THE PERCEPTION OF TIME

In this brief final chapter, we deal with a unique perception resulting from the duration of events: the perception of the passage of time.

The nature of time pervades many areas of intellectual thought, particularly literature, philosophy, physics, and biology. It is no wonder, then, that the subjective perception of the duration of time is of special interest in psychology. It should be stressed that our interest here is not with the physical notion of time but rather with its perception—the duration of which one is aware. Indeed, the general notion of time concerns issues that go far beyond the limits of this text. Consider the religious philosopher St. Augustine's evasive reply to the enigmatic question "What is time?": "If no one asks me, I know what it is. If I wish to explain what it is to him who asks me, I do not know" (Trefil, 1991). However, he wrote more confidently, though still arbitrarily, about the origin of time, saying essentially that time comes from the future—which does not exist yet; it moves into the present—which has no duration; and it goes into the past—which no longer exists (cited with credit to Anthony Scariano, 1991).

The perception of the passage of time has been termed **protensity** to distinguish it from physical duration (Woodrow, 1951). Time perception is an oddity in that its variables seem more cognitive than physical or neural.

Clearly, there are no obvious sensory receptors or organs mediating it, nor are there any direct, observable sensations emanating from specific time-relevant stimuli. Indeed, "duration" does not have the thing-like quality of most physical stimuli. As Fraisse (1984) observes, "Duration has no existence in and of itself but is the intrinsic characteristic of that which endures" (p. 2).

These points, stressing the elusive nature of time experience, are cleverly elaborated by Hans Castorp, Thomas Mann's protagonist in The Magic Mountain:

> . . . what is time? Can you answer me that? Space we perceive with our organs, with our senses of sight and touch. Good. But which is our organ of time . . . how can we possibly measure anything about which we actually know nothing, not even a single one of its properties? We say of time that it passes. Very good, let it pass. But to be able to measure it . . . to be susceptible of being measured, time must flow evenly, but who ever said it did that? As far as our consciousness is concerned it doesn't, we only assume that it does, for the sake of convenience; our units of measurements are purely arbitrary, sheer conventions. (1927, p. 66)

As we shall see, there is good reason to assume, along with Fraisse and Mann, that time is not an immediately given property but is per-

ceived indirectly: in other words, "time is a concept, somewhat like the value of pieces of money, that attaches to perception only through a judgmental process" (Woodrow, 1951, p. 1235).

Two main explanations will be examined— the biological basis and the cognitive basis of time perception. These two explanations are neither mutually exclusive nor exhaustive.

THE BIOLOGICAL BASIS OF TIME PERCEPTION

The cyclical nature of many bodily processes is well known. A clear example in the human is body temperature variation. There is about a 1.8°F difference in human temperature between the minimum at night and the maximum in the afternoon. For most animals, many recurrent bodily changes and activities—such as temperature variations and the patterns of feeding and drinking—reflect a fundamental adaptation to the daily solar cycle of day and night. Activity patterns that regularly recur on a daily basis are termed **circadian rhythms** (from the Latin words, *circa*, "about," and *diem*, "day," because the cycles approximate 24 hours; with exogenous conditions carefully controlled, Czeisler et al., 1999, calculates the average human circadian rhythm to be 24.18 hours; see also Moore, 1999).

The body's circadian rhythms appear to be regulated mainly by exposure of the retina to light. (Note, however, that blind individuals are also subject to circadian rhythmicity, which attests to the role of basic, endogenous, nonphotic influences; see Schibler, 2000, and Whitmore et al., 2000.) Retinal signals then travel through a special tract in the optic nerve to a clump or nucleus of brain cells of the hypothalamus (situated just above the optic chiasm) called the *suprachiasmatic nucleus* that serves as a pacemaker to regulate the circadian, temporal organization of many bodily activities (Dunlap, 2000; Jagota et al., 2000). From there the neural signals proceed to the *pineal gland*, a tiny structure located beneath the brain at the top of the brain stem. The pineal gland reacts directly to the presence and absence of light: it produces a hormone called *melatonin*, whose secretion is inhibited by light and stimulated by darkness. (For this reason, it is sometimes referred to as the "Dracula" hormone; see Lewy et al., 1980; see also Barrera-Mera & Barrera-Calva, 1998.) Melatonin synchronizes the activity of certain organs and glands that regulate daily biological cycles. In particular, it depresses body temperature and facilitates sleep onset. Interestingly, there is

evidence that the visual subsystem that mediates the light-induced suppression of melatonin secretion by the pineal gland remains functionally intact even in blind individuals (Czeisler et al., 1995). Finally, while exposure to light regulates the human endogenous circadian clock, the light does not have to stimulate the retina. Campbell and Murphy (1998; see also Oren & Terman, 1998) report that high-intensity light pulses applied to the region behind the knee rich in blood vessels can also affect circadian rhythms. The mechanism by which this is effected remains unknown.

The tendency of certain periodic changes in the natural environment to affect bodily rhythms and induce a behavioral reaction may provide a biological advantage for some species. For example, the roosting behavior of birds when the sun sets is adaptive since birds are then essentially sightless and hence defenseless in dim lighting. The almost total physical inactivity characteristic of roosting serves as an evasive reaction to potential predators. Similarly, the hibernation of many mammals is an adaptive response to the drop in temperature of winter—when food is scarce and energy demands are immense.

Given the ample evidence of biobehavioral cyclical activity, it is reasonable to seek in the nervous system a **biological clock** mechanism for perceiving time (Hoagland, 1933, 1935; Holubár, 1969; Treisman, 1963; Matell & Meck, 2000). The concept of an internal time sense assumes that there is a continuous and automatic biological rhythm, not easily or directly influenced by external stimulation, with which the organism compares the duration of stimuli or events. Periodic events with measurable frequencies are found in the electrical activity of the brain, the pulse and heartbeat, respiration, metabolic and endocrine function, thermal regulation, and general activity cycles (although many of these would not be good reference rhythms because they are so markedly and easily affected by external stimulation, and hence can vary widely). The effects of some of the more stable of these internal activities and processes on time perception have been studied. In particular, the effect of temperature and metabolic

processes on the passage of time has led to a biologically based explanation of time perception.

## Hoagland's Hypothesis: The Biological Clock

Hoagland (1933, 1935) attempted to develop a theory based on an internal biological clock. He reportedly began his work when his wife became ill and developed a high fever. After she made a significant misjudgment of time, he explored the possibility that her fever had affected her sense of time. Hoagland then had her estimate the passage of time by counting to 60 at what she felt was a rate of one count per second. Relating this measure of her subjective minute to her oral temperature, he found the relationship between body temperature and time perception shown in Figure 19.1. Specifically, he found that a subjective or judged minute was shorter at higher temperatures than at lower ones. For example, reading directly from Figure 19.1, when body temperature was at 98°F, the passage of about 52 sec was judged equal to a minute, whereas when body temperature was at 101°F, an interval of only about 40 sec was judged equal to a minute. In both instances (i.e., judging the passage of 52 or 40 sec as equal to a minute), Hoagland's wife was *overestimating* the duration of time. However, as Figure 19.1 indicates, the overestimation increased with body temperature. Hoagland reasoned from

this that an increase in body temperature speeds up bodily processes and causes overestimation of the passage of time. It follows, according to **Hoagland's hypothesis,** that there is a biological clock in the brain that regulates the body's rate of metabolism, which, in turn, affects perception of the passage of time.

Many studies support Hoagland's hypothesis that an internal biological clock accelerates when body temperature is raised. A number of investigators have found that subjects overestimated the passage of time when their body temperature was raised (Thor, 1962; Kleber et al., 1963; Pfaff, 1968; Hancock, 1993; see also the review by Wearden & Penton-Voak, 1995).

It follows that time perception when body temperature is reduced should have the opposite effect. It should slow down bodily processes (and the presumed internal biological clock) and thus result in an *underestimation* of the passage of time. Baddeley (1966) tested this theory with scuba divers in cold water (4°C or 39°F) off the coast of Wales in March. Before and after the temperature of the subjects was lowered by a scuba dive, they estimated time by counting (to themselves) to 60 at what they felt was a rate of 1 per second (as did Hoagland's wife). The results pertinent to our discussion are shown in Table 19.1. Clearly, the subjects were colder after their dive and, in agreement with Hoagland's hypothesis, counted more slowly than they did before the dive and thus underestimated time.

Most studies investigating time perception in conditions where body temperature is raised or lowered indicate a reliable affect of body temperature on temporal experience (Wearden & Penton-Voak,
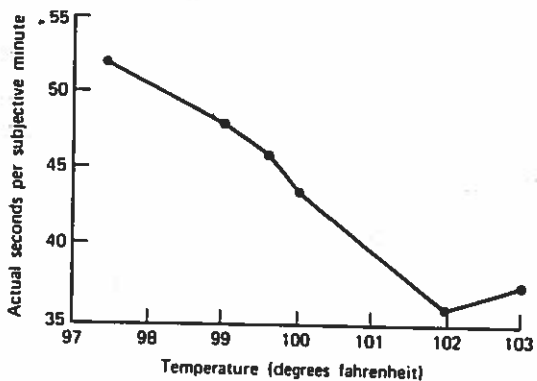
figure 19.1 The relationship between body temperature and the actual number of seconds in an experienced or subjective minute. As temperature increases, fewer seconds are required for a subjective minute; hence, time is overestimated. (*Source:* Based on data in Hoagland, 1933.)

table 19.1 Mean Body Temperature and Time Judgment in Cold Water

	Oral Temp. (°F)	Time Judged as 1 min (sec)
Before diving	97.39	64.48
After diving	95.03	70.44*
Difference	2.36	−5.96

*Note that after diving the subjects required 70.44 sec to count to 60; that is, they judged the passage of 70.44 sec to be equal to a minute. Thus, the lowered temperature produced an underestimation of time.

Source: Based on Baddeley (1966).

1995). Note, however, that some studies found no consistent relationship between time perception and body temperature, making a firm conclusion problematic (e.g., Bell, 1965; Bell & Provins, 1963; Lockhart, 1967; see also the analysis of Wilsoncroft & Griffiths, 1985).

Our discussion suggests that variations in body temperature may influence the timing of a presumed internal biological clock by speeding up or slowing down bodily processes. In the next section, we examine the effects on time perception of another factor that influences the rate of bodily activity: drugs.

Drugs and Time Perception

There is compelling evidence that certain drugs influence the experience of time. Frankenhauser (1959) and Goldstone et al. (1958) found that amphetamines lengthen time experience (i.e., promote an overestimation of time). Frankenhauser reported the same effect with caffeine. By contrast, pentobarbital, a sedative, had no such effect. Shortening of time experience has been observed with nitrous oxide (Steinberg, 1955) and other anesthetic gases (Adam et al., 1971). A general rule, according to Fraisse (1963), is that drugs that *accelerate* vital functions lead to an *overestimation* of time (i.e., lengthen time experience), and those that slow them down have the reverse effect.

Among the most striking effects on time perception are those that occur with the administration of so-called psychedelic drugs (marijuana, mescaline, psilocybin, LSD, etc.). Generally, these drugs dramatically lengthen the perceived duration of time (e.g., Conrad et al., 1972; R. Fisher, 1967; Weil et al., 1968). However, whether the psychedelics produce their effect directly, by influencing an endogenous biological clock, or indirectly, by altering various bodily processes, is not clear. Moreover, most of these drugs appear to increase awareness and alertness, which could also influence temporal experience. We will consider the implications of this point shortly.

COGNITIVE THEORIES OF TIME PERCEPTION

A very different perspective of time experience is that it is the outcome of cognitive activity. Specifically, experience of the passage of time is assumed to be a cognitive construction, a derived product of mental activity based on the nature and extent of the cognitive processing performed during a given interval of time. Several such cognitive theories of temporal experience have been proposed (e.g., Block, 1990; Gilliland et al., 1946; Kristofferson, 1967; Michon, 1966; Thomas & Weaver, 1975), but of all the cognitive approaches, one of the earliest, most representative, and widely studied one is that proposed by Robert Ornstein (1969).

Ornstein's Theory: Information-Storage Size

Ornstein (1969) adopts an information-storage size or memory approach to time perception, assuming that perceived time duration is based on the contents of one's memory. The basic premise of his theory is that the amount of information picked up consciously and stored in memory determines the perceived length of time. According to this view, time experience is derived or constructed from the storage of cognitive events. Relating his central theme to a *computer metaphor*, Ornstein comments:

> *If information is input to a computer and instructions are given to store that information in a certain way, we can check the size of the array or the number of spaces or number of words necessary to store the input information. A more complex input would require a larger storage space than a simpler. An input composed of many varied items would similarly require more space than more homogeneous input. ... In the storage of a given interval, either increasing the number of stored events or the complexity of those events will increase the size of storage, and as storage size increases the experience of duration lengthens. (p. 41)*

Time perception, examined this way, can be easily analyzed. According to Ornstein's **information-storage size theory,** stimulus factors such as the number and complexity of events occurring during a span of time, along with the efficiency of coding and storage of the events, affect the amount of information that must be processed. Thus, these factors strongly affect the experience of the passage of time. For example, increasing the number and complexity of the events in a given period of time demands increased information processing and should thus lengthen the perceived duration of that time. In

the next section, we examine the influence of several of these variables on time perception.

Number of Events Ornstein (1969) reported that duration experience is linked directly to the *number* of events in a given span of time. In one experiment, subjects were exposed to constant intervals of time (9 min, 20 sec), but the intervals varied in the number of stimuli they contained. Intervals were composed of sounds that occurred at the rate of either 40, 80, or 120 times per minute. As expected, increasing the number of stimuli (or the number of stimulus changes) within a constant period of time lengthened the perception of its duration. Specifically, the 120-sounds-per-minute interval was judged longer than the 80-sounds-per-minute interval, and both were judged longer than the 40-sounds-per-minute interval (see also Boltz, 1998, for related findings using melodic stimuli). The effect of the number of events within a given duration have also been confirmed in the visual (Mescavage et al., 1971; Mo, 1971; Schiffman & Bobko, 1977) and tactual modalities (Buffardi, 1971). In short, durations with more elements were judged longer than durations with fewer elements. (This was also found in children as young as 6 years of age: see Arlin, 1989.)

Kowal (1987) reported an interesting finding based on estimates of the duration of melodies. She found that sequences of musical notes that were judged to be more familiar, predictable, and organized were estimated as longer than their reverse melodic counterparts (i.e., the same melodies played backward). Although these results appear inconsistent with Ornstein's information-storage size notion, Kowal also found that the familiar sequences were perceived to have far more notes than the unfamiliar sequences. Hence, Kowal's findings are consistent with the information-storage size notion that time perception varies positively with the *number* of events or elements *perceived* within an interval. Similarly, Poynter and Homa (1983) and Block (1989) reported a positive relationship between duration estimations and the number of stimulus *changes* that occur within an interval of time.

Filled versus Unfilled Intervals Also consistent with the general relationship between numerosity and time perception is the problematic, but well-documented, observation that "filled" time intervals—containing stimuli such as sounds and lights—are typically judged longer than "empty" intervals—consisting only of a period of time between two bounding signals (e.g., Gomez & Robertson, 1979; Long & Beaton, 1980; Thomas & Brown, 1974; Thomas & Weaver, 1975).

In an offhand way, however, this situation also helps explain the lengthened time experience (and overestimation) of the "empty" interval when one is anxiously waiting for something to happen—for example, the receipt of an important letter, a person's arrival, or the results of a test. The lengthening of time experience in such cases is attributed to the cognitive–emotional effects of anticipation or expectation. Expectancy leads to increased vigilance by the individual, so that there is more "awareness of temporal input" and consequently a lengthening of perceived duration (Block et al., 1980; Cahoon & Edmonds, 1980; Ornstein, 1969; Zakay, 1993). This situation, in which the individual is waiting for an event to occur, is well summarized by the maxim "A watched pot never boils." (We will return to this phenomenon in a later section.)

In summary, then, an empty interval of time contains less information to process than a filled interval; hence, in comparison, it may be experienced as briefer. However, passively experiencing an empty interval of time can also increase the awareness of the passage of time and correspondingly lengthen time experience. It thus appears that, depending on the nature of the situation and the task, an empty interval may be experienced as either longer *or* shorter than a filled interval of equal duration (see Boltz, 1991; Grondin & Rousseau, 1991; Grondin, 1993; Rammsayer & Lima, 1991; Zakay & Block, 1997).

Stimulus Complexity Ornstein (1969) and others (e.g., Schiffman & Bobko, 1974) have examined the effect of varying the *complexity* of the stimuli during an interval on the perception of time. Generally, time seems to increase as the complexity of the stimuli increases. This was the case when the stimuli presented to subjects during the interval were various visual shapes (whose complexity was based in the number of interior angles), as well as when the stimuli consisted of sounds of varying complexity. A similar effect on time experience was observed when subjects listened to melodies that varied in complexity: Complex melodies were judged longer than simple ones (Yeager, 1969).

Boltz (1998a) has identified a related variable that appears to influence the perception of time: the familiarity and predictability of tasks performed during a given time interval. When a task is a familiar,

highly structured, and predictable one so that the individual knows in advance what to expect and what sequence of activities must be performed to successfully complete the task—say, for example, the task of a postal worker delivering mail in a set routine, or shopping down the aisles of a familiar food store, or taking apart or putting together a familiar gadget—time perception is relatively accurate. In contrast, when the task is an unfamiliar one, and the sequence of activities required of the task is not predictable, so that the individual is uncertain as to what to expect—as when first learning the steps involved in performing a complex perceptual-motor task such as learning to drive a car—the perception of the time elapsed during the performance of a given task is overestimated.

Organization and Memory

According to the information-storage size notion, perceived duration is also affected by how information presented within an interval is organized (i.e., coded and stored in memory) and by the amount of stimulus information retained. It follows that the more information retained from a given interval, the longer its apparent duration. Relevant to this matter, Ornstein (1969) found that unpleasant stimuli are more poorly retained than neutral stimuli, and unpleasant events are judged to be shorter. It is common experience that pleasant or interesting events are regarded later on as longer than they actually were. The reason may be that these events are better retained than uneventful, ordinary events; hence, compared to ordinary events, they seem longer.

Mulligan and Schiffman (1979), in a direct approach to the role of organization and memory in altering apparent duration, reported evidence in support of this aspect of Ornstein's information-storage size theory. In one experiment, they presented the ambiguous line drawing of Figure 19.2 for a fixed time interval, telling the subjects to study and remember the figure. The time interval was judged shorter if it was preceded or followed by a simplifying cue—a descriptive verbal label or caption—than if no cue was provided. In other words, the clarifying cue reduced the ambiguity of the figure and thus made it easier to recall. These results support the assumption that the cue, even when presented *after* the figure, makes it easier to store the figure in memory. Thus, intervals containing stimuli that are well organized in memory—requiring less information storage—are judged shorter than intervals in which the same stimuli are less organized.
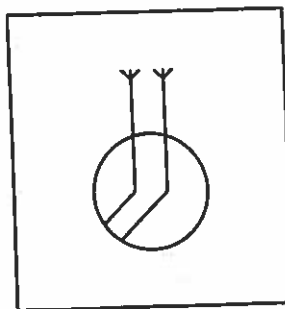
□ *figure 19.2* Ambiguous line drawing used by Mulligan and Schiffman (1979). The cue for reducing the figure's ambiguity is "an early bird who caught a very strong worm."

An interesting implication of the role of memory on perceived duration comes from a variation of the classic Gestalt *Zeigarnik effect* in which finished tasks are recalled less well than unfinished ones (Zeigarnik, 1927). Most students have probably verified this in a casual way after taking a timed examination composed of brief, varied items such as multiple-choice or fill-in questions. The items most likely remembered after the test are usually the ones that were uncompleted or whose answers students were unsure of (i.e., "cognitively incomplete"). Thus, since memory is better for uncompleted tasks than for completed tasks, the duration of uncompleted tasks should also be perceived as longer. In support of this idea, N. Schiffman and Greist-Bousquet (1992) found that subjects who were prevented from completing a series of simple tasks perceived them to be longer than did subjects who were allowed to finish (see also Fortin et al., 1993).

Before turning from Ornstein's information-storage approach to time perception, we should note that his approach is not the first to deal with temporal experience as principally a cognitive phenomenon (e.g., see Gilliland et al., 1946; Kristofferson, 1967; Michon, 1966.) Nor is it the only cognitive approach to time perception, as evidenced in the next section.

Cognitive–Attentional Theory

An alternative to Ornstein's storage model of time perception—and one that appears to be at the forefront of cognitive approaches—holds that the *focus of attention* directly affects temporal experience. Ac-

cording to this **cognitive–attentional theory**, attention is divided between two independent processors: (1) a nontemporal **information processor** that deals with ongoing cognitive events and (2) a **cognitive timer** that processes and encodes temporal information (see Thomas & Weaver, 1975; Underwood, 1975; Zakay, 1989, 1993). Thus, in a typical temporal task, observers divide their attention between the information-processing demands of the task and the processing of time information specific to the time span to be evaluated. Since both processors compete for a limited pool of attentional resources, it follows that the relative amount of attention given to these two processes directly determines the nature of the time experience. The perception of time *increases* with heightened temporal awareness and *shortens* with attention to nontemporal information processing. Based on this notion, temporal experience is directly related to the amount of *attention* focused on the passage of time. As Fraisse (1984) observes: "The more one pays attention to time, the longer it seems. . . . Reciprocally, duration seems short when the task is difficult and/or interesting" (p. 31).

This approach lends itself to a number of laboratory and common situations. Thus, the perception of an empty time interval noted earlier (with few or no sensory events or stimuli) may seem longer than a filled interval with attention-demanding stimuli (see Hogan, 1978). According to this notion, when dealing with a stimulus-filled interval of time, more attention is directed to meeting the cognitive demands of the task and less is allotted to the cognitive timer, minimizing temporal awareness. As a result, time seems to pass quickly. This is also supported by evidence that making the task more difficult seems to shorten the time (Brown, 1985; Hogan, 1978; Zakay & Fallach, 1984; Zakay et al., 1983).

With absorbing activities requiring effort (e.g., problem solving, test taking), there is an increase in information processing and a resultant decrease in temporal awareness. Therefore, time seems to pass rapidly. In contrast, when waiting in line, performing repetitive, boring tasks, or experiencing the "watched pot" phenomenon (introduced earlier and explained in an alternative way by Ornstein's emphasis on the "awareness of input"), there is less information processing and more attention to the cognitive timer. The result is a greater temporal awareness—"time seems to weigh more heavily"—and temporal experience accordingly lengthens. The

more attention you pay to the passage of time, the longer it seems to be.

This analysis may also apply to the familiar experience summarized by the statement "time flies when you're having fun." In such cases, attention is focused more on the activities in which one is engaged—on nontemporal information processing—than on the cognitive timer, and temporal awareness is reduced. So with less attention allotted to the passage of time (i.e., the cognitive timer), temporal experience is decreased (Mattes & Ulrich, 1998). Indeed, it seems that almost anything that draws our attention from monitoring or attending to the passage of time reduces the perception of time. J. B. Priestly's (1968) somewhat impressionistic commentary summarizes this point:

> as soon as we make full use of our faculties, commit ourselves heart and soul to anything, live richly and interestingly instead of merely existing, our inner time spends our ration of clock time as a drunken sailor his pay. What are hours outside seem minutes inside. (pp. 41–42, cited in Hogan, 1978, p. 419)

Biological versus Cognitive Basis of Time Perception

To review, there appears to be some relationship between bodily activity and a time sense. Similarly, the time perception of complex events is under certain cognitive influences. How can we resolve the discrepancy between the two explanations? It should be pointed out that the temporal experiences and responses assessed by experiments that support a biological clock basis of time perception are generally very different from the experiences employed in experiments supporting time perception based on cognitive processes. The biological clock type of experiment often employs brief intervals and uses response measures such as tapping or counting at the rate of one per subjective second. Perhaps the perception of very short intervals invokes very different psychological or physiological processes from those employed in the perception of longer intervals. It may be that with very brief intervals the individual focuses primarily on the time experience itself, which thus reflects the effect of physiological rhythms (e.g., Matell & Meck, 2000), whereas for longer intervals judgments rely more on indirect sources of the passage of time such as the number and complexity of activities being performed. With

increases in duration, memory and other, less specifiable cognitive processes are more likely to be engaged (e.g., Ferguson & Martin, 1983; Fortin et al., 1993). If this is the case, then both types of explanations may be drawn upon, depending on the duration experienced. The biological explanation can most usefully be applied to very brief intervals, whereas longer intervals, perceived less directly and with greater reference to external events and nontemporal factors, fall under a cognitive explanation.

The possibility should be kept in mind, however, that decidedly cognitive variables (e.g., numerosity, complexity, and attentional requirements of a task) may also exert a significant influence on estimates of short intervals of time. Moreover, using very brief intervals may induce a different relationship among the temporally sensitive variables than using moderate or relatively long intervals (Poynter & Homa, 1983). Similarly, biological factors may also influence the experience of long time intervals (Zakay & Block, 1997). Therefore, conclusions about the relation between cognitive variables and time experience must be qualified in terms of the kinds of intervals examined.

The psychological experience of time depends on complex interactions among the conditions under which the passage of time is perceived as well as on how the estimation is given (Boltz, 1998c). Not only may the duration of the time interval to be estimated determine the relative influence of endogenous or cognitive processes, but there are a number of variables (some of which have been introduced earlier) that may impact on both biological and cognitive mechanisms to affect the perception of time. Among these are how one measures and extracts duration estimates; the activity performed during the time span; the sensory modality that is addressed (e.g., intervals of time filled with sounds are judged longer than are identical time intervals filled with light stimuli; see Wearden et al., 1998 and Mattes & Ulrich, 1998); whether subjects are made aware that a time estimation will be extracted for a given duration prior to, or only after the duration has been experienced (referred to as *prospective* versus *retrospective* time estimations, respectively; Boltz, 1998 a,b,c, and Zakay & Block, 1997 elaborate on this variable); gender, personality traits, level of stress and arousal, and the age of the individual. This last variable—the effect of *age* on time perception—appears to affect all individuals and warrants a brief discussion.

AGE AND THE PASSAGE OF TIME

Both biological and cognitive effects can contribute to the perception of time. Interestingly, *age* is a variable that may involve both biological and cognitive effects on the perception of long intervals of time. Almost everyone senses that as they age annual events such as holidays and birthdays seem to occur more and more rapidly. It is a common and often perplexing and dismal observation that as we grow older time seems to pass more swiftly.

Why does a year (or any large unit of time) seem to pass by faster as we age? One possible explanation is that we automatically perceive the passage of long intervals—such as the time between birthdays or holidays—relative to the total amount of time we have already experienced. In other words, one's lifetime serves as a *reference level* for the perception of a given time span (see Joubert, 1983; Lemlich, 1975; Walker, 1977). So the duration between annual events (e.g., birthdays) is perceived relative to one's age. For example, the passage of a year to a 4-year-old represents 25% of the child's lifetime; this is a substantial amount and is experienced as a relatively long time. In contrast, the passage of a year to a 60-year-old person represents a very small fraction of the person's life (1/60th, or less than 2%. Accordingly, in comparison to the temporal experience of the child, it seems to pass quickly. Although the awareness of the acceleration of experienced time with advancing age is most obvious with large time spans (e.g., the passage of a month, or a season—especially the summer—or the time between birthdays), Craik & Hay (1999) report that an age-dependent underestimation of time (i.e., time passing faster) also applies to the experience of relatively short duration (i.e., time intervals of 30 to 120 sec).

Numerous neurological and physiological changes occur during the normal aging processes that may have a direct or indirect impact on the perception of time. Perhaps some biological pacemaker slows progressively with increasing age (e.g., Schroots & Birren, 1990). Mangan et al. (1997) suggest that the gradual reduction of the neurotransmitter chemical dopamine is a causative factor in the age-related change in temporal experience. Although the level of dopamine decreases throughout adulthood, the effects are most apparent beginning in the fifth decade of life—which is also when most

individuals recognize that they are typically under-estimating the passage of time, that is, that time seems to be passing at a faster rate than it did when they were younger. (See also Lalonde & Hannequin, 1999).

No matter what ultimately turns out to be the cause of experienced time apparently passing more swiftly with age, it is clear that our awareness of the passage of time and our imperfection in accurately judging its passage begin relatively early. Sherman (1996) captures this point well in the following somewhat poetic excerpt from his essay on the experience of time in the classroom:

> *From the schoolroom clock, students absorb a lesson, early and sustained, in the ordinary relativity of human time. Imperturbably, . . . the instrument doles out the real duration of seconds, minutes, and hours, giving clues all the while to their inner elasticity. The hands can seem to speed up or to stand still. Either way, their eager consultant learns to expect no simple correspondence between time felt and time told. (p. 35)*

TIME PERCEPTION AND THE SIZE OF THE SPATIAL ENVIRONMENT

A. J. DeLong (1981) proposed an **experiential space–time relativity** notion wherein space and time are related to each other, each being a psychological manifestation of the same phenomenon. According to this notion, modifying the size of the components that one interacts with should affect our perception of time. Bobko et al. (1986) tested this notion by having groups of subjects interact with two-dimensional visual environments of different sizes and then estimate how long it took. Display size was varied by using three sizes of television screens, with diagonals of 0.13, 0.28, and 0.58 m. Different groups of subjects viewed each screen and engaged in a modified video game that was constant for all screens and fixed in duration at 55 sec. The video game itself was constant, but the *size* of the images comprising the game varied directly with video screen size.

Subjects' verbal estimates of the 55-sec duration were found to depend on display size. This is shown in Figure 19.3, where time estimations are plotted against screen size. Note that the estimated time plotted on the *y*-axis is a derived score in
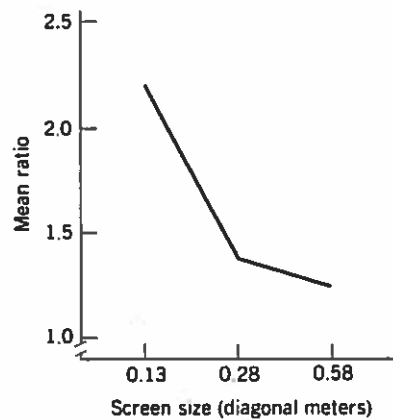

□ **figure 19.3** Mean ratios of verbally estimated time interval to actual interval (55 sec), plotted by viewing screen size. According to this conversion, ratios of 1.00 show perfect estimation, and ratios above 1.00 represent an overestimation of the interval ("time passes slowly"). (*Source:* Based on Bobko et al., 1986.)

which each estimation was converted to a ratio of the verbally estimated duration of the interval to its physical duration (i.e., 55 sec). Accordingly, ratios of 1.00 reveal perfect judgment, and ratios above 1.00 reflect an overestimation of the interval (i.e., a lengthening of perceived time or "time passes slowly"). The 55-sec interval was overestimated for each screen size, and the magnitude of the overestimation *increased* as display size *decreased*. Thus, the constant 55-sec duration was experienced as *longest*—2.3—when viewing the *smallest* visual environment, the 0.13-m video screen. In other words, clock or physical time is experienced as longer when the observed environment is *compressed*. The smaller the size of the visual environment, the greater the apparent duration.

Mitchell and Davis (1987) similarly found an inverse relation between the size of model environments (consisting of model railways, living rooms, and abstract nonrepresentational interiors) and apparent duration. Smaller environmental size was related to a compression of subjective time relative to physical time. Overall, it appears that environmental size affects perceived duration. Although we have no convincing explanation for this relationship, perhaps, as Mitchell and Davis suggest, subjective time compression is related to differences in the *density* of the information to be processed in environments

Forearm
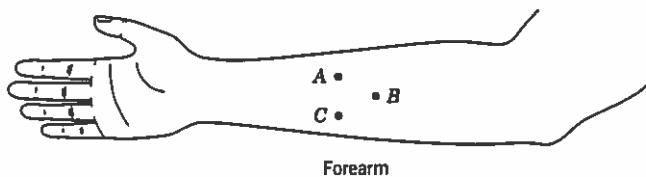
⇒ *figure 19.4* The tau effect. See text.

of different sizes. Clearly, experienced time and space vary together in a consistent fashion. Two further manifestations of this interdependence are given next: *tau* and *kappa* effects.

TIME AND DISTANCE: THE TAU AND KAPPA EFFECTS

Tau Effect

A close relationship between experienced time and the performance of certain activities exists: Each can influence the other. For example, in certain conditions the manipulation of time can affect the perception of distance and variation in distance, can influence the perception of time. The effect of time on the perception of distance is called the **tau effect.** An example of the tau effect attributed to Helson and King (1931) is shown in Figure 19.4. Three equidistant points (*A*, *B*, *C*) on the forearm of a subject are stimulated in succession (i.e., forming a tactual equilateral triangle). However, if the interval of time between stimulation of the first point (*A*) and the second point (*B*) is greater than that between the first (*A*) and third (*C*) points, the subject will perceive the *distance* between the first and second points as greater than that between the first and third points. Thus, the greater the time interval between successive stimulations, the greater the perceived distance. So if an observer is judging two equal distances, the distance defined by the longer interval of *time* will appear to be longer. A similar tau effect has been demonstrated in vision (Abbe, 1937) and in audition (Christensen & Huang, 1979).
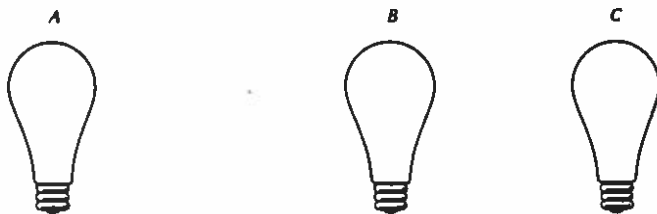
Kappa Effect

The converse effect, in which time perception is influenced by the manipulation of distance, has also been identified and termed the **kappa effect** (Cohen et al., 1953, 1955; Huang & Jones, 1982; Jones & Huang, 1982). Consider two equal temporal intervals defined by the onset of two successive stimuli (e.g., three lights arranged in a row, as in Figure 19.5). If the distance between the first and second stimuli is greater than that between the second and third, the first interval will be perceived as longer. A kappa effect also has been shown with audition (Cohen et al., 1954) and with touch (Suto, 1955).

SUMMARY

In this final chapter, we examined the perception of time or protensity. Two main explanations were reviewed. The biological approach to time perception is linked to the cyclical nature of many bodily processes, such as temperature variation, and general metabolic activities. Its basic assumption is that an internal biological clock controls the speed of metabolic processes and time experience.

The second explanation contends that time perception depends on the kind and degree of cogni-

⇒ *figure 19.5* The kappa effect. See text.

tive processing and the attentional focus of the individual. According to a major version of this notion (Ornstein's information-storage size theory), perceived duration depends on the contents of mental storage. Thus, the amount of information picked up and stored in memory determines the perception of the time interval. Several stimulus factors that seem to affect information storage, and hence time perception, were examined: the number and complexity of events occurring within a time interval, empty versus filled intervals, stimulus organization, and memory.

An alternative cognitive–attentional approach to Ornstein's theory was also outlined, which holds that attention is divided between two processors: an information processor and a temporal processor. According to this notion, the less attention paid to information processing and the more attention directed to the passage of time (e.g., "endlessly" waiting in line), the greater the temporal experience. By contrast, when attention is focused on an absorbing task (e.g., solving problems, taking a test), temporal experience shortens.

We briefly discussed the familiar experience that time appears to pass more quickly as we age. We speculated that the passage of long intervals of time (such as between birthdays and holidays) is perceived relative to the total time already experienced. One's lifetime serves as a reference level for the perception of a given period of time.

Next, the effect of the size of the spatial environment on time perception—experiential space–time relativity—was briefly described. The smaller the visual environment, the greater is the apparent duration. An experiment analyzing this principle by employing visual displays of different sizes was outlined.

In the final section, we considered the relation of time perception to the spatial variable of distance. The tau effect refers to the effect of duration on perceived distance; the kappa effect refers to the effect of physical distance on perceived duration.

KEY TERMS

STUDY QUESTIONS

1. Distinguish between physical time and protensity. What sensory structures and physical processes may mediate the subjective experience of time? Examine the possibility that the experience of time is derived immediately from perception.

2. Identify periodic or cyclic variations in bodily processes, including circadian rhythms that could serve as a biological clock.

3. Outline Hoagland's biological clock theory of time perception and summarize the evidence in its support. How does variation in body temperature affect time perception?

4. Summarize the effects of stimulant and depressant drugs on the experience of time.

5. Outline Ornstein's information-storage theory of time perception and indicate how it incorporates the effects of biological variations. Identify and examine the information-processing demands that influence time perception. Describe the effect of the number of events, stimulus complexity, and the role of memory.

6. How does the cognitive–attentional theory compare to Ornstein's storage model? Describe how the allocation of attention affects time experience. What is the cognitive timer?

7. Based on the cognitive–attentional theory, explain the experiences summarized in the statements "A watched pot never boils" and "Time flies when you're having fun."

8. Explain why time seems to pass by faster as we get older.

9. Discuss the effect that the apparent size of the spatial environment has on time perception. What is experiential space–time relativity?

10. Describe the tau and kappa effects.