resources are taxed. (Lacey, 1967; Mason, 1975)

Situation-based definitions of stress have been criticized because of large variations in individual responses to the same situation. Past history, threat appraisal, and coping styles vary across persons. Furthermore, with the exception of very extreme stimuli, no stimulus is a stressor to all persons or the same person across all different times or situations. It has also proven difficult to scale situations in terms of the degree of stress they evoke. Finally, the importance of the consequences of behavioral or physiological disruption is not adequately conceptualized by situation-based models of stress.

These problems have led most stress researchers both inside and outside environmental psychology to adopt more relational, interactive definitions of stress. According to this perspective, stress is a process that occurs when there is an imbalance between environmental demands and response capabilities of the organism (Lazarus, 1966; Lazarus & Launier, 1978, McGrath, 1970a).

A specific aspect of this relational perspective on stress emphasized by Lazarus and his co-workers is that for stress to occur the individual must evaluate this imbalance. Thus stress occurs when one decides that environmental stimuli are likely to tax or exceed one's personal coping capacities. In general, environmental psychologists have accepted the interaction perspective. Recent books and major reviews of environmental stress all emphasize that stress is fundamentally a relational concept signifying an imbalance between environmental opportunities and individuals' goals, and capabilities to cope with that imbalance (Baum, Singer, & Baum, 1982; Caplan, 1982; Carson & Driver, 1970; Evans, 1982; French, Rodgers, & Cobb, 1974; Lazarus & Cohen, 1977; McGrath, 1976; Stokols, 1979). We favor this perspective because it encompasses both major components of the organism–environment interface. Nevertheless, the task of developing criteria that indicate when adaptive resources are critically strained remains formidable. There are several important unresolved theoretical and methodological issues with respect to the stress construct. Some of the more salient issues are discussed later in the chapter.

Several concerns have been raised about interactive approaches to defining stress. One concern is that reliance on measures of perceived stressors eliminates the study of objective correlates of stressors (Dohrenwend, Krasnoff, Askenasy, & Dohrenwend, 1978). Moreover, if denial or other intrapsychic coping strategies are functioning, individual reports of perceived stress may obscure the severity of environmental conditions. Measures of perceived stress may also be inaccurate because they reflect the degree to which stress is attributed to a particular situation. Errors in explaining sources of stress have been shown in studies of emotions (Schachter & Singer, 1962) as well as for crowding (Keating, 1979; Worchel & Teddlie, 1976).

A second concern raised about the interactive approach to defining stress is that other variables such as individual psychological status (e.g., neuroticism, sick role behavior) may influence the relationship between reports of perceived stress, objective situational conditions, and outcome measures. Some dispositional tendencies may influence personal views of both health and levels of stress experienced (Mechanic, 1974, 1978; Schroeder & Costa, 1984).

Another problem in relying on measures of perceived stress emanates from ambiguity about direction of causality. It is often difficult to determine whether stress has produced greater negative mental health outcomes or whether the direction of causality is the reverse (Dohrenwend & Dohrenwend, 1974, 1981; Moss, 1973; Rutter, 1983).

Finally, controversy exists over whether the degree of association between perceived measures of stress and psychological or physical health outcomes is inflated because of overlap between items contained in the two sets of measures (Dohrenwend, Dohrenwend, Dodson, & Shrout, 1984; Lazarus, DeLongis, Folkman, & Gruen, 1985). This problem is exacerbated by an overreliance on self-report measures of both perceived stress and perceived health.

Lazarus (Lazarus et al., 1985), McGrath (1970a), Stokols (1979), and others have argued that stress, like most psychological constructs, is inherently relational and cannot be reduced into separate personal and environmental components (cf. Magnusson, 1981). Stress is best considered, according to this view, as a complex rubric reflecting a dynamic, recursive relationship between environmental demands, individual and social resources to cope with those demands, and the individual's appraisal of that relationship.

Nevertheless, a major source of information about stressors and various coping opportunities lies within the configuration of the physical environment. We are not arguing that stimulus characteristics are more important than other factors influencing the dynamic, mediational process of person–environ-

ment transactions. Our goal is simply to draw greater attention to many aspects of the physical settings in which we work and live that are likely to cause stress. Because of the psychologists' interest in human behavior, there has been a tendency to focus attention in stress research on individual and social resources that affect coping abilities plus personal appraisals of threat. Insufficient attention has been paid to qualities of physical environments that may be more likely to place adaptive demands on the organism (Dubos, 1965; Evans, 1982).

15.3.2. Characteristics of Stressors

Four general types of environmental stressors have been identified: cataclysmic events, stressful life events, daily hassles, and ambient stressors (Baum, Singer, & Baum, 1982; Campbell, 1983; Lazarus & Cohen, 1977). Cataclysmic events are sudden catastrophes that demand major adaptive responses from all individuals directly affected by the event. Usually cataclysmic events affect whole communities of people. Fischhoff, Svenson, and Slovic, Chapter 29, this volume, reviews several examples of natural and technological disasters that fall within this category of stressful environmental events. Floods, earthquakes, volcanic eruptions, major storms, nuclear power plant accidents, and discoveries of toxic waste dumps are examples of cataclysmic events. Two other types of cataclysmic events not discussed in this volume are war and imprisonment (cf. Monat & Lazarus, 1977).

Stressful life events are major incidents in the lives of people that typically require personal or social adaptive responses. Life events typically have clearly delineated time referents. Life events include such things as major change in family status (e.g., divorce, marriage, birth, death), or major changes in economic conditions (e.g., gain or loss of job, change in job position, change in educational status). Events that are uncontrollable, undesirable, or unscheduled in the life cycle are more likely to cause harmful outcomes (Dohrenwend & Dohrenwend, 1974; Pearlin, 1982; Rabkin & Struening, 1976; Thoits, 1983; Wheaton, 1983).

Daily hassles are the typical events of ordinary life that may cause frustration, tension, or irritation. Environmental events (e.g., noisy party, crowded elevator), work issues (e.g., argument with coworker, deadline), or interpersonal problems (e.g., argument with friend or family member) constitute the majority of daily hassles (DeLongis, Coyne, Dakof, Folkman, & Lazarus, 1982; Kanner, Coyne, Schaefer, & Lazarus, 1981). Daily hassles are more common and short-lived than most life events.

The term *ambient stressors* has been developed to distinguish more continuous, relatively stable, and intractable conditions of the physical environment (Campbell, 1983). Many ambient stressors are background conditions, passing largely unnoticed unless they interfere with some important goal or directly threaten health. Individuals living with chronic air pollution, for example, are likely to habituate to these environmental conditions. More active, instrumental coping responses to air pollution are infeasible or come at a higher perceived cost (e.g., relocating) than accommodating to the suboptimal living conditions (see also Wohlwill, 1974).

Sociologists have drawn a similar distinction between life events and chronic sources of stress. Chronic strains are the persistent, difficult, and demanding experiences of daily life. Unlike life events, chronic strains are continuous with largely unnoticeable peaks or discrete impact periods (Pearlin, 1982; Wheaton, 1983). Examples of chronic strains include work overload, rapid social change, poverty, and family conflicts. Many chronic strains emanate from conflicts between individual or social resources and values, beliefs, and aspirations (H. B. Kaplan, 1983; Mechanic, 1978; Pearlin, 1982).

The various types of environmental stressors can be categorized along eight dimensions. One dimension is the degree to which a stressor is *perceptually salient* or easily identifiable or noticeable (Baum, Singer, & Baum, 1982; Campbell, 1983; Stokols, 1979; Wohlwill, 1974). Many physical sources of stress, particularly if chronic, of low-moderate intensity, and uncontrollable, rapidly become background stimuli. Habituation in response sensitivity and general awareness is a by-product of chronic exposure to many low-level ambient stimuli (Glass & Singer, 1972; Sonnenfeld, 1967; Wohlwill, 1974).

A second dimension for characterizing sources of environmental stress is the *type of adjustment required* by the environmental condition. Environmental conditions that are very intense or uncontrollable are likely to lead to accommodation and emotion-focused coping rather than efforts to deal with the stressor directly (Kiretz & Moos, 1974; Lazarus & Cohen, 1977). These coping and adaptation processes may in turn influence the health consequences of exposure to that stressor.

The *value or valence of events*, whether one gains or loses, may also bear important consequences for reactions to the stressor. Some environmental

sources of stress, while demanding major adaptive resources, may be positively valued. This dimension for characterizing stressors highlights one of the major differences between the physiological and psychological approaches to stress. The physiological perspective emphasizes the disruption of equilibrium and consequential adaptive efforts to restore homeostasis. The psychological perspective, while acknowledging the importance of adaptive demands, asserts that the negative value of the threat to equilibrium is also crucial.

Degree of controllability over an environmental stressor is the fourth dimension in distinguishing different kinds of stress. Control can function as a psychological (appraisal) process that is influenced primarily by individual disposition (e.g., locus of control) or personal coping resources. Here control is viewed as an intrapersonal moderator of stress. Control also can refer to instrumental opportunities to exercise influence over the occurrence or duration of an environmental event. In this sense control refers to characteristics of a situational variable. Uncontrollable stressors are typically appraised as more threatening, at least initially, and are frequently associated with negative effects on health and behavior (Baum, Singer, & Baum, 1982; Cohen, 1980; Glass & Singer, 1972)

Yet somewhat paradoxically if a stressor remains uncontrollable and is chronic, it is probably more likely to become an unnoticed, background characteristic due to habituation (Campbell, 1983). Accommodation to stressors impervious to change through instrumental efforts has been noted in research on coping with various interpersonal sources of strain (Kiretz & Moos, 1974). When an aversive situation cannot be modified or eliminated, one has few options available other than some form of denial or reappraisal of the stressor (Folkman & Lazarus, 1980; Pearlin & Schooler, 1978; White, 1974).

Related to controllability is the *predictability* of stressors. Some environmental stressors may be more predictable than others, which can have consequences for both the way they influence our health and the manner in which we may choose to cope with them. For example, habituation to continuous noise (e.g., highway traffic) is probably more readily accomplished than habituation to airport noise, which is intermittent and less predictable.

A sixth dimension is the *necessity and importance* of the source of a stressor. Environmental stressors that are seen as necessary and/or important (e.g., military aircraft vs. pleasure flying) cause different kinds of reactions. Related to importance of source is whether the source of the stressor is *tied to human behavior*. As we shall see, air pollution and heat do not fit the same pattern of stress effects that crowding and noise do. Most citizens view air pollution and heat as either natural phenomena or caused by other societal entities (e.g., industry) rather than caused by the behaviors of individuals. Personal responsibility cannot be easily affixed for pollution and heat. This may have consequences for the way in which these environmental conditions are appraised and coped with.

Finally, the *duration and periodicity* of environmental stressors are important characteristics of stimuli. Duration has two dimensions—the extent of previous personal history with the stressor and the length of current exposure to the condition. The term *periodicity* refers to the regularity or predictability of the stressor as well as its continuity. Some stressors are more discrete (e.g., stressful life event), whereas others are more continuous (e.g., air pollution). Adaptation processes may be strongly affected by both duration and periodicity.

15.3.3. General Theoretical Perspectives on Stress

One way of viewing research in environmental stress is to classify work as falling within one of two research traditions: the physiological tradition or the psychological tradition. These theoretical paradigms are not necessarily contradictory, but rather focus on somewhat different dimensions of the stress process. In order to provide an overview of theoretical approaches to environmental stress, we will describe these broader traditional approaches first, and then we will discuss several less encompassing models that elaborate on the linkages between environmental stressors and a range of very specific outcomes.

Physiological Perspective

Two of the pioneer researchers on stress, Walter Cannon and Hans Selye, developed physiological models of stress that centered on the sympathetic nervous system and the pituitary–adrenocortical axis, respectively. Each of these models emphasized the physiological responses of the body to noxious stimuli. In addition, each model concentrated on homeostatic processes wherein the body responds to aversive conditions that disrupt some internal equilibrium. Responses to these aversive agents, termed *stressors*, are focused on reequilibration to achieve homeostatic balance.

Sympathetic Nervous System

Cannon (1932) argued that the body has an autonomic, emergency response system allowing the organism to fight or flee from any serious, aversive, or challenging situation. Stress is a direct strain on the homeostatic mechanisms of the body. Homeostasis reflects the necessity of maintaining the internal composition of the body within some limits despite the fluctuations of the external environment. The sympathetic nervous system acts directly on the adrenal medulla to secrete catecholamines including epinephrine. These substances in turn heighten response readiness for dealing with the emergency at hand. This response readiness includes increased metabolism of carbohydrates to produce more glucose and the release of fatty acids for greater energy, higher heart rate and oxygen consumption, and constriction of blood flow to peripheral areas of the body with greater blood supply to the skeletal muscles, kidneys, and brain. While the adaptive value of this array of physiological readiness for response to aversive circumstances is evident, Cannon was also mindful of some of the potential deleterious consequences of this emergency response syndrome. In particular Cannon was concerned about continual triggering of the response syndrome as well as what happens if this physiological readiness is activated but the individual is unable to "fight" or "take flight." If some somatic discharge is unavailable because of physical or social restraints, are there damaging consequences due to continual activation of this body mobilization system?

Many scholars since Cannon have raised the interesting dilemma of whether the stress and strain of modern, urbanized civilization are particularly harmful because of their distinctiveness from the type of environmental settings under which we evolved as a species (Boyden, 1970; Dubos, 1965; Esser, 1974; Kaplan & Kaplan, 1982). Social norms, complexity of organizational roles, and physical construction of the settings where we work and live have dramatically altered the quality of the environmental sources of stimulation and demands that modern human beings must cope with in comparison to the types of stimulation and stressors that challenged our forebears.

While the importance of modernization on stress and health is difficult to assess, we do know that chronically increased levels of circulating catecholamines have direct links to cardiovascular diseases causing fibrin formation in arterial walls, platelet aggregation, hemodynamic effects like increased blood pressure, ventricular arrhythmia, and uptake in oxygen requirements of the heart (Krantz & Manuck, 1984; Steptoe, 1981)

Pituitary–Adrenal Axis

A complementary, physiological model of stress has been developed by Selye (1956, 1975). According to Selye, various psychological and physiological insults elicit both specific effects and nonspecific physiological reactions. These nonspecific effects, which Selye called the general adaptation syndrome, include three stages: alarm, resistance, and exhaustion. During the alarm phase, the pituitary gland secretes various chemicals, including ACTH, which stimulates the adrenal cortex to produce various substances including a group of anti-inflammatory hormones called corticosteroids. In the resistance phase of the general adaptation syndrome, increase in these steroids sets up a feedback loop stimulating adrenal medulla activity and subsequent release of catecholamines. Exhaustion, the third phase of the syndrome, occurs if the stressor is sufficiently severe or prolonged to deplete somatic defenses. During exhaustion, the adrenal glands are unresponsive to environmental demands, with various susceptible organs suffering breakdown or damage.

Three specific implications of the physiological stress model need to be emphasized:

1. Various environmental pathogens and social–psychological strains will cause nonspecific responses characterized by the nonspecific, tripartite response syndrome, the general adaptation syndrome. This in turn implies that stress may be additive. Responses to a specific stressor will be influenced by both the severity of the specific event and the severity and recency of other threatening events (Fleming, Baum, & Singer, 1984).
2. Some costs or pathological effects can occur from the adaptation processes themselves. In addition to the effects of catecholamines on the cardiovascular system, there is emerging evidence for enhanced susceptibility to infectious diseases due to interference with the immune system by corticosteroids (Ader, 1981; Jemmott & Locke, 1984; Krantz, Grunberg, & Baum, 1985; Moss, 1973).
3. The body has a finite amount of adaptive energy. When this capacity has been exceeded, deleterious effects occur (Cohen,

Evans, Stokols, & Krantz, 1986; Glass & Singer, 1972)

One of the most problematic aspects of Selye's model of stress has been understanding the mechanism(s) that triggers the general adaptation syndrome. There is some evidence that the initial stimulation of the pituitary is from the hypothalamus, but how it becomes directly involved is less clear. Related to this issue is recent evidence that the pituitary–adrenal sequence is triggered only when the person perceives threat or psychological harm (Mason, 1975; Mason et al., 1976). Whether cognitive appraisal of threat or harm is necessary to precipitate a stress response is a point of major controversy both in the stress literature itself (cf. Mason, 1975; Selye, 1975) and in research on emotion more generally (cf. Lazarus, 1984; Zajonc, 1984).

Mason and others have also challenged claims that the stress response syndrome is largely nonspecific. Mason's work suggests that particular types of stressors cause unique patterns of physiological responses in terms of both the types and the amounts of different psychendocrine responses (Mason, 1975; Mason et al., 1976). There is also increasing evidence that the kinds of coping processes engaged in can also influence physiological responses to stress. Efforts to maintain optimum task performance during stress cause a physiological profile distinct from stressor exposure where little or no coping efforts are made to maintain performance (Frankenhaeuser, 1980; Lundberg, 1978; Manuck, Harvey, Lechleiter, & Neal, 1978; Obrist et al., 1978). Lacey's research indicates as well that the kinds of cognitive tasks one is engaged in during stressor exposure can influence physiological outcomes (Lacey, 1967).

Psychological Perspective

Psychological stress focuses on the individual's interpretation of the meaning of environmental events plus an appraisal of personal coping resources (Lazarus, 1966). *Primary appraisal* is the term used to describe the process of evaluation of the stressor. Stressors are evaluated for potential threat–anticipated harm, harm/loss–damage that has already occurred, or challenge–threat that can be dealt with.

Primary appraisal of stressors depends on personal and situational variables. Personal factors influencing primary appraisal include general beliefs about self-efficacy or mastery, the centrality of goals/needs threatened by the stressor, and various dispositional factors. Situational variables that may influence primary appraisal include the imminence of harm, the magnitude of the stressor, the ambiguity of the stressor, the duration of the stressor, and the potential controllability of the stressor.

If the individual makes an appraisal of threat, harm, or challenge, then secondary appraisal processes come into play. During these processes, one evaluates his or her coping resources to deal with the stressor. Coping processes can generally be partitioned into problem-focusing coping or emotion-focused coping. Problem-focused coping strategies involve changes in the situation to reduce aversive impact whereas emotion-focused coping strategies alter individual responses to the negative situation. Either of these coping styles can assume various forms such as information seeking, direct action, or palliative activity (see Lazarus, 1966; Lazarus & Launier, 1978, for more details).

In terms of the psychological perspective, stress occurs when a situation has been appraised as demanding with the potential of exceeding coping resources. Three important implications of the psychological stress perspective are:

1. The individual's perception of environmental demands and personal coping resources is the critical variable in determining the nature of the stress response. The objective conditions of the environment are important only to the extent that they influence these processes of primary and secondary appraisal.
2. Stressful situations are not uniformly aversive. Important personal and social mediators can ameliorate or enhance the effects of stressors. This mediation can occur by influencing either one or both of the appraisal processes. Thus for example perceived control over a stressor may make the stressor seem less threatening (primary appraisal) and/or enable the individual to feel that he or she will have more options available to cope with the stressor (secondary appraisal).
3. Stressors will affect the individual in a host of ways in addition to the physiological impacts emphasized by Cannon and Selye. These impacts will include self-reports of stress and related symptoms (e.g., nervousness, tension, anxiety), negative affect and interpersonal behaviors, and deficits in task performance (for

further discussion and comparison of the psychological and physiological models of stress see Baum, Singer, & Baum, 1982; Cohen et al., 1986; Fleming et al., 1984).

15.3.4. Models of Environmental Stressors

In addition to the traditional models of the stress process described in the previous section, there have been several less encompassing models that significantly influenced environmental stress research. These models primarily derive from the psychological stress tradition, although some influence of the physiological tradition is also found. Each elaborates on the nature of properties of the environment and individual that lead to a stress response, and/or the linkage between environmental stressors and a specific type of outcome. In the following section, we describe five such models: stimulation level, adaptation and coping, control, predictability, and systems models.

Stimulation Levels

The most common explanation of the effects of environmental stressors has been the stimulus or information load model. The stimulus-level hypothesis posits an inverted-*U*-shaped function between physical stimulation levels and human affect, performance, and health. Either too much (overload) or too little stimulation (sensory deprivation) in the environment is said to produce stress. Physical variables related to stimulation load include the intensity of stimulation, the complexity or variety of stimulation, novelty, ambiguity, conflict or inconsistent sources of information, and, finally, instability or change (Berlyne, 1960, 1971; Fiske & Maddi, 1961; Mehrabian & Russell, 1974; Wohlwill, 1974). In addition to single-stimulus properties like complexity or incongruity, patterns of environmental stimulation may influence stimulation levels as experienced by the individual. Patterns of stimulation as influenced by multiple features that are repetitive or express some underlying theme or symbolic meaning may contribute to an overall sense of coherence and thus reduce information levels (Kaplan & Kaplan, 1982; Lynch, 1960). Scott and Howard (1970) have emphasized that not only do physical factors influence the characteristic activity levels of people, but sociocultural variables (e.g., multiple roles, work demands) can also produce stimulation overload.

Crowding and noise can readily be incorporated into the stimulation load models since each stressor increases the amount of physical stimulation in an ambient environment (Hall, 1966; Kaminoff & Proshansky, 1982; Saegert, 1976; Wohlwill, 1974). Two principal mechanisms, arousal and information overload, have been suggested as the underlying mechanisms of the inverted-*U*-shaped function between crowding or noise with human responses.

Arousal is a behavioral continuum ranging from sleep to high excitement that has a physiological basis in the reticular activating system of the brain. Persons usually perform optimally under and prefer moderate levels of alertness. Low arousal levels render one sluggish and inattentive whereas too much arousal makes it difficult to concentrate and control one's activities well. Evidence of increases in arousal include elevated catecholamines, skin conductance, and blood pressure, as well as self-reports of restlessness, nervousness, tension, and anxiety. Furthermore, observational indices of overarousal consist of more frequent automanipulative behaviors and behavioral sterotypies (Evans, 1978b).

One of the more complicated and interesting links between stimulus levels and environmental stressors has been in the area of task performance. Considerable research indicates that human performance under higher stress levels produces a particular pattern of deficits. Little or no effects of short-term stressors are noted for simple tasks but decrements are apparent on complex performance tasks (Broadbent, 1971; Hockey, 1979; Kahneman, 1973; Keele, 1973). Although the effects of underarousal on task performance can readily be explained, why too much arousal is debilitating, particularly for more complex tasks, has been the center of considerable discussion. One position holds that under stress overarousal produces a narrowing of attention to more dominant or central task cues. Since complex tasks have greater numbers of cues per unit time that must be attended to (e.g., multiple-signal tasks, rapid frequency signal), this narrowing of attention causes errors because some relevant cues are missed. Simple tasks on the other hand have fewer task-relevant cues per unit of time and thus are less affected by attention narrowing (Easterbrook, 1959; Hockey, 1979; Kahneman, 1973). Some tasks, like the Stroop effect (e.g., word *red* written in green ink), may actually be improved under stress because of attention narrowing and the subsequent enhanced filtering of task-irrelevant distraction cues (see Cohen, 1978, Evans, 1978b, for more details on the meaning of task complexity).

Alternatively, stimulus overload may be understood in terms of demands on information-processing capacity. The demands to monitor a stressor, particularly if unpredictable and uncontrollable, plus the cognitive demands of a task itself may exceed the limits of an individual's information-processing capacity. Capacity will be exceeded more easily when performance demands are high, that is, for more complex tasks (Cohen, 1978). Furthermore, when there are prolonged, extremely high demands from a stressor and/or a difficult task, information-processing capacity may shrink because of fatigue. When overload does occur, available resources will be directed toward the most relevant aspects of the task. Simmel (1950) and Milgram (1970) in their analyses of urban residents' adaptations to the high stimulation of the city setting argued similarly that people deal with overload by either eliminating or filtering low-priority inputs.

Changes in interpersonal behaviors such as altruism during stress can be explained by attention focusing from hyperarousal or overload demands on cognitive capacity. Several studies reveal that persons under stress from noise, for example, do not perceive subtle social cues for distress (e.g., an arm cast, Matthews & Cannon, 1975) or cues in photographs indicating people in need of assistance (e.g., person falling off a bicycle, Cohen & Lezak, 1977). Because of attention focusing under stress, peripheral cues including information about the needs of other persons for help may not be perceived.

Two advantages of the information overload model in comparison to the arousal model of environmental stressors are: (1) The overload model more readily explains why uncontrollable or unpredictable stressors produce greater stress; and (2) the overload model can more readily account for aftereffects of stressors. Stressors that are uncontrollable or unpredictable are more difficult to monitor and thus place greater demands on information capacity. An important distinction should be made between ambient stimulus levels and information; while the latter demands some cognitive response from the receiver, the former does not (Saegert, 1973, 1978, 1981; Suedfeld, 1979, 1980; Wohlwill, 1974). Saegert notes for example that crowding is aversive not so much because of heightened stimulus intensity and variety but rather because of high information loads produced by involuntary and unpredictable social interaction. The relative salience of social and physical, nonsocial cues is an important, largely unresearched question. Aftereffects are a residue of cognitive fatigue, reflecting some of the costs of trying to operate at or above maximum cognitive capacity.

An advantage of the arousal-based models of environmental stressors is that they more readily explain the physiological changes accompanying reactions to environmental stressors. Arousal models also explain more straightforwardly how combinations of some stressors (e.g., noise plus sleep deprivation) cancel out one another's aversive effects in comparison to exposure to either stressor alone (Broadbent, 1971; see McGrath, 1970b, Moss, 1973, Wohlwill, 1974, for more discussion of these two models of environmental stressors).

Adaptation and Coping

Another perspective that has proven useful for understanding environmental stressors is provided through models of adaptation and coping. These models of environmental stress emphasize psychological aspects of human adaptive capabilities. Human beings have a broad and flexible repertoire of coping resources that allows them to maintain equilibrium or near equilibrium in the face of a broad array of environmental conditions. People are able to withstand, at least for short periods of time, substantial environmental demands. Of particular interest to the adaptation and coping perspective on environmental stress is the question: Are there costs associated with human adaptation to environmental demands? This question can be addressed on at least two levels. For the human species in general, we can wonder what the long-term costs are of accommodating to physical surroundings that are drastically different from the types of environments that human beings first evolved in (Boyden, 1970; Dubos, 1965; Iltis, Loucks, & Andrews, 1970; Kaplan & Kaplan, 1982).

Adaptation-level theory may be a psychological expression of these concerns at the individual level. According to adaptation-level theory, human standards of judgment to dimensions of physical stimuli (e.g., brightness) change in proportion to both current and previous, chronic experiences with that dimension. Specifically, adaptation-level theory predicts that either immediate or previous exposure to a high intensity of some dimension will cause a habituation process wherein current judgments of the intensity of that dimension will be lowered relative to judgments by others without exposure to that dimension (Helson, 1964; Wohlwill, 1974). In applying this perspective to air pollution, for example, Wohlwill and Kohn (1976) and Evans, Jacobs, and Frager (1982)

have shown that individuals who have resided in areas of the United States with poor visual air quality (e.g., smog) habituate to poorer visibility. However, one's history of environmental demands is probably not the key to understanding how an individual will react to such demands. Instead individual experiences in developing and utilizing coping resources to meet environmental challenges are most likely the crucial factors in predicting how one will respond to a current stressful context (Moss, 1973). The adaptation-level perspective is particularly valuable in focusing our attention on some of the potentially positive effects of dealing with stressors. It is unfortunate that nearly all stress research has focused on the negative consequences of coping with adaptive demands of environmental challenges.

Dubos and others have also raised the interesting issue of how the increasing power of human beings to alter the environment to fit human needs is creating settings that are less diverse and challenging than prehistoric environments (see also Parr, 1966). The selective advantage of the ability to adapt to a variety of ecological niches may slowly become less salient in human evolution. The adaptive advantage of adaptability may no longer be as powerful. The long-term implications of this trend are potentially important, especially given the increasingly poor conditions of the global ecosphere.

Looking at the issue of adaptation at a more individual level, Glass and Singer (1972) and Cohen (1978, 1980) have suggested that a cumulative cost of adapting to stress may be cognitive fatigue. Coping with stressors, particularly uncontrollable ones, requires effort. Negative aftereffects in frustration tolerance or cognitive performance following exposure to crowding, noise, or air pollution are examples of the cumulative effects of effort expended to cope with environmental stressors. Cumulative fatigue may also reduce the capacity to cope with subsequent environmental demands. Frankenhauser and Lundberg (1977) found that immediately prior exposure to loud noise produced poorer performance during a second noise session. Subjects had worked on the same task (mental arithmetic) in an initial session under one of three levels of uncontrollable, continuous white noise. In session two, subjects were all exposed to the same level of moderate noise. Evans, Jacobs, Dooley, and Catalano (in press), looking at a chronic stressor, found that individuals in the greater Los Angeles area who had recently experienced one or more stressful life events suffered psychological symptoms from exposure to higher smog levels. Levels of smog had no main effects on individuals' psychological symptoms.

Another result of coping with stressors may be overgeneralization, where a strategy that has been adopted to cope with a stressor becomes a characteristic operating mode for the individual even when the stressor is no longer present. Milgram (1970), for instance, argued that urban residents become characteristically different than rural people because of adaptations urbanites make to cope with the high level of information associated with city living. People's coping processes of blocking or filtering low-priority information are said to generalize and become part of one's urban personality, as manifested, for example, by the alleged defensive and brusque urban character as well as inattentiveness to those in need of assistance (e.g., the bums and beggars working the streets, crime victims). This view of urban character development as an overgeneralized manifestation of coping with overload has not gone unchallenged, however (cf. Fischer, 1976; Korte, 1978).

A more specific example of overgeneralization to environmental stress that has been empirically validated is tuning out noise. Evidence from several studies (Cohen, Evans, Krantz, & Stokols, 1980) shows that one way individuals learn to cope with noisy settings is to tune out auditory stimuli. Unfortunately, however, this tuning-out process becomes indiscriminate and includes both speech-irrelevant and speech-relevant sounds. As a consequence persons with normal auditory thresholds tested under quiet conditions who have resided in noisy areas develop poorer auditory discrimination abilities. Decrements in measures of auditory discrimination ability from chronic noise exposure have included the perception of similar-sounding words or subjects' ability to distinguish optimum auditory-signal-to-noise ratios. Poorer auditory discrimination in turn has been associated with difficulties in the acquisition of reading skills (Cohen, 1980; Cohen & Weinstein, 1982). Other evidence for tuning out includes data indicating that children from noisier residential settings are less susceptible to auditory distractors while performing tasks (Cohen et al., 1980; Cohen, Evans, Krantz, Stokols, & Kelly, 1981; Heft, 1979). Overgeneralization of responses to crowding has also been documented, with prior experiences of crowding causing greater social withdrawal from strangers in uncrowded, interactive laboratory tasks (cf. Baum & Paulus, Chapter 14, this volume; Epstein & Karlin, 1975).

Finally, coping responses themselves may have direct physiological effects. Smoking or drug consumption may function to relieve stress, but each has clear health costs of its own. When effort is expended to maintain task performance during stress or to assert control over an aversive event (e.g., reactance), cardiovascular activity greatly increases. Furthermore, if control efforts do not yield direct, relevant feedback to the organism about the efficacy of the coping attempts, even more physiological activity results. Moreover, if these activities are prolonged, they can lead to ulcers and other evidence of direct damage (see Cohen et al., 1986, for more details). Chronic adaptive efforts may lead to disease, either directly, as in the case of greater cardiovascular activity, or more indirectly, as by reduced immunological defenses to infectious diseases. More research is sorely needed both on the precise mechanisms of these two general types of stress–disease links and on the physical, social, and psychological characteristics of situations that are more or less likely to support coping activities that are successful (Cohen et al., 1986).

Control

There is considerable evidence that human beings have a strong need for environmental mastery and a sense of self-efficacy (Averill, 1973; White, 1959). Negative consequences associated with lack of control include negative affect, cognitive deficits, and reduced motivation to behave instrumentally when the option is available (Seligman, 1975). Actual or perceived control over a stressor generally leads to fewer negative consequences than exposure to stressors that are uncontrollable (Averill, 1973). This is particularly true if the individual believes that control has the potential to modify his or her experience of the stressor.

Research consistently shows that environmental stressors that are uncontrollable or unpredictable cause greater stress in human beings. Studies on crowding (Baum & Paulus, Chapter 14, this volume; Epstein, 1982), noise (Cohen & Weinstein, 1982), air pollution (Evans & Jacobs, 1982), and heat (Bell & Greene, 1982) have found complete or partial amelioration of many negative impacts of exposures to these environmental stressors with the provision of instrumental control over the stressor. Thus control may function as a powerful situational mediator of the stress process.

Furthermore, research on crowding suggests that, when control is further restricted, for example, by blocking of goals or interfering with physical movement, greater negative outcomes occur. This has led some researchers to suggest that crowding is aversive precisely because it reduces freedom by constraining certain behavioral options (Proshansky, Ittelson, & Rivlin, 1970; Stokols, 1972). Moreover, crowding, noise, and other stressors are viewed as especially aversive when they occur in residential settings or other places where people expect to have reasonable control over the conditions of their surroundings (Stokols, 1976). In addition, people rate settings as more crowded when they attribute behavioral constraints to the close presence of other people or to insufficient space (Baron & Rodin, 1978; Schmidt & Keating, 1979).

Chronic exposure to environmental stressors that are uncontrollable may also produce greater susceptibility to learned helplessness. If one cannot predict or assert control over an environmental source of stress, one may learn that he or she has little ability to influence environmental outcomes by his or her own behaviors. Thus if coping efforts fail to modify an environmental source of stress it is possible that an individual may experience some helplessness. Several recent studies provide suggestive evidence that persons who reside in crowded or noisy settings may be more susceptible to learned helplessness. Rodin (1976), for example, found that children from more crowded residences suffered helplessness more frequently in a laboratory experiment where they were confronted with a series of failure experiences. Saegert (1981), however, did not find any effects of residential density on learned helplessness among children. Baum and his colleagues (Baum & Paulus, Chapter 14, this volume) have found greater withdrawal and giving up in competitive game situations by college students who live in dormitories that are perceived as more crowded and with greater unwanted social interactions. Finally, Cohen and his colleagues (Cohen et al., 1980; Cohen et al., 1981; Cohen et al., 1986) have found children who attend noisy schools giving up more often on challenging puzzles than quiet school counterparts. Rodin (1976) and Cohen et al. (1986) have also found evidence that children chronically exposed to environmental stressors more readily abrogate choice over positive reinforcements or opportunities to experimenters.

Data on aftereffects from noise, crowding, and air pollution suggest some evidence of helplessness as well. Persons previously exposed to uncontrollable sources of environmental stress often are less persistent on cognitive tasks that require frustration tolerance (Cohen, 1980). Furthermore, these negative

aftereffects are essentially eliminated by providing perceived control over the stressor during the administration period. Sherrod (1974), for example, found that the negative aftereffects from exposure to high density in a laboratory setting were virtually eliminated by informing crowded subjects that they could leave the room if they needed to.

Recent revision of learned helplessness theory suggests that learned helplessness in human beings is a more complex phenomenon than first developed with animal operant-learning paradigms. In particular, the attributions individuals make about the causes of their inability to control a stressor bear directly on whether or not helplessness is likely to occur or generalize to other situations (cf. Abramson, Garber, & Seligman, 1980). Furthermore, under some circumstances (e.g., important goal blocked) lack of control, at least temporarily, may lead to reactance and greater efforts to establish mastery. Recently Baum and his colleagues have applied the revised model of human helplessness to students' reactions to living in crowded college dormitories. They find, for example, that changes over the first semester in attributions about the causes of unwanted social interactions in the residential living environment accompany shifts in susceptibility to learned helplessness in game-playing situations conducted in the laboratory (see Baum & Paulus, Chapter 14, this volume, for more details).

Another effect of coping with chronic exposure to aversive, uncontrollable stressors may be a shift in coping strategies from problem-focused to emotion-focused coping. Reappraisal of threat may occur, for example, whereupon an aversive condition (e.g., smog) that was initially critically viewed becomes reappraised as a minor problem or threat. Denial of harmful effects or other rationalizations may also occur as continual experience with an uncontrollable ambient stressor occurs (Campbell, 1983).

Evans and colleagues (1982), for example, compared two groups of persons who had recently migrated to a residential location with high levels of smog. One group had little or no previous residential experience with air pollution, whereas the other had chronically been exposed to poor air quality. The newly exposed group were much more likely to rate smog as a serious community problem, sought out information about smog, complained about it, and believed more strongly that smog could be reduced if people would use mass transportation. Furthermore, recent migrants who were more internal in locus of control, in comparison to recent migrants more external in locus of control and in comparison to all residents with previous exposure to poor air quality, reduced outdoor activities during smog episodes. Persons with a previous residential history of smog exposure, however, showed few if any of these behaviors, instead engaging in more emotion-focused coping. For example, persons chronically exposed to smog were less aware of visual air pollution in photographic scenes, exaggerated their own relative imperviousness to negative health effects from air pollution, and overestimated the extent of their own personal knowledge about the causes and effects of smog.

In sum, there is considerable evidence that chronic exposure to environmental stressors can cause negative reactions because of restrictions in individual control. Furthermore, provision of actual or perceived control over stressors frequently ameliorates or at least partially reduces the negative effects of environmental stressors on human health and behavior. Nevertheless, there is an emerging body of literature suggesting that control over stressors is not uniformly positive (cf. Folkman, 1984). An interesting area of further work in environmental stress research is the examination of situational characteristics that can influence the efficacy of control over stressors. More research is also needed to understand the interrelationships among variable environmental opportunities to exercise control over stressors and psychological appraisal processes of control.

Predictability

A number of scholars have noted the tendency of environmental stressors like noise to disrupt or interfere with ongoing behaviors. Unpredictable stressors are more distracting and make concentration on tasks more difficult. Poulton (1977, 1978) has emphasized that distraction is the principal mechanism of task decrements noted in noise (see Broadbent, 1978, for an alternative view). Distraction has physiological consequences as well, related to the orienting reflex, which triggers a state of mental alertness and vigilance (Berlyne, 1960). Predictability is also related to patterns of environmental stimulation. Settings that are unfamiliar or highly ambiguous or difficult to interpret may be stressful. When one cannot discern the meaning or function of an object or a setting, confusion as well as stress may occur (Archea, 1978; Gibson, 1979).

Predictability has also been linked to control and stress. Aversive events that are unpredictable are more difficult to control and prepare for. Mechanic's (1962, 1978) work has emphasized the role of prepa-

ration inadequacy as a cause of stress. A person's ability to master difficult situations is often highly dependent on individual preparation for problem solving. Unpredictable stressors may also be more aversive because individuals are left without any cues indicating when the aversive event is not present; that is, one cannot estimate when it is safe (Seligman, 1975). When confronted with an aversive stimulus condition that is predictable, one can at least relax momentarily and thus achieve some recovery during safe periods.

Prediction also relates to the concept of interruption. Changes in response sequences that have previously been organized produce stress. This stress is caused by the blocking of actions that were judged by the initiator of the response sequence as most appropriate for that situation (Mandler, 1975). People plan many activities before executing them. Activities are mentally rehearsed, alternatives are assessed, and reasonably fixed decisions are made prior to engaging in behavioral sequences (Hebb, 1972; Miller, Galanter, & Pribram, 1960). With interruption come cognitive disorganization and accompanying emotional arousal, followed closely by attempts to persevere in the originally planned response sequence. Physiological data indicate strong arousal activation by incongruity between novel experiences and personal memories and expectancies, which Pribram has termed *neural plans* (Pribram & McGuinness, 1975).

Systems Models

The psychological perspective on stress, as discussed earlier, emphasizes the dynamic balance between environmental demands and the organism's ability to cope with those demands. Congruence or the extent of fit between person and environment has been used to explain stress. Stress occurs when environmental opportunities are insufficient in affording important personal or group needs and goals. Stress is an outcome of incongruence between person and environment (Caplan, 1982; Michelson, 1970; Stokols, 1979).

This approach to environmental stress has been applied primarily to human spatial behavior by several authors. Argyle and Dean (1965) as well as Patterson (1976) state that the regulation of interpersonal intimacy is the underlying dynamic that explains most proxemic behavior. Thus persons tolerate closer interpersonal distance without eye contact or accompanied by more defensive body postures because of the compensatory relationships among these different nonverbal behaviors in maintaining interpersonal intimacy. Analogously, individual needs for privacy may help regulate proxemic behaviors. Crowding can be viewed as a state of the person when achieved privacy levels are less than desired privacy levels. Personal space and other spatially related behaviors can be understood in part as boundary control mechanisms that help maintain or modify desired levels of privacy. When perceived and achieved privacy levels match, congruence is achieved and satisfaction results (Altman, 1975). When a discrepancy occurs between desired and achieved privacy, tension to reequilibrate the system occurs. If this tension cannot be resolved, stress results.

Ecological models of spatial behavior also adopt a systems view by emphasizing the relationship between the number of people in a setting and the number of roles needed adequately to maintain that setting. When overstaffing occurs, crowding results because of less personal involvement and feelings of not being needed by the organization. These feelings in turn cause alienations, negative affect, and possibly more negative interpersonal interactions (Wicker, 1979, Chapter 16, this volume).

It is interesting to note that, while the various models of congruence and stress are essentially psychological theories of stress, they rely on a key component of the original psychologically based models of stress. The body has a natural tendency to maintain homeostasis, and stress is seen as a response to environmental conditions that create strong pressures to disequilibrate the system.

Zimring (1982) has applied the concept of misfit or incongruence as a source of stress to poorly designed and planned architectural settings. He suggests that design features can produce stress by interfering with the achievement of personal goals in designed environments or by limiting coping strategies available to reduce incongruence. Certain psychosocial needs may be facilitated by environments that provide spatial hierarchies ranging from opportunities for public social interaction (e.g., social contact and networking) to very private spaces (e.g., solitude, intimacy). Environments that do not provide ready access to spatial hierarchies may interfere with variable personal needs for social interaction. Stress may result from these unmet needs.

Another systems perspective on stress has been described by Magnusson (1982, 1984). Stress reactions are considered a joint function of individual vulnerability that can be psychological or somatic and the extent of environmental demands. In an important series of studies, Magnusson has shown that in-

dividual differences in reaction to stressors cannot be adequately explained without careful specification of the situation in which the individuals are stressed. Consistent gender, age, and cultural differences, for example, have been found in situation-specific contexts. When the situation is similar, good stability in rank order of individual behavioral and physiological reactions to various stressors is demonstrated. Over discontinuous situations, however, marked shifts in relative individual standings in degree of stress reactivity are noted.

15.3.5. Effects of Stressors

In this subsection we briefly review the range of stressor effects noted in previous studies. This overview of stressor impacts will provide a template for us to match the influences of various environmental stressors. This is one way in which we will be able to evaluate the utility of the stress paradigm for understanding how various components of the environment affect human health and well-being. Five specific areas of stressor impacts have been identified.

Physiological Effects

As suggested by both physiological models of stress, various endocrinological responses have been used to measure stress in human beings. There is a good deal of evidence that a wide variety of aversive stimuli cause increased catecholamine and corticosteroid output that is detectable either in blood or in urine (Baum, Grunberg, & Singer, 1982; Frankenhauser, 1971; Mason, 1968). These circulating hormones, epinephrine in particular, produce secondary changes in various target organs related to activation of sympathetic arousal. Thus numerous investigations of a wide array of noxious stimuli have recorded psychophysiological indices of stress including increased blood pressure, skin conductance, respiration rates, muscle tension, and cardiac output (e.g., heart rate) (Baum, Grunberg, & Singer, 1982; Lazarus, 1966; McGrath, 1970b). Heart rate measurement, however, has proven to be more problematic because of the influences of cognitive activity on heart function (Jennings, in press; Lacey, 1967). For example, tasks that require attention to external information sources cause cardiac deacceleration, thus offsetting the effects of sympathetic arousal.

Task Performance

The influence of stressors on human task performance continues to be extremely difficult to characterize. The reason for this is probably that, at least for short periods of time, most people can effectively overcome the aversive effects of a stressor by coping devices such as increased effort or concentration. Nevertheless, there are certain patterns of task deficits that occur under stress. Stressors interfere with tasks that require rapid detection, sustained attention, or attention to multiple sources of input. Rapid-detection tasks typically require individuals to respond to information appearing at a very rapid rate. A serial reaction time task, for example, requires subjects to respond as rapidly as possible to a signal. As soon as a response is made, another signal appears and the sequence repeats. Sustained attention to uncertain, low-frequency signals is also interfered with by stressors. Vigilance tasks, for example, require persons to detect the presence of infrequent target signals. Stress may also interfere with multiple-cue tasks where more than one target cue must be attended to. In this procedure the subject must monitor two different signals. It is of particular interest that stressors interfere only with the secondary signal and usually do not affect the primary signal. *Primary* and *secondary* refer to the relative importance of the two signals as specified to the subject by the experimenter.

Two principal memory deficits have also been noted under stressors. Memory for incidental or secondary information in a task is poorer under stressor conditions. An example of an incidental memory measure would be to ask a person to recall the style of typeface words were printed in. Stressors also cause faster processing of information in working memory but apparently at the expense of total capacity. Working memory is defined as a temporary storage where operations are carried out prior to storage in long-term memory (Hockey, 1979). The memory span in working memory may be shorter under stress. There is also evidence of poorer comprehension of complex information such as context or thematic structure that is believed to occur because of reduced working memory capacity (Broadbent, 1971; Cohen et al., 1986; Hockey, 1979).

Affect and Interpersonal Behavior

Both self-reports of affect and interpersonal behaviors like aggression are influenced by stressors. Many studies have demonstrated greater anxiety, tension, and nervousness plus greater ratings of stress under aversive conditions (Lazarus, 1966; McGrath, 1970a). As noted by Baum and colleagues (Baum, Singer, & Baum, 1982), self-reports of stress can generally be classified into reports of experiences believed to be associated with stress (e.g., stressful life events), the emotional or somatic ex-

pression of symptoms (e.g., anxiety, tension), or ratings of the aversiveness of the stressor itself (e.g., stress, threat, harm). Two important issues need to be considered with respect to self-reports of stress. First, to what extent can individuals validly report the degree of stress they are experiencing? Second, according to the psychological perspective on stress, perceived stress rather than some objective indicator (e.g., temperature) should be the driving force behind response outcomes to an aversive situation.

Some research has found more negative social interpersonal behavior under stress, including less altruism and cooperation and greater competitiveness, hostility, and aggression. Aggressive behaviors are typically elicited in game situations or mock learning experiments where participants believe they are delivering punishment (e.g., shocks) to fellow subjects. Furthermore, these behaviors are more pronounced when subjects have been previously angered or exposed to aggressive modeling behaviors (Cohen & Spacapan, 1984; Rule & Nesdale, 1976). There is some evidence that hostility and aggression have a curvilinear, inverted-*U*-shaped relationship to stress. The reason for this is believed to be that under extreme stress (e.g., very high temperature) individuals become so debilitated that their primary motivation becomes escape or avoidance of the noxious conditions (Baron, 1978). Helping behavior has also been directly measured by observing persons' reactions to a person in distress or by monitoring cooperation to requests for aid. In general, helping is found to decrease under stress (Cohen, 1980; Evans, 1982).

Another aspect of interpersonal behavior influenced by stress is decision making. Studies suggest that stress causes premature closure wherein decisions are made before all pertinent data have been considered (Janis, 1982; Janis & Mann, 1977). Related deficits in decision making under stress include fixation on one or two dominant aspects of a task with little regard for other components. Stereotyped thinking also may result in oversimplified classification and decision categories. Reversion to dominant, traditional thinking patterns is common under stress. Novel information or tasks requiring different approaches are more apt to be redefined in terms of preexisting schemata (Holsti, 1978; Staw, Sandelands, & Dutton, 1981).

Observation

Both verbal and nonverbal categories of stress measurement have been developed. Verbal indicators include speech faults (e.g., repetition, sentence change, tongue slips), filled pauses (e.g., *ah*, *um*), accelerated rate under certain conditions, and increased pitch. Words or phrases that reveal tension or anxiety about the problem at hand (e.g., *hopeless*, *worried*) may also occur (Siegman, 1982; Spence, 1982). Nonverbal indicators of stress include more defensive body posturing (e.g., leaning away, crossing arm/leg), reduced eye contact or facial regard, greater automanipulative behaviors (e.g., itching, touching hair, fidgeting with clothes), and stereotyped object play (e.g., tapping pencil, manipulating small objects such as beads) (Ekman & Friesen, 1974; Hutt & Hutt, 1970; McGrath, 1970a; Webb, Campbell, Schwartz, Sechrest, & Grove, 1981).

Adaptation

If people are able to adapt to stressors through various coping mechanisms, cumulative costs associated with the adaptive processes may manifest themselves after stressor exposure. While these adaptive behaviors may reduce the immediate stress response in the form of habituation, the process itself may take its toll. These negative aftereffects of coping may include less ability to cope with subsequent stressors, lower motivation, socioemotional adjustment problems, and greater susceptibility to infectious diseases (Cohen, 1980; Dubos, 1965; Glass & Singer, 1972).

There are three general clusters of adaptive effects. The first group of effects is habituation or decrements in response sensitivity with repeated exposure to a stressor (Glass & Singer, 1972; Wilkinson, 1969). Another aspect of habituation is characterized by adaptation-level theory (Helson, 1964; Wohlwill, 1974). According to adaptation-level theory, judgments of stressor intensity are a function of both immediate background conditions and chronic history with the stressor. Adaptation level is an acquired reference point or baseline one uses to make comparative judgments. Previous experience or current background conditions of loud noise, for example, will raise one's comparison level for evaluating a specific noisy stimulus. Persons with little previous noise experience and/or low-noise background conditions would judge a given loudness as noisier than persons previously experiencing loud noise and/or under current noisy background conditions.

Adaptation effects in the second group are related to the cumulative or residual costs of coping with stressors. Cohen (1980) has identified several types of aftereffects following exposure to acute stressors, including decrements in tasks requiring moderate or high motivation, decreased altruism and sensitivity to the needs of others, increased aggression, and increased susceptibility to learned helplessness. Another type of residual coping behavior is over-

generalized coping responses. An example of overgeneralization is learning to cope with loud noise by tuning or filtering out auditory stimulation. Evidence indicates that tuning out becomes a routine part of the cognitive repertoire of persons chronically exposed to noise even when they are in quiet conditions (cf. Cohen et al., 1980).

The final group of aftereffects from chronic exposure to stressors includes physiological and psychological disorders. Immediately following exposure to acute, uncontrollable noise, catecholamine levels drop (Frankenhauser & Lundberg, 1974; Lundberg, 1978). Similar patterns have been identified after helplessness induction using inescapable electric shock (Seligman, 1975). Furthermore, as suggested by Selye and Dubos, when adaptive resources are continually summoned over long time periods, some deleterious health effects are likely to occur. Three general types of physiological effects associated with coping with chronic stressors are cardiovascular disorders, gastrointestinal problems, and lowered immunological resistance to infectious diseases (Dubos, 1965; Elliott & Eisdorfer, 1982; Moss, 1973). It should be noted that, while some progress has been made in identifying the mechanisms of these effects, this area of research is just beginning. Chronic exposure to stressors has also been linked to psychological disorders including symptomatology, case openings, and hospitalization (Dohrenwend & Dohrenwend, 1974; Neufeld, 1982; Rabkin & Struening 1976; Thoits, 1983). A more specific syndrome, posttraumatic stress disorder, has been identified following exposures to extremely stressful, traumatic events. This syndrome is characterized by sleep disturbance, diminished interest in significant activities, feelings of social estrangement, and emotional detachment and numbness (e.g., work on Vietnam combat veterans, Roberts et al., 1982).

Summary

Table 15.1 is a summary of the effects of stressors on human health and functioning. Three points about measures of stress should be reiterated here. These measures generally do not correlate highly with one another. There are large individual differences in both the magnitude and the profile of responses to stressors. Several major factors can moderate reactions to a stressor. We will return to these issues in a later section of this chapter.

15.4. ENVIRONMENTAL STRESSORS

In this section of the chapter we discuss the effects of noise, crowding, heat, and air pollution on human health and behavior. Additional research on crowding as well as information on proxemic variables (personal space, territoriality) can be found in Chapters 12, 13, and 14 of this volume. Following an overview of the effects of environmental stressors, the utility of the stress paradigm for understanding these four environmental problems is examined.

15.4.1. Effects of Environmental Stressors

One of the greatest contributions of applying the stress perspective to environmental problems is the broadened scope of analysis that is provided. This point is perhaps best illustrated by noise research. Until the 1960s, the major focus of noise research was on auditory impacts (cf. Kryter, 1970). Yet we know that there are several very important nonauditory effects of noise. These nonauditory effects are generally understood within the perspective of stress.

Another major contribution of applying the stress perspective to environmental problems has been to sensitize biological and physical scientists to the importance of moderating factors. There is strong impetus within the fields of medicine, public health, and engineering to document dose–response curves for environment–health relationships. The concept of psychological stress provides an alternative framework that highlights the importance of individual differences in response sensitivity.

In this part of the chapter we review the stress effects of noise, crowding, heat, and air pollution. Overviews and summaries are provided because of space limitations in this volume plus the availability of several good reviews on these areas (Baum & Epstein, 1978; Baum & Singer, 1982; Baum, Singer, & Valins, 1978; Carson & Driver, 1970; Cohen et al., 1986; Cohen, Glass, & Phillips, 1979; Evans, 1982; Glass & Singer, 1972). An additional purpose of this part of the chapter is to map out what is and what is not known about the stress effects of these four environmental stressors. This will be done by comparing research on each environmental stressor to the array of stress effects outlined in Table 15.1.

Noise

Noise is defined as unwanted sound. Noise is typically characterized by intensity (e.g., dBA), frequency (e.g., pitch), periodicity (continuous or intermittent), and duration (acute or chronic). Other important characteristics include predictability of noise bursts (random or fixed interval) and degree of personal control over noise. Although the importance

Table 15.1. Effects of Stressors

Physiological	Task Performance	Affect and Interpersonal Behavior	Observation	Adaptation
Elevated catecholamines	Deficits in rapid detection	Greater self-report of negative affect	Increased speech faults and filled pauses	Habituation in response sensitivity
Elevated corticosteroids	Deficits in sustained attention	Reduced altruism and other forms of social cooperation	Accelerated speech rate	Negative performance aftereffects
Elevated blood pressure	Deficits in multiple signal tasks[b]	Greater aggression and hostility[c]	Higher vocal pitch	Reduced altruism and interpersonal sensitivity aftereffects
Elevated skin conductance	Deficits in incidental memory	Overly focused and stereotyped decision making	Lexical leakage	Greater susceptibility to learned helplessness
Elevated respiration rate	Increased processing speed in working memory with reduction in capacity		More defensive body postures	Reduced immunological resistance following chronic exposure
Elevated muscle tension			Reduced eye contact	Higher rates of cardiovascular disorders from chronic exposure
Elevated cardiac output[a]			Greater automanipulative behaviors Greater stereotyped object play	Higher rates of psychological symptoms from chronic exposure

[a]Deceleration is possible under some tasks—see text for details
[b]Deficits occur primarily in secondary tasks—see text for details
[c]The relationship between aggression and stress may be curvilinear—see text for details

of these various characteristics of noise has been widely acknowledged, in most research programs noise has been treated simply as high sound levels. Common sources of noise include occupational exposures, transportation sources, and activities of nearby residences.

There is strong evidence that loud (usually > 90 dBA), unpredictable noise exposure increases catecholamines, elevates blood pressure, and increases heart rate and skin conductance (Cohen & Weinstein, 1982; Glass & Singer, 1972; McLean & Tarnopolsky, 1977). As noted earlier there are emerging data suggesting that these psychophysiological indices are elevated when individuals expend effort to cope with a stressor during task performance conditions. Research on noise, for example, shows that, when subjects are instructed to allow performance to drop off, cognitive efforts diminish along with epinephrine levels and heart rate (Lundberg & Frenkenhaeuser, 1978). There are few data on noise and corticosteroids, respiration, or muscle tension.

Noise levels of 90 dBA and above also interfere with some types of tasks. Several studies have found decrements in secondary tasks in dual-task paradigms under noise. Noise also interferes with tasks requiring rapid detection and response to continuous signals (e.g., serial reaction time tasks). Finally, there is evidence that noise interferes with detection of infrequent signals during sustained vigilance

(Broadbent, 1971; Cohen & Weinstein, 1982; Hockey, 1979).

Tasks that require gating or filtering of competing stimuli are sometimes enhanced by noise. For example, performance on the Stroop task may be better under noisy than under quiet conditions. In the Stroop task one is required to name the color of the print that color words are written in, ignoring the word itself (e.g., the word *red* written in green ink) (Kahneman, 1973). Most studies of noise and task performance have employed simple tasks requiring little to moderate information-processing capacity. As we shall see, stress has little or no effects on concurrent task performance unless the task places considerable demands on processing capacity of the individual.

Noise may also influence memory in complex ways, producing both decrements on some tasks and enhanced performance on others. Noise appears to speed up processing in working memory but with concomitant reductions in memory capacity. For example, if subjects in a memory experiment are suddenly stopped in the middle of a string of words and then asked to recall as many words as possible, recall of recent items is the same or better under noise conditions. However, the span or length of items back into the list is shorter for noise subjects. Some data also suggest that the speeded processing of information in working memory may be responsible for poorer comprehension of complex meaning and thematic/abstract knowledge. Verbatim memory of words, names, and so on as well as the order in which they occurred in a prose passage is better under noise. This also may occur because of the speeded processing of information in working memory (Hamilton, Hockey, & Rejman, 1977; Hockey, 1979).

Memory for incidental information is poorer under noise conditions. For example, if individuals are asked to memorize a list of words written on cards and then probed about what color or typeface the words are printed in or in which corner of each card they were located, noise will interfere with incidental recall. Noise typically will not interfere with the verbal recall of the list (Cohen et al., 1986; Hockey, 1979).

Affect and interpersonal behaviors are also influenced by exposure to noise. Many community studies have documented annoyance with loud sources of noise (e.g., housing adjacent to airports). It is instructive to note, however, that the intensity of noise levels is only a modest predictor of the degree of annoyance. Other situational and personal factors contribute significantly to the prediction of annoyance. For example, fear of airplane crashes, whether the noise is viewed as necessary and important, perceived control over the noise, and the types of activities interfered with (e.g., sleeping children) are all strong predictors of annoyance with airport noise (Cohen & Weinstein, 1982). Some persons may be more sensitive to noise. Self-report measures of general noise sensitivity have been associated with more negative physical and psychological health reactions to high community noise levels (Tarnopolsky, Barker, Wiggins, & McLean, 1978; Weinstein, 1978). Preliminary work suggests that noise-sensitive individuals may have less developed interpersonal coping skills (Weinstein, 1978) and be emotionally less stable and more anxious in general (Iwata, 1984). Acute exposure to noise under laboratory conditions also causes self-reports of stress, tension, and annoyance.

There is abundant evidence that altruistic behavior and sensitivity to others diminish in noise (Cohen & Spacapan, 1984; Cohen & Weinstein, 1982). The effects of noise on aggression and hostility are more complex. Some studies have found greater aggression and hostility under noise, particularly if subjects have had prior anger provocation or exposure to aggressive models (Cohen & Spacapan, 1984; Rule & Nesdale, 1976). As we shall see later, for other stressors there appears to be a curvilinear relationship between the level of stress and aggression, with less aggression under extremely noxious levels of heat or air pollution, for example. This possibility has not been adequately evaluated with noise since most studies have used moderate levels of noise. The evidence for effects of noise on attraction and interpersonal judgments is equivocal, with some studies finding no effects and others suggesting less positive evaluation of others under noise (Cohen & Spacapan, 1984).

A few data on noise and decision making are potentially interesting. Noise may produce more extreme and premature judgments (Siegel & Steele, 1979) and seems to interfere with the individual's ability to differentiate characteristics of people occupying different roles (e.g., self or best friend) (Rotton, Olszewski, Charleston, & Soler, 1978).

There are insufficient data on verbal and nonverbal indices of stress during noise. However, several studies have examined adaptation to both acute and chronic noise. Glass and Singer (1972), for example, reviewed evidence of physiological habituation to acute noise. Loud noise that is unpredictable or uncontrollable often leads to negative performance af-

tereffects (Cohen, 1980) and in some cases aftereffects of reduced altruism or increased aggression (Cohen, 1980). Evidence for habituation in response sensitivity to chronic noise is decidedly mixed (Cohen & Weinstein, 1982). There is also some suggestive evidence that chronic exposure to noise leads to greater susceptibility to learned helplessness (Cohen et al., 1980; Cohen et al., 1981).

Reviews of occupational noise exposure generally conclude that there is moderate to strong evidence linking noise to cardiovascular disorders in workers (Welch, 1979). Several community studies have also associated residential noise exposure to heart disease (Cohen & Weinstein, 1982). The effects of chronic noise exposure on gastrointestinal disorders as well as on resistance to infectious diseases are inconclusive.

Many studies have noted associations between chronic noise exposure and psychological symptoms, psychiatric admissions, and use of tranquilizers. Because of the serious methodological weakness of these studies as well as the existence of a sufficient number of inconclusive studies, the data on noise and mental health must be regarded as contradictory or insufficient at this time (Cohen & Weinstein, 1982)

In comparing noise results with Table 15.1, it is clear that there are many partially or completely unanswered questions about noise and stress. Of the seven physiological indices of stress, high-intensity noise has been clearly linked to four; increased catecholamines, blood pressure, heart rate, and skin conductance. Insufficient data exist on noise and corticosteroids, respiration, and muscle tension. Of the five human performance impacts of stress, noise has yielded somewhat consistent data on all but one of the measures, speeded processing in working memory. There is also good evidence linking noise with negative affect and interpersonal behaviors, with decision making the only inconclusive category. There are little data on observations of verbal or nonverbal behaviors during noise and a noteworthy mix of evidence on adaptation results. The data on long-term adaptation to noise are contradictory, as are studies linking noise exposure to psychological symptoms.

Crowding

Crowding has been distinguished from density, which is a physical measure of the number of persons per unit of space (e.g., room, acre, square mile). Crowding is a psychological state that occurs when needs for space exceed the available supply (Stokols, 1972). While most environmental psychologists recognize the value of distinguishing between crowding and density, there have been some criticisms of this approach (Freedman, 1975). Different measures of crowding have been discussed in the literature. Crowding has been associated with measures of inside or outside density (Galle, Gove, & McPherson, 1972; Zlutnick & Altman, 1972). *Inside density* refers to the number of people per living or interior spatial unit (e.g., number of persons per room, or per square feet of interior space). *Outside density* refers to measures of a real extent outside of the residential unit (e.g., people per square mile, buildings per acre). Several researchers have noted limitations of external density measures. Galle and colleagues (1972) and Zlutnick & Altman (1972), for example, argue that external density measures do not adequately capture the individual's daily experience of cramped living space, lack of privacy, interference from others, and so forth. Furthermore, descriptive measures of external density are frequently misleading because of the unequal distribution of people over geographic space. Thus to speak of the mean number of people per square mile in the United States as one country combines density measures of major cities that are quite high with extremely sparsely populated areas like New Mexico (Day & Day, 1973).

Crowding can also be defined in terms of changes in the number of people per unit of space (social density) or changes in the amount of area provided for a given number of people (spatial density) (Loo, 1972; McGrew, 1970). As in the case of noise, most researchers have not paid careful attention to these various characteristics of crowding. For example, few if any studies have used crowding as an independent variable in experimental designs, relying on density manipulations instead. This issue and other problems with ignoring defining characteristics of the various stressors are discussed further in the last section of this chapter.

Only a few studies have measured endocrine levels under varying density conditions. Elevated catecholamines were noted in crowded commuter trains in Sweden (Lundberg, 1976; Singer, Lundberg, & Frankenhaeuser, 1978), as well as elevated cortisol levels among crowded shoppers (Heshka & Pylypuk, 1975). Aiello, Epstein, and Karlin (1975), however, failed to find increases in cortisol levels in crowded dormitory residences. Many studies have found significant density-related increases in blood pressure, heart rate, and skin conductance (Baum & Paulus, Chapter 14, this volume; Evans, 1978b). No data are available on respiration rate or muscle tension.

Research on density and task performance has found deficits for information-processing tasks with multiple signals, tasks requiring sustained attention (Baum & Paulus, Chapter 14, this volume; Evans, 1978b), tasks requiring rapid responses to sequential stimuli (Evans, 1978b), and decrements in incidental memory (Saegert, MacKintosh, & West, 1975). Few or no other data exist for density and other memory tasks. Much as has been the case with noise research, many crowding studies have found no effects of high density on simple task performance (Evans, 1978b; Freedman, 1975).

Crowding is frequently accompanied by negative affect, including reports of tension, anxiety, and stress (Baum & Paulus, Chapter 14, this volume; Sundstrom, 1978). Preliminary evidence indicates that certain individuals are more sensitive to the effects of high density. Males tend to be more negatively affected, particularly under competitive conditions (Epstein, 1982; Sundstrom, 1978). Moreover, persons with external locus of control respond more negatively, at least to acute high-density exposures (see Baum & Paulus, Chapter 14, this volume), along with persons who have larger personal space zones (Dooley, 1978; Evans & Eichelman, 1976). Finally, there is some evidence suggesting that younger children are more susceptible to residential density than are young adults (Evans, 1978a; Saegert, 1981).

A few studies have noted reduced helping behavior under high-density conditions, but a more consistent finding has been greater social withdrawal. Social withdrawal has been shown by several indices during high-density encounters, including: less eye contact, greater interpersonal distancing, and less initiation of conversation (Baum & Paulus, Chapter 14, this volume; Sundstrom, 1978). The potential link between greater social withdrawal and less sensitivity to others' needs has not been investigated in any systematic manner.

Research on density and aggression is very complex. Studies with children, for example, have found evidence for both increased and decreased aggression under very dense conditions (Loo, 1978; Sundstrom, 1978). Less aggression may be caused by the greater social withdrawal behaviors as noted previously. It is possible that a curvilinear relationship might exist between degree of crowding and aggression. When density levels are sufficient to produce extreme discomfort and crowding, motivation to withdraw from other people may predominate over aggressive or hostile feelings. As in the case of noise, insufficient attention has been given to manipulating a wide range of densities within an experiment. Extremely few studies have compared more than two levels of density. There is also some evidence that the ratio of the number of people to the number of resources influences aggression under crowded conditions (Wicker, 1979). Children are more aggressive, for example, when there are fewer toys than when a sufficient number of toys is available. There is also evidence of gender differences in aggressive reactions to crowded environments. Negative interpersonal behaviors are much more common among crowded males than among crowded females (Baum & Paulus, Chapter 14, this volume; Epstein, 1982).

In addition to the nonverbal indices of social withdrawal, a few density studies have found evidence of greater automanipulative and behavioral stereotype behaviors (Evans, 1978b). There are insufficient data on crowding and decision making to draw any firm conclusions. A few studies have found suggestive evidence of interference in group cooperation tasks under high density (Evans, 1979a).

Several investigations of density have examined evidence for adaptation. Most studies have found that short-term exposures to high density do *not* lead to decreased response sensitivity. Chronic exposure to high-density environments, however, does seem to lead to greater tolerance for crowding (Sundstrom, 1978). Negative aftereffects in performance have also been noted in several studies of density, particularly when subjects have no control over the crowding (Cohen, 1980; Sherrod, 1974). Insufficient data exist on altruism aftereffects from exposure to density. A few studies have linked high residential densities with greater susceptibility to learned helplessness (Baum, Aiello, & Calesnick, 1978; Rodin, 1976).

There are a large number of crowding studies in the animal literature that have linked high-density living environments with heightened susceptibility to infectious diseases as well as directly to cardiovascular disease (Christian, 1961; Dubos, 1965; Thiessen, 1964). Human high-density studies on cardiovascular data are too few in number to draw any conclusions, but several studies have found associations with poorer physical health (Baum & Paulus, Chapter 14, this volume; Cox, Paulus, McCain, & Karlovac, 1978; Sundstrom, 1978). Many of these studies are static, correlational designs using aggregate levels of analysis and thus suffer from serious methodological limitations. Nevertheless, there are evident trends in the literature to suggest some link between residential density and poor physical health. The data on high density and psychological health are very con-

tradictory and emanate primarily from seriously flawed field studies (Esser, 1974; Sundstrom, 1978).

The degree of overlap between the stress effects matrix and research on crowding is also reasonably good, although not as complete as in the case of noise. There is strong evidence that high density causes elevated blood pressure, heart rate, and skin conductance, weaker data on catecholamines, and contradictory findings on corticosteroids. As in the case of noise, there are insufficient data on density and respiration rate and muscle tension. The evidence on human task performance and high density is generally weak, with the only clear trend showing more errors in multiple-signal tasks during crowding. The data on density and self-reports of negative affect as well as interpersonal behavior are mixed. There are weak or insufficient data linking density with changes in altruistic behavior or decision making, and contradictory results on aggression. There are, however, reasonably consistent data showing that crowding increases ratings of negative affect. The data on high density and aggression are potentially understandable in terms of an inverted-*U*-shaped function wherein increases in density up to some moderate point cause increasing aggression but then lead to withdrawal as higher levels are approached. There is some evidence linking high density and nonverbal indices of stress but contradictory findings on crowding and adaptation. Several short-term exposure studies have found exacerbation of reactions over time, whereas long-term studies have found some evidence for habituation to high-density settings. There are contradictory data on density and psychological health but reasonably consistent data showing that high density is linked to greater ill health in animals and possibly in humans as well. Finally, several studies have found negative aftereffects following exposure to uncontrollable high-density conditions.

Heat

The perception of temperature is due primarily to the relationship between the temperature of the external environment and the core temperature of the body. Thermoregulation by the human body maintains core temperature within a restricted range around 37°C. If the core exceeds this temperature, serious disorders of heat stroke and heat exhaustion may occur that can lead to death (Bell & Greene, 1982). Other factors that affect the exchange of heat between the body and the atmosphere also influence the effects of ambient temperature on human health and well-being. Among the more important factors affecting heat exchange are relative humidity, clothing, and acclimatization.

The physiological effects of heat center around the thermoregulatory mechanism, which is controlled by the hypothalamus. It is believed that changes in ambient temperature are monitored by thermosensitive cells in the skin that feed back to the cortex, which in turn innervates the hypothalamus. Elevations in temperatures produce an initial increase in blood pressure that is quickly followed by peripheral vasodilation (to allow heat escape). The peripheral vasodilation causes a subsequent drop in blood pressure. If the body is unable to restore core temperature within a safe range, blood pressure will rise again. This is actually a sign of imminent danger that if not dealt with may rapidly lead to heat exhaustion and a marked dropping off of blood pressure and other vital signs. If core temperature is not quickly restored, serious consequences including death may arise. Both heart rate and skin conductance increase as ambient temperature rises. Excessive demands on the thermoregulatory system may lead to heart attack. During prolonged heat wave conditions there are marked increases in cardiac arrests, particularly among the elderly (see Bell & Greene, 1982, for more details on physiological reactions to heat).

While some of these physiological reactions to heat are similar to stress responses (e.g., heightened heart rate and skin conductance), in general it is probably fair to say that there is little direct physiological evidence linking heat to the stress response pattern outlined in Table 15.1. Nearly all of the physiological responses to heat are centered on improving heat exchange between the body and the environment. Skin conductance, for example, elevates because of increased sweating, which is a cooling mechanism. There are few data on endocrine responses to heat stress. This is unfortunate since they are less directly influenced by thermoregulation mechanisms and thus might show more unambiguously whether heat is a psychological stressor for some individuals.

Mason and his co-workers (1976) have used heat as one type of stressor to study the importance of psychosocial factors in endocrine responses to noxious environmental conditions. As noted earlier, Mason's work suggests that perception of threat or harm may be necessary to provoke the array of physiological responses suggested by Selye (1956). Human subjects were exposed to very gradual temperature changes (ranging from 74 to 105°F at relative humidity of 50%). Core temperature and urinary corticosteroids were monitored. No evidence of

psychoendocrine responsiveness was found even under the hottest conditions where core temperature increased by 1.6°. There are insufficient data on heat and muscle tension or respiration rate.

The effects of heat on task performance are extremely complex and not well understood from any one theoretical perspective. Generally, heat is more likely to produce performance decrements in unacclimatized subjects exposed to heat (approximately 32°C) over a long period of time. Tasks with multiple signals are adversely affected by heat. Studies have shown vigilance tasks improved, unaffected, and worsened by performance during heat exposure. For rapid signal detection and response tasks, heat exposure seems to improve initial performance, which then tapers off and eventually declines under heat conditions (Bell & Greene, 1982; Poulton, 1970)

Research on heat and task performance is particularly difficult to characterize because there are several important methodological variables that vary markedly across studies. Levels of heat and whether it is measured at core body temperature or at ambient levels, relative humidity, duration of exposure, and use of acclimatized or unacclimatized subjects all bear importantly on the relationship between heat and human performance. To our knowledge there is no research on heat and memory.

Self-report measures of heat focus on thermal comfort ratings. Thermal comfort is strongly related to ambient temperature, humidity, and clothing insulation properties (Griffiths, 1975). For moderate clothing and 45% relative humidity, the range of comfort for most persons is 24 to 27°C. When temperatures are higher than this, people typically report discomfort, irritability, and, if exposure is prolonged, fatigue. Measures of perceived tension, nervousness, anxiety, or stress have not been monitored systematically in heat research (Bell & Greene, 1982) There are mixed data on heat and interpersonal attraction, with some suggestive evidence that heat reduces interpersonal attraction only for persons who are not also suffering from the same uncomfortable conditions (i.e., no shared distress) and when there are no strong preexisting attitudes about the target person(s) (Bell & Greene, 1982). Heat has little or no effects on altruistic behaviors (Bell & Greene, 1982). There are also insufficient data on heat and decision-making behaviors.

As noted in the above sections on noise and crowding, the relationship between environmental stressors and aggression may be curvilinear. This theory comes primarily from research on heat and negative affect. As ambient temperature rises there is a linear increase in negative affect that is accompanied by greater hostility and aggression. However, at some point (approximately 35°C) the hot setting becomes so negative or noxious that, instead of aggression, behaviors to withdraw or escape from the hot environment predominate. Thus at some moderately high temperature aggressive behaviors actually drop off (Baron, 1978).

The evidence for this model of negative effect, heat, and aggression is pretty consistent. As heat increases beyond a certain point, whereas negative affect continues to mount, aggression decreases. Self-reports are also consistent, with subjects indicating that their primary needs as temperature continues to climb are to escape from the situation (see Baron, 1978, for a good review of the evidence). Furthermore, manipulations that hold temperature constant but reduce negative affect (e.g., giving someone a cool glass of water) show a drop in negative affect and a continuing increase in aggression at high temperatures. Field studies of collective violence tend to show the same curvilinear effect, with rioting increasing as temperatures rise up to some point (around 32°C) and then dropping off with increasing temperature (Baron, 1978; Bell & Greene, 1982)

There are few or no data on verbal and nonverbal indicators of stress during heat but some interesting research on heat and adaptation. While there are few data on heat and aftereffects, susceptibility to infectious diseases, or changes in vulnerability to helplessness, there are consistent findings showing increased risk of cardiovascular disease during periods of increased temperature. Yet if people live in a hotter climate there is no evidence of increased cardiovascular disease. These two sets of data suggest that it is a change in temperature rather than higher temperature per se that challenges the cardiovascular system. Acclimatization to heat is a well-documented phenomenon that occurs typically after 4 to 7 days of exposure to a hotter environment. Acclimatization is caused by increased sweating efficiency and is accompanied by lower discomfort, less physiological reactivity, lower core temperature, and better task performance during hotter temperatures. There is also a large but contradictory body of work on genetic differences in heat acclimatization (Frisancho, 1979).

While there are enough trends in both the noise and the crowding literature to suggest that the stress model has some support, the situation is markedly hazier for heat. There are insufficient data for most of the physiological indices of stress and heat, with most physiological changes accompanying heat proba-

bly due to thermoregulatory activities. Research on heat and task performance is very mixed, and insufficient data exist for altruism and decision making. The inverted-*U*-shaped function between heat and aggression is strongly supported. There are also many studies showing habituation with heat exposure. Data on heat and observational indices as well as various measures of psychological adaptation processes are largely absent.

Air Pollution

It is immediately apparent when examining the air pollution literature that there is considerably less research on air pollution and human behavior than there is on the other three environmental stressors we have considered thus far. Furthermore, especially in the case of air pollution and perhaps for heat as well, few researchers have explicitly examined whether these environmental conditions are stressors.

Air pollution is a ubiquitous problem, affecting the majority of the population of the United States, and costing upwards of $250 million per year in direct health costs alone (Evans & Jacobs, 1982). Air pollution is actually a collection of several toxic agents that include photochemical oxidants or smog (chiefly ozone as the toxin), sulfur oxides, nitrogen oxides, carbon monoxide, and particulates. There are two other categories of air pollutants that are not as thoroughly documented as the list of ambient pollutants. The first of these, indoor air pollutants, is only now gaining the serious attention it deserves in the health community (National Academy of Science, 1981). Indoor gas heating and cooking exhausts, insulation and other construction materials, and occupationally related toxin exposures are the most prominent sources of indoor air pollution exposure. The most common harmful compounds found in indoor air pollution include nitrogen dioxide, carbon monoxide, formaldehyde, asbestos, and various solvents.

The second category of air pollutants that have not been as extensively analyzed as the ambient pollutants includes heavy metals such as lead, mercury, cadmium, and other compounds. These chemicals find their way into the human body via particulant settlement from the air, ground water supplies, and plant absorption (Waldbott, 1978).

Unfortunately, to date, even fewer behavioral scientists have been involved in studying indoor air pollution or heavy metal toxins than the already paltry numbers looking at ambient air quality and human behavior. This is particularly unfortunate because many of the effects of the toxic compounds found indoors (e.g., formaldehyde) or in heavy metals (e.g., lead) include neurosensory dysfunction (Weiss, 1983). There is also evidence for critical developmental periods for childhood exposure to some of these compounds. Many of these chemicals may not have obvious direct negative outcomes until years after childhood exposure. The emerging field of teratology is examining such issues (Fein, Schwartz, Jacobson, & Jacobson, 1983).

As one might expect, the overwhelming majority of air pollution and human studies have focused on respiratory-related outcomes. Since this research has been extensively reviewed (Coffin & Stokinger, 1977; Goldsmith & Friberg, 1977), we will focus our attention here on the few behavioral studies of air pollution. As will be apparent from reading the next few paragraphs, this research is at a very early stage.

With the exception of cardiovascular measures, no research to our knowledge has examined physiological indices of stress from exposure to air pollution. There is evidence that exposure to carbon monoxide increases heart rate because of demands for more oxygen. There is a good deal of evidence that carbon monoxide interferes with tasks requiring sustained attention and may also disrupt multiple-attention tasks (Evans & Jacobs, 1982). There are conflicting data on rapid signal detection tasks. For example, some studies have found slowing of reaction times during exposure to carbon monoxide, whereas other studies have found either no effects or the same pattern of decrements, but only for those individuals with preexisting respiratory impairments. There are insufficient data on air pollution and memory, but there is some suggestive evidence that carbon monoxide may slow down working memory. Note that this is in direct opposition to what noise and other stressors do to working memory. There are very few data on other pollutants and human task performance. Nearly all of this work has focused on carbon monoxide (Evans & Jacobs, 1982; Gliner, Raven, Horvath, Drinkwater, & Sutton, 1975). It is difficult to know whether any of the task deficits associated with pollutant exposures are due to stress. At least in the case of carbon monoxide, it is probably more parsimonious to attribute task deficits to oxygen deprivation to the brain.

There is a moderate amount of survey research measuring citizens' attitudes and awareness of air pollution. Individuals are annoyed by air pollution and will indicate that it is a serious community problem when directly queried (Evans & Jacobs, 1982). How-

ever, when individuals are simply asked to rank order community problems, air pollution is not very salient in comparison to other community issues (Barker, 1976). Much of the survey research has focused on other variables that influence people's reactions to air pollution. Consistent data suggest for example that concern and awareness are greater for those with more education, for women, and for individuals with greater internal locus of control. Individuals who have resided under poor ambient air quality for a long period of time or those economically dependent on a major pollution source are less likely to be bothered by air pollution (Barker, 1976; Evans & Jacobs, 1982). The significance of these and other moderating factors for environmental stress is discussed in more detail in a later section of this chapter.

Interpersonal relationships have been examined in a few studies of air pollution. Both malodors and cigarette smoke cause annoyance and more negative evaluations of the immediate environment. Interpersonal attraction appears to diminish under poor air quality so long as the target individual is not viewed as also suffering from exposure to similarly noxious conditions. When subject and target are both exposed to poor air quality (e.g., malodor), a sense of shared distress seems to create empathy for the other person (Rotton, Barry, Frey, & Soler, 1978). Note the similarity of this trend with earlier data on heat and interpersonal attraction. Furthermore, some research indicates less altruism under poor air quality conditions and increased aggression up to a point with increasing air pollution (Evans & Jacobs, 1982). Rotton, Frey, Barry, Milligan, and Fitzpatrick (1979), however, found a curvilinear relationship, as in the heat studies, between air pollution levels and aggression. Once again subjects' behaviors and self-reports suggested that, when environmental conditions became sufficiently noxious, efforts to withdraw from the situation were more salient than hostility or aggression. There are no data to our knowledge on decision making under air pollution nor observations of verbal or nonverbal indices of stress.

Some recent research, however, has begun to examine possible evidence of adaptation to air pollution. Rotton (1983) found performance aftereffects following exposure to uncontrollable, malodorous pollution. This finding and several survey studies suggest some feelings of helplessness in the face of exposure to chronic air pollution. Few people feel any personal means are available for reducing air pollution, and for some this leads to feelings of hopelessness about the problem (Evans & Jacobs, 1982). For example, Rankin (1969) found that very few people felt like complaining about air pollution even when they were annoyed by it. About half of those who were annoyed did not complain because they felt it would not do any good. Air pollution may become an accepted, largely unnoticed background characteristic of the everyday environment because nothing can be done about it (Campbell, 1983; Wohlwill, 1974). Both physiological (Dubos, 1965) and psychological evidence exists for habituation in response sensitivity with chronic exposure to air pollution. Evans and colleagues (1982) found that persons who had previously lived in high air pollution zones were less aware and less affected by poor quality in their current residence in a high pollution area that they had recently migrated to than new migrants who had previously lived in low pollution areas. There is also some evidence of short-term habituation in respiratory sensitivity to air pollutants plus inhibited immunological response with chronic air pollution exposure as well as greater incidence of cardiovascular disease (Goldsmith & Friberg, 1977). The latter effects are probably due to direct effects of greater oxygen demand. Some pollutants like carbon monoxide also accelerate atherosclerosis.

Finally, there are a few studies linking air pollution levels with poorer mental health. Simple correlations without extensive controls for other factors have been found between pollution levels and psychiatric admission rates (Briere, Downes, & Spensley, 1983; Strahelivitz, Strahelivitz, & Miller, 1979). Several other studies have reported no such associations, however. Two recent studies with more thorough controls and better research designs have found evidence for poorer psychological health as measured on a standardized scale (Evans et al., in press) and 911 emergency calls for psychiatric-related problems (Rotton & Frey, 1984). In the study by Evans and associates, however, only persons who had recently experienced a stressful life event were vulnerable to the negative psychological impacts of air pollution. This finding is interesting in light of earlier discussions about adaptation to stressors. Exposure to a stressor that is either major or prolonged may interfere with subsequent ability to cope with other environmental sources of stress.

The overall picture is incomplete for characterizing air pollution as an environmental stressor. The only consistent evidence linking air pollution to stress is from negative affect data. There is also some support for task performance data, although these findings are limited to carbon monoxide. Furthermore, as noted in the text, these performance deficits may be due to hypoxia and not stress. There

is also moderate support, showing habituation in response sensitivity with chronic exposure to air pollution. While the data on rapid signal detection tasks are contradictory, the remaining stress-related effects are either weak or for the most part insufficient to draw any firm conclusions about the status of air pollution as an environmental stressor.

15.4.2. Evaluating the Stress Paradigm

A central question addressed by this chapter is whether the four environmental problems of noise, crowding, heat, and air pollution can be understood, at least in part, as psychological stressors. We suggest that the answer is yes for noise and crowding and possibly yes, pending further investigation, for heat and air pollution. Both noise and crowding have effects on human health and behavior that can be characterized as stress effects. Heat and air pollution may or may not function as stressors with too few data available to warrant any conclusions at this time. When one examines the various matrices of stress effects and environmental stressor data, several research questions are immediately apparent. The important conceptual issue of whether perceived threat is a prerequisite to experiencing psychological stress is a central issue for work on environmental stressors as well. While theoretical distinctions have been made between physical measures of the environment, density and sound levels, and corresponding perceived measures, crowding and noise, these same distinctions have not been developed and evaluated for heat or air pollution. Furthermore, for all of these four stressors, we really do not know to what extent each of them is perceived as threatening to health or well-being, nor do we know what the relative, empirical relationships are between perceived versus actual measures of environmental conditions and human health and behavioral outcomes (Cohen et al., 1986).

Heat and air pollution are typically low-level, chronic aversive conditions that may not be salient to most people. Perhaps among more vulnerable subgroups of the population (e.g., heat and cardiac patients or air pollution and those with respiratory impairments), these stressors may be threatening and initiate a wider array of symptoms resembling psychological stress. Heat and air pollution may also be viewed as more "natural" stressors that are harder to attribute directly to the behavior of other individuals. This may produce less annoyance and an attitude of acceptance that such conditions are part of everyday life and not readily modifiable.

Considerably more work is needed on environmental stressors and task performance. This type of research, however, will continue to be plagued by weak and inconsistent findings until a better conceptual understanding of stress and cognition is developed. More basic research is needed on how cognitive mechanisms are affected by stress. In addition, the role of individuals' attitudes toward the stressor may prove to be a critical parameter in performance research on stress. We already know, for example, that cognitive effort for at least short periods of time can strongly influence the effects of stressors on performance (Cohen et al., 1986).

In the area of affect and interpersonal behavior, two prospective research areas stand out. First, there is a noticeable dearth of studies on environmental stressors and decision making. The effects of psychological stressors on decision making are sufficiently validated that they warrant examination under aversive environmental conditions. More work is also called for on aggression and environmental stressors. We know from heat research that high levels of temperature appear to depress aggressive behaviors in the face of rising negative affect. There are some similar findings in the air pollution literature as well. We also know that under high-density levels, a frequent social behavior is withdrawal. While these patterns of data may fit the inverted-U-shaped function between aggression and negative affect posited by Byrne (1971), an alternative explanation of the data may be learned helplessness, which also is associated with retarded aggression responses. Perhaps under very averse environmental conditions individual feelings of helplessness cause withdrawal and less aggression.

Another large research gap in environmental stressors is observation indices of stress. With the exception of a few crowding studies (Evans, 1978b), there has been essentially no work on verbal or nonverbal indices of stress during exposure to environmental stressors. Research on adaptive processes and environmental stressors has focused primarily on habituation, performance aftereffects, and indices of health status. Both heat and air pollution could be studied with aftereffect paradigms, as has been done more extensively with noise and crowding. Another type of aftereffect that warrants further research in all four of the environmental conditions reviewed here is susceptibility to other stressors. One of the costs associated with coping with stressors may be reduced capacity to respond to other environmental challenges. There is markedly little research on how coping with one stressor affects our ability to deal with another source of environmental demand (see

Cohen, 1980; Cohen et al., 1986, for some preliminary ideas on the effects of coping with environmental stressors).

More work is also needed to understand the physical and social conditions that predispose some individuals at certain times to habituate to chronic stressors as opposed to increasing their reactance with experience. Some research suggests that the extent of threats to health and/or the importance of goals interfered with by the stressor may influence the ways in which people cope with chronic environmental stressors (Campbell, 1983; Stokols, 1979). The relationship between exposure and learned helplessness also warrants further exploration. While there is some noise and crowding research on helplessness, we do not understand what aspects of the environment produce these effects, nor do we know much about the circumstances that are more likely to augment them. Of particular interest in this regard and more generally is the question: What are the environmental conditions that are most likely to cause one to perceive a general sense of loss of environmental mastery?

A final question emanating from our comparison of the overall stress matrix with the various results on environmental stressors is: To what extent are physical and mental health influenced by chronic exposure to suboptimal environmental conditions? Basic research is rapidly emerging on the physiological mechanisms that link stress to cardiovascular diseases as well as infectious diseases. Environmental stress research on physical health needs to take advantage of this emerging knowledge

15.5. THEORETICAL AND METHODOLOGICAL ISSUES

15.5.1. Cognitive Mediation of Environmental Stressors

A critical limitation in focusing only on physical sources of stress in situations is the fact that people vary greatly in their reactions to the same configuration of physical demands. The role that cognitive analyses of stress have played in the development of the noise or crowding literature, for example, is apparent in the lexicon of both of these literatures. The distinctions between sound and noise or between density and crowding point to the importance of individual evaluations of environmental demands. Cognitive appraisals of a stimulus configuration as threatening or harmful are a core component of stress (Lazarus, 1966; Lazarus & Launier, 1978). Stress occurs when environmental demands are perceived as taxing or exceeding the organism's ability to cope with those demands. Thus the meaning of a physical configuration of an environment has powerful influences on whether those physical conditions will elicit stress.

It is interesting to note that, while most environmental psychologists accept this position on the central, mediating process of appraisal, there is markedly little research comparing, for example, density to crowding measurements or sound to noise measurements in their respective explanatory power to predict human health on behavioral outcomes. Cohen and his colleagues (1986) have recently compared actual sound levels and perceived noise ratings on several measures of children's health and behavior. These analyses suggest that children's perceptions of noise accounted for significant proportions of variation in some outcome measures (e.g., blood pressure) when controlling for actual noise levels. Teachers' perceptions of noise-related classroom interference also predicted children's performance on attentional tasks, after controlling for objective noise levels. The latter finding is particularly interesting because it suggests possible links between children's and adults' reactions to shared stress. Research on crowding also suggests that subjective feelings of crowding may be associated with negative outcomes after controlling for physical density measures (Baldassare, 1979). On the other hand, Saegert (1981) has found that, while apartment density was significantly related to classroom behaviors and school performance among elementary school children, perceived crowding did not mediate the effects of density. Moreover, Evans and his colleagues (in press) found that ozone levels, but not visibility, in conjunction with recent stressful life events, were related to psychological health symptoms.

The stressful life events literature has examined the issue of objective versus perceived stress levels in some detail. This issue has some important conceptual roots going back to the physiological and psychological perspectives on stress discussed at the beginning of this chapter. The early stressful life event literature derived primarily from Selye and Cannon's emphases on stress as symptomatic of bodily reactions to reestablish homeostasis in the face of adaptive challenges from the environment. Stressful life events were thus originally conceived of in terms of the amount of change or disruption the events produced, that is, the amount of disequilibrium (Dohrenwend & Dohrenwend, 1974, 1981;

Holmes & Rahe, 1967). Subsequent research has suggested, however, that the perceived severity of a stress life event is a better predictor of health outcomes than is the amount of environmental change or disruption per se (Cohen, 1981; Cohen, Kamarck, & Mermelstein, 1983; Evans, Palsane, & D'Souza, 1983; Thoits, 1983).

Some important tasks for persons interested in the issue of perceived versus objective measures of environmental stressors are: (1) to develop some conceptual framework to explain how and when perceived stressors will predict some outcomes better or worse than objective measures of environmental stressors; (2) to construct outcome measures that are not overly confounded with the perceived stress measures in terms of both actual content (e.g., use of illness symptoms as stressors) and the method used (measures using the same method typically share some method-based error, e.g., linking self-reports of perceived stress to self-reports of anxiety or health); and (3) to determine what characteristics of physical and social environments are most likely to cause different patterns of perceived stress. Some preliminary progress has been made on some of these issues. Data suggest that subjective measures predict better than objective ones under low or moderate levels of stressors. Under very aversive conditions such as extremely high noise impact zones, decibel levels are more highly associated with outcome measures (Neus, Ruddel, & Schulte, 1983) Research in the environmental assessment field has also examined the interrelationships among objective and subjective indices of environmental quality (cf. Carp & Carp, 1982; Craik & Zube, 1976).

The most investigated mediating construct between environmental stressors and human outcome measures has been perceived control (Averill, 1973; Glass & Singer, 1972). Control has been implicated as a principal mechanism for the aversive effects of several environmental stressors (see Section 15.3.4). Research on crowding, noise, and to some extent air pollution has shown that, generally, when these stressors are uncontrollable, they produce more negative effects on human functioning. Furthermore, the provision of actual or perceived control over environmental stressors significantly reduces their aversive impacts (Cohen, 1980; Cohen et al., 1986; Glass & Singer, 1972). Chronic exposure to uncontrollable environmental sources of stress has also been implicated in learned helplessness.

Several aspects of further research on control and environmental stressors are apparent. More work on control and heat and air pollution is warranted. There is suggestive evidence that prolonged exposure to either or both of these conditions may lead to feelings of hopelessness (Bell & Greene, 1982; Evans & Jacobs, 1982). Moreover, at least one study has shown that perceived control over air pollution dramatically reduces some of its aversive effects (Rotton, 1983).

The manner in which people adapt to chronic exposure to environmental stressors may vary as a function of the intractability of the stressor. People may be more likely to seek instrumental coping strategies when the negative environmental costs are viewed as malleable (Campbell, 1983; Evans et al., 1982). Control may also influence both the perceived severity of a stressor and the relative predictive power of objective and perceived measures of environmental stress.

Finally, there are forms of control in addition to behavioral control, such as cognitive control, which may prove to be potent mediators of environmental impacts. For example, Mechanic's research on students preparing for exams found that mastery was achieved primarily through cognitive preparation and social comparisons prior to the exams (Mechanic, 1962). Similarly, research on medical procedures shows that preparatory information, particularly if coupled with suggestions for pain reduction, strongly influences patient recovery and well-being (Janis, 1983). Saegert and her colleagues have applied this type of cognitive control intervention with some success in crowded settings. When individuals are forewarned about impending crowding conditions in retail stores, their task performance is less severely affected by crowding and they feel less stress (Langer & Saegert, 1977; Love & Saegert, 1978; Saegert, Mackintosh, & West, 1975). Baum and his colleagues have also shown differences in behavioral reactions to high-density settings utilizing different cognitive control manipulations (see Baum & Paulus, Chapter 14, this volume). Furthermore, as noted earlier, while greater control is generally efficacious, some situational and personal factors may lead to no effects or possibly negative effects from instrumental control over a stressor. More research is needed on this topic.

The attitude of the individual toward environmental stressors is another important cognitive mediator. For example, as noted earlier, many studies of annoyance with environmental sources of stress like noise indicate that attitudes about sound levels are consistently better predictors of citizens' annoyance than are physical measures of sound. Fear of crashes, perceptions of whether the noise source is

necessary and important, and whether any attempts are being made to modify the noise have all been found to be potent mediators of the sound level–perceived annoyance relationship (Cohen & Weinstein, 1982).

The mediating role of expectancies is dramatically illustrated by research on crowding and noise showing that anticipation of these environmental stressors causes reactive symptoms strikingly similar to actual exposure to stressors (Baum & Paulus, Chapter 14, this volume; Spacapan & Cohen, 1983). These anticipated stressor effects include performance aftereffects, physiological arousal, coping behaviors, and negative affect.

The social climate of a setting may also moderate individual reactions to specific environmental stressors. Three basic dimensions characterize the social environments of most organizations. The relationship dimension describes how involved individuals are in a setting as well as the extent of social support offered by that setting. The personal development dimension deals with opportunities in a setting for personal growth and self-enhancement. The system maintenance dimension reflects the degree of order, control, and clarity in a setting (Insel & Moos, 1974; Kiretz & Moos, 1974; Moos, 1973). Unfortunately, research on various environmental stressors has generally ignored the potent interplay of organizational factors like social climate, work pressure, and role structures with various physical stressors (McGrath, 1976; Zimring, 1982). Hospital settings illustrate the importance of organizational factors as well in understanding influences of the designed environment on behavior. The large and often sterile physical form of hospital settings (e.g., bright lighting, tile floors and walls) plus organizational policies (e.g., patient management strategies, physician status) may interact to augment feelings of helplessness and vulnerability among patients (Shumaker & Reizenstein, 1982). Finally, Ahrentzen and her colleagues have indicated that the interactions of social climate variables with physical (e.g., noise) and architectural setting (e.g., open plan) variables are better predictors of student behavior than either of these factors alone (Ahrentzen, Jue, Skorpanich, & Evans, 1982).

The critical role of mediators in the environmental stressor–human reaction process reiterates the importance of measuring and explaining human variation in response to aversive physical conditions. An important task for environmental psychologists is to uncover how the physical setting itself contributes to these mediating processes.

15.5.2. Coping with Environmental Stressors

It is clear that human beings are not passive respondents to environmental conditions. We maintain a dynamic transaction with our physical and social surroundings that typically includes instrumental attempts to achieve mastery as well as cognitive and emotional equilibrations that enable us to accommodate changing environmental conditions that are more difficult to control instrumentally (White, 1974). Environmental stress researchers need to integrate coping and adaptation concepts more fully into their research and theory. We know, for example, that cognitive efforts can mask, for at least short periods of time, many of the negative effects of environmental stressors like noise on task performance. It is only when we carefully monitor tasks that demand considerable cognitive capacity (Cohen, 1978; Evans, 1978b) or use aftereffects paradigms (Cohen, 1980; Glass & Singer, 1972) that some of these short-term aversive effects are manifested.

An intriguing question that the previously discussed pattern of results and others like them suggest is: What are the direct effects of stressors on human health and well-being, and what are the effects of coping with environmental stressors? The gains and losses associated with coping with chronic stressors are an important issue that is just beginning to be looked at in the environmental stress field. As noted earlier, some of the suspected effects of coping with chronic environmental stressors include cumulative fatigue (e.g., aftereffects), overgeneralization of learned coping responses (e.g., tuning out noise), and physiological activation due to efforts to maintain control or optimum functioning (e.g., reactance behaviors or catecholamine activity). Personal failures to cope with stressors adequately may cause some persons to become susceptible to other control-related situations such as learned helplessness. Continual exposure to environmental sources of stress that are not responsive to instrumental efforts may also lead to greater emotion-focused coping such as denial, rationalization, or various defensive reactions (Cohen et al., 1986).

Social support consists of the resources provided by one's interpersonal relationships. Current research on social support generally considers support to consist of several dimensions, including the availability of material aid (tangible support), the availability of someone to discuss problems with (appraisal support), the availability of others to compare oneself to

(self-esteem support), and the opportunity to engage in social interactions with other people (belonging support) (Cohen & Syme, 1985; Gottlieb, 1978; House, 1981). While social support as a possible stress buffering agent has been examined in occupational and medical settings as well as interpersonal conflicts, to our knowledge the potential mediating role of social support in environmental sources of stress has only been examined in one study. Fleming, Baum, Gisriel, and Gatchel (1982) found that persons living near the Three Mile Island nuclear plant reported fewer psychological symptoms when they had persons available to talk to about problems than when they did not. Support was relatively unimportant for persons in nonstressed control areas. The role of support processes in protecting persons from stress may be especially interesting in relation to crowding, noise, and temperature because of their interplay with social relations. Crowding in particular raises some intriguing questions for social support research since members of a primary social support system may also function under certain physical circumstances as a source of stress (Epstein, 1982; Evans et al., 1983). Noise might interact with the close availability of others to provide support by interfering with interpersonal communication. Heat and air pollution can increase interpersonal attraction and create empathy for others when they too are perceived as suffering from stress (cf. Rotton, Barry, Frey, & Soler, 1978).

15.5.3. Methodological Issues

In addition to the theoretical questions raised about environmental stressors, there are several remaining areas of concern in the environmental stress literature. We discuss several important methodological issues in the following sections, which include individual differences, temporal parameters, multiple levels and types of stressors, setting, measurement, and theoretical concerns.

Individual Differences

The search for mediators of the stressor–stress reaction process was initiated early on by Lazarus and others primarily because of individual differences in response to similar aversive conditions. Social scientists often view individual differences as nuisances because they make theoretical work considerably more difficult and contribute to the impression that theories of human behavior are not scientific. Social scientists may be relieved to learn that a similar situation exists for our biological colleagues interested in environmental problems. The fact is that large individual differences, some explainable, most not, are the rule rather than the exception when examining the relationship between health effects and exposures to environmental toxins (Weiss, 1983). The question of central concern is explaining individual differences that are systematic. One issue in particular that warrants further research is the concept of vulnerability to stressors. Some individuals may have lower or higher resistance to stressors in general, whereas for others variable resistance may be stressor specific (Magnusson, 1982; McGrath, 1982). For example, Kobasa argues that the individual characteristics of hardiness inoculates some high-risk individuals (e.g., business executives) from stress-related disorders (Kobasa, 1979). Hardiness consists of feelings of commitment, the tendency to appraise demands as challenging, and a sense of self-efficacy. Children, the poor, the elderly, and institutionalized persons may on the whole be more susceptible to aversive effects of environmental stressors because they have less control over stressors and may have fewer coping resources to draw upon to deal with them (Cohen et al., 1986; Evans, 1978a; Sherrod & Cohen, 1979).

Children, for example, appear to be more vulnerable than adults to negative consequences from exposure to residential crowding in measures of both psychological and physical status (Evans, 1978a; Saegert, 1981). Children are also more reactive to respiratory effects of air pollution (Evans et al., 1982). The effects of early physical environments on the development of social and cognitive competence are receiving increasing attention in the developmental community (cf. Wachs & Gruen, 1982). This recent work continues a long tradition of research on critical periods of development, which has focused on issues like the effects of insufficient physical stimulation or social isolation during various restricted periods of development on maturation processes (cf. Denenberg, 1972; Wohlwill & Heft, Chapter 9, this volume).

Research with elderly people also suggests greater sensitivity to physical surroundings (Lawton, 1980), particularly among institutionalized individuals. Orientation and way finding, building quality, spaces for social interactions, privacy opportunities, and security from crime have been identified as important dimensions of housing for senior citizens (Rowles & Ohta, 1983; Schooler, 1982).

More specific stressor-related susceptibility may

prove valuable for gaining some understanding of the processes by which stressors influence people in different ways. Weinstein's (1978) and Iwata's (1984) research on noise-sensitive individuals is an example of this approach. Other variables worth exploring are control-related phenomena like locus of control and Type A behavior; stimulus seeking and screening (cf. Mehrabian & Russell, 1974); quantity as well as variability of individual coping resources; previous experience and other variables related to learning and expectations about a specific stressor; and developmental, gender, and cultural factors.

Measurement

There are some important measurement implications for research on environmental stress that follow from the previous discussion of individual differences. Scaling of self-reports of stress is an area that has received very little attention in the stress literature in general. Paper and pencil measures of perceived stress, threat, annoyance, and so on implicitly assume various underlying measurement models. Before we can adequately understand what variables predict annoyance or how perceived stress interrelates with objective measures of the physical environment to affect human health and behavior, more psychometric work is needed to develop self-report scales that are reliable and valid.

As an example of this work, the Berglunds and their colleagues have documented that survey measures of community annoyance to noise or malodor can be dramatically improved by calibration procedures. When response criteria are established to a common reference point when judging how annoying a particular situation is, dose–response relationships between the physical configuration (e.g., sound level) and annoyance are dramatically better than are the dose–response curves when the typical scaling approach is followed (e.g., "Please rate how annoyed you are where 1 = extremely little annoyance and 7 = extremely annoyed.") (Berglund, Berglund, & Lindvall, 1975). These data suggest that earlier research indicating low correlations between noise levels and annoyance (Cohen & Weinstein, 1982) or air pollution content and annoyance (Barker, 1976; Evans & Jacobs, 1982) may reflect both the absence of meaningful conceptual components of the relationship and poor measurement properties of the annoyance scales themselves.

Another reason that some measures of stress have not been as sensitive as they may be is the problem of range adjustment. Both the initial resting value and the maximum possible value for a scale have strong influences on how one's reactions to a given physical or psychological demand are scaled (Borg, 1978; Wilder, 1968). For example, initial resting levels of various physiological indices correlate in the .4 to .6 range, with difference scores between the resting, control condition and reactions during stress (Pittner, Houston, & Spiridigliozzi, 1983). Failure to make statistical adjustments for initial values and range of effects renders many research designs in stress work very inefficient for detecting effects. This may also contribute to the generally low intercorrelations found among various measures of stress. This problem is particularly serious in between-subjects designs.

Measurement issues also occur on the independent variable side. Nearly all studies of the four environmental stressors discussed herein have used two levels of the independent variable, consisting of a control condition with little or no stressor present (e.g., background noise levels or silence) and either a moderate or a high level of the experimental conditions (e.g., 75 dBA or 90 dBA). There are several very important limitations of this state of affairs. First, given the suggestive evidence of some nonlinear functions between stressor intensity and human reactions such as found in heat and aggression, it is very important at a minimum to expose individuals in experiments to low, moderate, and high levels of the environmental stressor. Second, the concept of threshold, which predominates in epidemiological research on environmental health effects, suggests the presence of some minimum level or range of a pollutant that is necessary for any health effects to occur. Low-level exposure to an environmental stressor, particularly for short time periods, may yield incorrect assumptions of no effects. It is important to establish some sense of the threshold range of the various environmental stressors in order to present properly various levels of stressors in experiments.

Temporal Issues

There are several temporal issues in stress research generally that apply strongly to environmental work (see McGrath, 1970a, 1982, for an excellent discussion of temporal issues). The pioneering work of Glass and Singer (1972) on stress aftereffects has sensitized many researchers to the importance of temporal factors in assessing stress reactions. Measurements of reactions in anticipation of, during, and after the presence of a stressor are clearly warranted, and can yield important insights into the stress process. Looking at temporal issues from a

more macro perspective, it is important to examine environmental stressors under both acute and chronic conditions. People who have to live with aversive environmental conditions undoubtedly develop various coping strategies. Laboratory research on short-term reactions to stressors can provide us models of the effects of stressors that then need to be examined under field conditions (Cohen et al., 1980). We also need to bring people experienced with various stressors into the laboratory to see how they respond to controlled presentations of various sources of stress. Research on adaptation to air pollution, for example, has shown that people chronically exposed to smog react in some systematically different ways to laboratory tasks (e.g., visual detection of smog in pictorial scenes) than do residents recently exposed to ambient air pollution (Evans et al., 1982). The issue of long-term adaptation to environmental stressors has only been touched on by environmental psychologists. We know very little about the physical, social, or interpersonal processes that predispose individuals to become more or less sensitive to environmental pollutants over time (Campbell, 1983; Wohlwill, 1974). We do not know what it is that people do to cope successfully or unsuccessfully with environmental stressors.

Temporal parameters also influence measurement. Various dependent measures of stress have differential sensitivity over time to stressors. Urinary catecholamine measures are responsive to cumulative secretions of psychoendocrine hormones over relatively long periods of time whereas plasma catecholamine measures reflect momentary reactions to stress. Moreover, physiological measurements are often monitored continuously, whereas self-report variables are usually summary reports (Mechanic, 1978). Because different measures of stress have different temporal characteristics, convergence among multiple measures of stress may be low when taken at one point in time.

Multiple Stressor Levels

A major question about multiple stressors concerns the issue of examining the additive and multiplicative effects of environmental stressors. From a conceptual perspective, the concepts of convergent and divergent validity are very applicable here. If two or more environmental stressors operate through some similar mechanism (e.g., arousal levels or interference with control), then there should be some measurement convergence reflected by either parallel results between two different stressors or some additive effects when the two stressors are combined. Broadbent (1971), for example, reasoned that, if the effects of noise were due to overarousal, experimental treatments that reduced arousal (e.g., sleep deprivation, pharmaceuticals) should interact with noise at least partially to cancel out its effects on task performance. While Broadbent's data were generally consistent with his hypothesis, others have been less successful in finding additive effects when combining stressors that should each increase arousal (Finkelman, Zeitlin, Romoff, Friend, & Brown, 1979). At a more general level, the issue raised earlier about the degree of specificity (cf. Mason, 1975) or nonspecificity (cf. Selye, 1975) inherent in the stress concept is embedded in this issue as well. The degree to which individuals are vulnerable to stressors in general versus manifest stressor—specific vulnerabilities can also be examined by the analysis of individual and multiple stressor effects.

Both from a conceptual and a policy perspective, research on multiple stressors is important because of ecological covariation. Most sources of environmental stress covary in the natural environment. Crowding and noise, for example, or heat and air pollution frequently fluctuate together in the natural environment. From a policy standpoint we need to know whether and how much stressors interact to influence human health and well-being. Conceptually speaking, important theoretical questions are raised by suppression or amplification effects of interacting variables (cf. Winkel, Chapter 3, this volume). For example, biologists have developed explanations about the mechanisms of particle transport from the observation that sulfur dioxide effects are amplified by high humidity or the presence of ozone, a toxic component of photochemical smog.

Setting

Much has been written about the relative strengths and weaknesses of laboratory and field research settings (cf. Cohen et al., 1980; Patterson, 1977; Stokols, Chapter 2, this volume; Winkel, Chapter 3, this volume). Some of the concerns about settings are very salient for work on environmental stressors. The issue of realism is one very critical concern. If threat is an important component of stress, then participants' feelings about the validity of threat present in an experimental setting are critical (Cohen, 1981; McGrath, 1982). Most laboratory contexts minimize threat because of the implied if not explicit contract between the experimenter and the subject that no serious harm will befall him or her. Furthermore, experimental periods are usually of short duration and subjects are told that they can exit from the situation

at any time without penalty if they so choose. Thus most laboratory experiments provide subjects choice and some degree of control over aversive events (Gardner, 1978). On the other hand, some aspects of laboratory settings such as physiological recording equipment may also artificially increase threat or aversiveness of the setting.

The problem of realism is also affected by task variables. It is often difficult to simulate meaningful tasks that may be affected by sources of stress. Furthermore, as noted earlier, we typically have little knowledge of the cognitive processes involved in specific performance measures. This has prohibited the development of a performance-based taxonomy of tasks that would in turn allow us to assess, except at the grossest level (e.g., whether memory is involved), how particular tasks are related to one another. Reactivity may result from responses to tasks that are viewed as trivial or unrelated to the individual's concerns at work or in other realistic performance contexts.

Field settings are not a panacea for all of the problems associated with doing research on stress in laboratory environments. In the field one frequently has a problem of mutual selection, wherein those who could not cope well with a particular stressor have left, whereas those remaining have developed good coping resources to deal with the stressor (Cohen et al., 1981; McGrath, 1982). For instance, Cohen and his colleagues found in a longitudinal study of airport noise that individuals with the highest blood pressures at time 1 were more likely to be absent from the longitudinal sample, measured a year later. The myriad of potential methodological problems in the field should not be ignored, either. Self-selection of subjects into the setting as well as attrition can raise serious questions about causality. Adequate control groups can also be very difficult to construct.

Thus the issue is not one of the laboratory versus the field situation, but rather one of determining what factor(s) in each situation is important in influencing the stress and coping process. Stress researchers can ask questions such as: Are differences in length of exposure, perceived control (escape), feelings of importance about the setting, and so on likely to differ between the laboratory and the setting in which a particular environmental stressor is present? Probably the best methodological strategy is to examine the effects of environmental stressors in both field and laboratory situations. Reliable effects of stressors can be carefully charted in the laboratory and then validated under more natural conditions. Field research can suggest certain dimensions of the stressor that appear to be important, and laboratory work can rule out plausible rival hypotheses that exist in the field (Cohen et al., 1980).

Because individuals will vary in their sensitivity to various environmental demands, in the ways in which they appraise them, and in personal coping resources, stress will not invariably result when one or more aversive physical characteristics are present. Nonetheless, since stress is a function of environmental demands and individual coping resources, it behooves us to develop a more thorough description and analysis of the physical and social components of everyday situations that are likely to evoke the stress and coping process.

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