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8 Time and Consciousness

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1 Introduction: Approaches to Time and Consciousness

Consciousness is permeated by a succession of temporally-defined events and temporal relationships between events. Stated somewhat differently, "the nature of experience itself is far more involved with time than anything else" (Orme, 1969, p. 2). For this reason, it is not surprising that theoretical and empirical work on time and consciousness was done by some of the first psychologists in the late 1800s and that the topic is currently receiving increasing interest. Most psychological studies of consciousness were conducted either before 1920 or after 1960 (Ornstein, 1977), but the annual number of psychological studies of time shows a fairly continuous acceleration (Zelkind and Sprug, 1974). Notable psychological attempts to relate time and consciousness include those by James (1890), Boring (1933/1963), Schaltenbrand (1967) and Ornstein (1969, 1977).

This chapter presents a selective review of relationships between consciousness and several related kinds of temporal experience, such as simultaneity and successiveness, short temporal experiences, longer temporal experiences and temporal perspective (cf. Ornstein, 1969). The emphases are on empirical evidence and theories based on such evidence. The review includes a consideration of temporal experience in both "ordinary" waking consciousness and several categories of altered states of consciousness. There are many possible approaches to the study of time and consciousness, but this review assumes a cognitive, or information processing, approach. Cognitive approaches to temporal experience have been promoted by James (1890), Boring (1933/1963), Frankenhaeuser (1959), Fraisse (1963), Ornstein (1969), Michon (1972) and many others. Cognitive approaches to consciousness have been promoted by many other theorists in recent years (see

Ch. 7). Abundant evidence suggests that a cognitive approach is the most parsimonious and integrative approach to take in relating consciousness and temporal experience.

In the literature on temporal experience, a persistent controversy has revolved around the relative merits of "internal-clock" and "cognitive" approaches (Michon, 1972; Ornstein, 1969). Most theorists have argued that one of these two kinds of approaches is necessary and sufficient to explain temporal experience, while the other is neither necessary nor sufficient; however, different theorists do not agree on which approach is better. One cause of the nearly exclusively dichotomous reasoning has been the rather implausible assumptions made by both kinds of theorists. Some internal-clock theorists have assumed that one simple biological (usually, neural) mechanism underlies all human temporal experience. On the other hand, some cognitive theorists have assumed that biological processes play little or no role in temporal experience.

Internal-clock theories have roots in older philosophical and psychological discussions of the "time sense", but almost all recent varieties of them have been influenced by the seminal work of François (cited by Hoagland, 1933) and Hoagland (1933, 1951). In Hoagland's words:

> Measurements of the estimations of short durations indicate the existence of a master chemical clock of a specific nature. . . . Longer intervals of time appear to be judged in terms of the velocities of other master chemical reactions . . . which determine cyclic diurnal rhythms. Large scale conceptions of duration evidently depend upon slowly accumulating irreversible effects in the internal environment composing the body humors.
>
> (Hoagland, 1933, p. 283)

Hoagland's only assertion that is directly supported by his evidence is that a master chemical clock mediates estimations of short durations. His data, which are remarkably shabby considering the specific nature of his assertions, were obtained from just three subjects. All showed increased body temperature, two as a result of influenza and one as a result of diathermy. When asked to count at the rate of 1 per sec, they counted more rapidly as body temperature increased.

Since Hoagland's original proposal, many researchers have engaged in a fruitless search for a specific internal-clock mechanism. However, only Hoagland's assertion regarding short durations has received much empirical testing. Some experiments in which body temperature was either manipulated, or observed during normal diurnal variation, support an internal-clock hypothesis, while others do not (O'Hanlon *et al.*, 1974; Ornstein, 1969). Inconsistent findings have also been

reported in studies of heart rate (Bell and Provins, 1963), cortical alpha rhythm frequency (Legg, 1968) and other physiological variables. Generally, studies measuring counting, tapping, handwriting and other motor tasks support an internal-clock approach more consistently than studies employing verbal estimation, production, reproduction and other more symbolic tasks. Ornstein's conclusion is typical of some recent cognitive theorists' criticisms of internal-clock approaches:

> The argument is not that increases in body temperature (or the speeding up of a "biological clock" with a drug) do not lengthen time experience, but rather that these manipulations are more parsimoniously considered as affecting cognitive processing rather than altering one of the maze of possible "chronometers".
>
> (Ornstein, 1969, p. 34)

In other words, it is foolish to attack all internal-clock approaches by questioning the reliability of reported effects. But it is equally foolish to cling to the belief that all human temporal experiences are mediated by an internal clock or even several clocks. In recent years there has been a distinct shift of the "Zeitgeist" away from internal-clock approaches and toward cognitive approaches. There is now abundant evidence that cognitive processes play a central role in temporal experience, and the present review emphasizes this evidence. What is needed is a conciliation of the two approaches, with further research into the questions of how physiological variations affect cognitive processes and how information-processing activities affect physiological processes (Kahneman, 1973).

2 Temporal Experiences in "Ordinary" Consciousness

2.1 The Psychological Moment: Fine Structure of Consciousness

When the fine structure of consciousness is considered, a recurring question is whether consciousness is continuous or intermittent. Of course, no awareness accompanies some physiological conditions, such as dreamless sleep, coma and some epileptic seizures; but the question can be asked nevertheless regarding "ordinary" waking consciousness. Phenomenologically, there is wide agreement that consciousness is continuous, and James's (1890) metaphor of consciousness as a "stream" certainly seems reasonable. However, some experimental studies suggest that consciousness might actually be intermittent.

In 1898 Richet (cited by Fraisse, 1963) proposed a basic oscillation in the nervous system. However, Stroud (1955, 1967) is usually acknowledged as the originator of an explicit intermittency hypothesis.

(The proposed intermittency has often been related to the cortical alpha rhythm, but evidence supporting such a specific physiological assertion is meagre and inconsistent.) Stroud's basic assumption was that time is represented as a discrete, rather than a continuous, variable. Thus, his hypothesis is usually called the "discrete-moment" hypothesis. It says that information is processed in temporally distinct, or non-overlapping, integrations and that the temporal order of information within each integration is not preserved. In other words, events that occur within a single moment are experienced as simultaneous, while events that occur in different moments are experienced as successive. An alternative proposal, the "travelling-moment" hypothesis (Allport, 1968), says that information is not processed in non-overlapping integrations, but rather in a continuously moving temporal "window". All events separated in time by less than the span of the moving window, or travelling moment, are experienced as simultaneous; events separated by greater than the span are experienced as successive. In order to evaluate these two hypotheses, empirical studies concerning the duration of the psychological moment, as well as those concerning phenomena of simultaneity and successiveness, need to be considered.

Different sensory systems transduce and transmit information at slightly different speeds, so that an experience of successiveness can occur when stimuli in different sensory modalities are physically simultaneous. When simultaneous stimuli are presented in the same modality, an expected event may be experienced as occurring earlier than an unexpected one. Most experiments on simultaneity, however, have used stimuli presented in the same modality and expected to about the same degree. In one early study, Hylan (1903) successively presented six letters that formed a word, and all observers reported them as simultaneous if the total presentation duration was less than about 90 msec. Stroud (1955) reviewed a number of different kinds of studies, including some concerned with motor as well as perceptual phenomena, and concluded that the duration of a moment was between 50 and 200 msec. White (1963) found that judgments of the number of stimuli in a rapid sequence were underestimates, and he inferred from them that the duration of a moment was about 140–170 msec. Allport (1968) used a successive oscilloscope display of 12 lines that could be cycled at various rates, and he found that all 12 lines were reported to be simultaneously present when the cycle period was decreased to about 70–100 msec. Efron (1970, 1972) measured the duration of visual and auditory perceptions by asking observers to adjust a brief index stimulus, which was presented in a different modality from a control stimulus, so that it seemed to be simultaneous with either the onset or

the offset of the control stimulus. He found that the interval between onset and offset of the index stimulus was adjusted to be about 130 msec with any auditory or visual control stimulus duration less than about 130 msec. Efron concluded that the duration of the perception of a stimulus less than about 130 msec is constant.

Some theorists have regarded these and other similar findings, which are consistent with the hypothesis of a discrete moment of about 50–200 msec, as evidence that a fairly constant biological pacemaker, or internal clock, underlies human temporal experience. Some other findings, however, complicate and contradict both the discrete-moment hypothesis and the internal-clock hypothesis. Allport (1968) obtained phenomenological evidence rejecting the discrete-moment hypothesis in favour of the travelling-moment hypothesis. When subjects observed his rapidly cycling oscilloscope display of lines, they reported that a shadow appeared to move in a direction that was the same as the sequence of lines. This effect is predicted by the travelling-moment hypothesis, but it is the opposite of what is predicted by the discrete-moment hypothesis. Estimates of the duration of a moment are also affected by stimulus variables, such as the luminance of the visual stimuli used (Allport, 1968; Efron and Lee, 1971). Efron and Lee asserted that these findings make even the travelling-moment hypothesis, "less interesting theoretically, since the duration of the alleged 'moment' [is] primarily determined by stimulus parameters rather than by temporal parameters of any neurophysiological sampling mechanism" (p. 374).

Other experiments reveal that successiveness may be experienced under certain conditions when the interval between two brief stimuli is as short as 2 msec (Exner, cited by James, 1890; Hirsh, 1959). In addition, trained subjects could make judgments of temporal order of two stimuli with 75% accuracy when the interval between the stimuli was as short as 20 msec (Hirsh and Sherrick, 1961). These findings seem to be inconsistent with the discrete-moment hypothesis, the travelling-moment hypothesis and any other hypothesis that attempts to explain both the experience of simultaneity and the experience of successiveness by referring to the duration of a moment in which information is integrated. It may be that these findings are obtained only under ideal conditions, using trained observers, repeated stimulus presentations and so on. Another possiblity is to conclude, as Baron (1971) did, that, "there is no evidence . . . for a periodic psychological moment which has anything to do with successiveness discrimination" (p. 206). It seems to me, however, that psychological moment hypotheses, which were originally proposed to explain experiences of simultaneity, should also be able to explain experiences of

successiveness. This viewpoint was implicit in the work of Robinson *et al.* (cited by Robinson and Pollack, 1971), who proposed an "overlapping-moment" hypothesis. It retains the notion of discrete moments, which can explain experiences of simultaneity, but it says that there is a substantial overlapping of successive moments. In that regard, it is like the travelling-moment hypothesis, except that it regards the movement of the travelling window as discontinuous in time. Experiences of simultaneity are related to the duration of the moment, while experiences of successiveness are related to the relatively short (several milliseconds) time period during which successive moments do not overlap. Another solution to the problem of explaining the evidence on experiences of successiveness may be to modify the travelling-moment hypothesis. It might be assumed that the trailing edge of the travelling window is blurred over a few milliseconds and that successiveness is experienced when this edge "passes by" successive stimuli separated by more than a few milliseconds. Experiences of simultaneity would still be related to the duration of the moment.

All of the moment hypotheses discussed so far have proposed a relatively stimulus-independent intermittency or scanning process, and none of them seems completely satisfactory. A radically different kind of approach would be to assume that both the experience of simultaneity and the experience of successiveness are based on comparisons of the duration and overlapping of the initial registration of events—the activation of perceptual traces—in some central location. Specifically, Efron (1963) presented evidence indicating that the left cerebral hemisphere of most individuals is intimately involved in experiences of simultaneity and successiveness. (This notion is explored further in Section 3.8 of this review.) Regardless of the ultimate resolution of these complex issues, it is clear that phenomena of the psychological moment do not indicate the existence of an internal-clock mechanism. Rather, these phenomena are apparently based on dynamic aspects of the human information-processing system. A more complete understanding of the dynamic processes that are involved requires additional research.

2.2 Sensory Information Storage and the Indifference Point

Some researchers have attempted to determine psycho-physical functions describing judgments of durations ranging from fractions of a second to many years. Michon (1975) provided an excellent theoretical integration of some of the findings. Of relevance here is Michon's (1967) finding that judgments of durations between about 100 and 500 msec increase approximately with the square root of the actual durations, while judgments of durations between about 500 msec and 2 sec increase linearly. Thus, different processes apparently underlie experiences of durations less than 500 msec and those greater than 500 msec. Michon (1975) ascribed the difference to, "the transition from immediate memory to short term memory" (p. 304). It is notable that the transitional time period (about 500 msec) corresponds closely with the most typically obtained "indifference point" (Fraisse, 1963; Woodrow, 1951). The indifference point, which is sometimes called the "indifference interval", is a time period that is, on the average, neither overestimated nor underestimated. What is usually called "Vierordt's Law" was apparently first discovered by Höring (cited by Fraisse, 1963), who was a student of Vierordt. It refers to the finding that relatively short time periods tend to be overestimated while relatively long time periods tend to be underestimated compared to physical, or clock, time. The indifference point is usually found to be about 500–700 msec, although estimates range from about 300 msec–5 sec or longer (Woodrow, 1951). Many studies show that the indifference point can be affected by various factors, especially the range of time periods used, and that it varies from subject to subject and from task to task. Some well-designed studies have found no indifference point at all. Early theorists related the indifference point to the duration of physiological processes underlying heart rate, walking rate and so on. Fraisse (1963) speculated that the indifference point is related to reaction time and the "complete perceptual process" (p. 126). In modern cognitive terminology, it seems that Fraisse was referring to the processing of information in the sensory information storage systems. Blumenthal (1977) provided a recent review of "buffer delays" (in sensory information storage) that makes the relationship between the transitional time period and information storage systems more explicit. He asserted that the indifference point "may be an artifact of an intrinsic buffer delay. That is, short events may be prolonged subjectively by the holding action of buffer processes and slightly longer events may be constricted subjectively by the same process" (p. 64). Support for Blumenthal's assertion comes from the frequent finding that brief stimuli which are more intense seem longer in duration than those which are less intense (Berglund *et al.*, 1969). One possible explanation is that intense stimuli take longer to decay from sensory information storage than weak stimuli.

2.3 Very Short Duration Experiences

Many other studies have investigated variables that affect very short duration experiences. (For present purposes, "very short" duration experiences are those typically resulting from stimulus durations of less

than about 1 sec.) At least two additional cognitive processes must be considered in attempts to explain the findings: pre-attentive processes through which a stimulus contacts a memorial representation; and processes of selective attention, which may involve time-sharing between attention to stimulus information and attention to the passage of time itself. These processes are probably intimately related; the nature of the relationship is made explicit in the theoretical account that follows.

When a stimulus occurs for a very short duration, the experienced duration of the stimulus depends on the observer's familiarity with it. A recent series of experiments (Avant and Lyman, 1975; Avant *et al.*, 1975) found a lengthened experience of duration of an unfamiliar non-word (e.g. E1O) compared to a familiar word (e.g. DIG), a familiar word compared to a familiar letter (e.g. I) and an inverted word (e.g. ƆIG) compared to an upright word. Since these differences were found with stimulus durations of 10–30 msec, it follows that two different types of stimuli presented for an equal duration less than that of the psychological moment may produce different duration experiences. Regarding the findings of Efron (1970, 1972), which were discussed in Section 2.1, Avant *et al.* said that "while the real-time duration of the processing of a single perceptual unit may be no briefer than 130 msec . . . the *apparent or subjective duration* of shorter presentations is not constant" (p. 253, their italics). Further, the differences were found even when identification of the stimuli was at chance level. A tentative hypothesis is that the experienced duration of a brief presentation of a stimulus depends on the time taken for the stimulus to contact a memorial representation.

With somewhat longer but still very short durations, a number of different stimulus variables lengthen duration experience, including increased numerosity of pattern elements (Mo, 1971), increased area and decreased perimeter of a figure (Cantor and Thomas, 1977) and higher frequency of occurrence of words in a language (Warm and McCray, 1969). Although some of the effects seem to contradict the findings of Avant and his colleagues (Avant and Lyman, 1975; Avant *et al.*, 1975), an important difference is the much shorter durations used by Avant. As Avant and Lyman note, with durations that allow identification (full recognition) of a stimulus, other cognitive activities may occupy a greater proportion of the duration. This kind of notion has been clarified by Thomas and his colleagues (Thomas and Weaver, 1975). They developed and tested a mathematical model of experienced duration of visual stimuli in which attention is shared between two parallel processors, a temporal information processor ("timer") and a non-temporal information processor ("visual information processor"). As visual information increases, more attention is allocated to the visual information processor; as visual information decreases, more attention is allocated to the timer. When more attention is allocated to one processor, the other becomes more unreliable. Thus, experienced duration is assumed to be a weighted average of the information encoded by each processor.

2.4 Longer Temporal Experiences: Durations and Intervals

A clarification of the distinction between the terms duration and interval seems necessary at this point. The term "duration" refers to "the time during which something exists or lasts", while the term "interval" refers to "a space of time between events" (Webster's New Collegiate Dictionary, 1977). The more neutral term "time period", or simply "period", is used here to refer in a general way to either a duration or an interval.

The distinction is both historically and theoretically necessary in order to understand diverse temporal phenomena involving longer time periods. Historically, phenomena related to intervals have been a concern of psychologists primarily studying memory, while phenomena related to durations have been a concern of psychologists primarily studying time. To my knowledge, only Michon (1975) has attempted to integrate these topics, and his discussion was limited. A comprehensive synthesis of the two separate lines of research is clearly needed.

Some recent memory research has focused on the nature of memory attributes and processes mediating judgment of recency, temporal position and spacing (lag). A "recency" judgment involves the estimation of an interval between a past event and the present occurrence of an equivalent event. A "temporal-position" judgment, which is similar to a recency judgment, involves the estimation of the temporal location of a past event on a scale representing a given sequence of events. A "spacing" ("lag") judgment involves the estimation of an interval between two past events. In memory research on these judgments, the events to be judged are typically embedded in a sequence of similar events. In contrast, some psychological research on time has focussed on the nature of the processes mediating judgment of duration. When longer duration experiences are studied, researchers typically use cohesive sequences of events. Distinctive events mark the beginning and end of the durations, and a distinctive cognitive context is present throughout each. The distinctive cognitive context is what unifies long durations, so that even long time periods can be properly called durations.

Given these clarifications, an attempt can be made to synthesize diverse studies of longer temporal experience.

2.5 The Psychological Present: Contents of Consciousness

James (1890) proposed that humans "are constantly conscious of a certain duration—the specious present—varying in length from a few seconds to probably not more than a minute" (p. 642), with longer durations conceived by adding and shorter durations by dividing portions of the specious present. A metaphor James used was that of "a saddle-back, with a certain breadth of its own on which we sit perched, and from which we look in two directions into time" (p. 609). His statement that the nucleus of the specious present "is probably the dozen seconds or less that have just elapsed" (p. 613) contained the seeds of a controversy about the temporal extent of the phenomenon. Boring (1933/1963) said that the "conscious present can certainly include a rhythmical grouping that occupies a second or a second and a half, and that with somewhat less 'immediacy' . . . may extend to include a rhythm of a quarter or perhaps even half a minute" (p. 135). Fraisse (1963) said that the "psychological present", as he called it, enables us to "perceive units of change which . . . are elements from which we construct the unity of our whole psychological life" (p. 98). From a cognitive viewpoint, it seems clear that the psychological present is related to the temporal dynamics of short-term memory. Unrehearsed information is "lost" from short-term memory over a period of about 10–20 sec. This is an upper limit, and for practical purposes the psychological present may be limited to about 5 sec (Fraisse, 1963; Woodrow, 1951). Some memory theorists equate the contents of short-term memory with the contents of consciousness (see Ch. 7). Thus, the direct awareness of succession or continuous change—what James (1890) called the "stream" of consciousness (p. 607)—pervades short-term memory, which is thought to relate information from the sensory information storage and long-term memory systems. When attention is focused on discrete events, there is apparently an automatic awareness of their durations. Under uninformed ("incidental learning") conditions, subjects can make somewhat accurate judgments of event duration when the events are no longer within the psychological present (Hintzman, 1970). Awareness of rhythm seems to be an awareness of durations of events and of intervals between related events in the psychological present (Fraisse, 1963).

If an event is repeated in two similar contexts, we seem to be frequently (perhaps always, if the contexts are similar enough) aware of and able to judge the approximate recency of the first occurrence of the event. It has been proposed that judgment of recency is based on the decreased "strength" (Hinrichs, 1970) or "fragility" (Wickelgren, 1974) of the retrieved representation, or memory trace, of an event. However, evidence from studies in which judgments of the temporal position of events were requested seriously discredits these hypotheses (Hintzman and Block, 1971; Hintzman *et al.*, 1973; Tzeng *et al.*, 1979). Instead, a "contextual-association" hypothesis is supported. It proposes that judgment of recency is based on retrieval of contextual information associated with the earlier occurrence. Automatically-retrieved contextual information may produce an awareness of the approximate recency of the event, as well as of other attributes such as its duration and sensory modality. In other words, awareness of recency is apparently the result of an implicit comparison of the context associated with the previous occurrence and the context prevailing during the present occurrence. It must be noted that we are ordinarily not automatically aware of an interval separating two unrelated events. Judgments of spacing between two remembered, but unrelated, events that occurred in a sequence of similar events are usually very inaccurate (Hintzman and Block, 1973; Hintzman *et al.*, 1975; Underwood, 1977). However, if one event creates a unique cognitive context and another event terminates that context, we may properly speak of the experience of duration. A judgment of the duration of a sequence of events no longer within the psychological present may be mediated by an effortful memorial reconstruction of certain aspects of the conscious contents during the duration (see Section 2.9).

2.6 Short, Long and Very Long Temporal Experiences

In evaluating research and proposing theories concerning longer temporal experiences, a general issue is whether different processes mediate experiences of time periods of different lengths. For present purposes, "short" time periods are those within the psychological present, or up to about 10 or 20 sec; "long" time periods are those from about 10 or 20 sec to a few hours; and "very long" time periods are those longer than a few hours.

First, consider whether or not experiences of durations of different lengths are mediated by different processes. Abundant psycho-physical evidence shows that judgments of durations ranging from a few tenths of a second to a few minutes can be described by a power function. The exponent of the function varies between about 0·7 and 1·3, but averages about 1·1, across experiments (Eisler, 1975, 1976; Michon, 1975). Simply stated, such duration judgments are approximately veridical, since the exponent is probably not significantly different from 1·0.

Based on this evidence, Michon hypothesized that the transition between short-term and long-term memory is not observable in the duration judgments of normal subjects. To my knowledge, Michon has not overlooked any evidence showing a discontinuity at durations of about 10 or 20 sec. An exception mentioned by Michon is the case of "H.M.", which is often cited as evidence for a distinction between short-term and long-term memory. A bilateral hippocampectomy was performed on H.M. to relieve his frequent epileptic seizures, and the resulting deficit has been described as an inability to transfer new information from short-term to long-term memory. An experiment conducted by Richards (1973) revealed that different power-function exponents are needed to characterize H.M.'s judgments of durations less than about 20 sec (an exponent of 1·05) and his judgments of longer durations (an exponent of 0·44). Richards extrapolated the data in order to remark that, "one hour to us is like 3 minutes to H.M." (p. 281). With the exception of H.M., however, we can evaluate research on duration experiences without distinguishing between those using short and those using long durations, since there is no evidence that the underlying processes differ. There are few studies using very long durations, and to my knowledge no one has investigated durations between a few minutes and a few hours. However, a study by Crombag *et al.* (cited by Michon, 1975) found that judgments of duration are linear and approximately veridical in the range from about 5–80 h. Results of this study suggest that processes mediating judgment of long and very long durations do not differ. Thus, there is no evidence that different processes mediate judgments of durations between about 500 msec and 80 h.

A related question is whether or not processes underlying judgment of an interval between events differ depending on the length of the interval. Experiments investigating judgment of spacing between two equivalent or related events reveal no discontinuity in such judgments over a range of onset-to-onset intervals from 5–130 sec (Hintzman and Block, 1973; Hintzman *et al.*, 1975). Similarly, Hinrichs and Buschke (1968) and Hinrichs (1970) found no discontinuity in recency judgments across onset-to-onset intervals from 3–45 sec. Apparently no distinction between processes involved in judging short and long intervals (such as, short-term and long-term memory processes) is necessary. The observed psycho-physical relationship relating judgment of recency and actual recency could be described by either a logarithmic or a power function, with the former fitting the data slightly better. The exponent of the best-fitting power function was 0·46. This exponent is clearly different from the exponent of about 1·1 that is usually found for judgments of durations of similar length. Thus, judgment of an interval between events must be based on different processes than those

involved in judgment of duration. This conclusion is supported by an earlier study of the apparent recencies of "real-world" events (Cohen *et al.*, 1954). Subjects were asked to indicate subjective temporal positions of past events on a line from "birth" to "now". They found a logarithmic function for events within the past 6 months; intervals closer to "now" were judged disproportionately longer than more remote intervals. For events which occurred more than about a year previously, judgments were related to actual temporal position in a linear way. Cohen *et al.* suggested that a process of calculation based on calendar dates could explain the linear relationship. Other theorists have suggested that judgment of recency or temporal position of events which occurred months or years previously are mediated by logical inferences based on direct or indirect associations with well known calendar dates, distinctive temporal "landmarks", seasons of the year, and so on (Linton, 1975; Underwood, 1977). Thus, judgments of very long intervals seem to be based on different processes than judgments of shorter intervals.

2.7 Experienced and Remembered Duration

Following James (1890), some theorists have emphasized the need to distinguish between duration experiences in passing—referred to here as "experienced duration"—and duration experiences in retrospect—referred to here as "remembered duration". In fact, James proposed that apparently contradictory effects could occur:

> *In general, a time filled with varied and interesting experiences seems short in passing, but long as we look back. On the other hand, a tract of time empty of experiences seems long in passing, but in retrospect short.*
>
> (James, 1890, p. 624, his italics)

In an attempt to explain effects such as these, James proposed that experienced duration lengthens when "we grow attentive to the passage of time itself" (p. 626), while remembered duration lengthens with "the multitudinousness of the memories which the time affords" (p. 624). Fraisse (1963) proposed that "direct time judgments [are] founded immediately on the changes we experience and later on the changes we remember" (p. 234).

Experiments typically have studied either experienced duration or remembered duration by informing a subject either before or after the time period that the experimenter is requesting a duration judgment. Some researchers have studied only remembered duration in order to avoid attempts of some subjects to be accurate by counting, tapping and so on. When experienced duration is studied, subjects are usually

asked not to count or tap unless, of course, counting or tapping rate is the dependent variable of interest. The psychological effect of such instructions on both conscious and unconscious processes is admittedly not known, but most subjects seem to be quite willing and able to comply. In some recent studies, experienced duration has been compared with remembered duration in the same experiment. Hicks *et al.* (1976) found that the experienced duration of a 42-second time period was shorter when more information was processed, but remembered duration was not affected by the manipulation. Miller *et al.* (1978) found that the experienced duration of a 32- to 54-second time period spent rehearsing verbal information was lengthened as the number of previous study trials was increased, but remembered duration was shortened. Both of these studies suggest that cognitive control processes, which presumably require conscious involvement, differ depending upon whether the focus is on experienced duration or remembered duration. It seems that James (1890), Fraisse (1963) and others were justified in making such a distinction.

Until recently, many researchers and theorists have failed to realize the importance of distinguishing between experienced and remembered duration. An effect of this negligence has been a general confusion, with different studies seeming to find opposite or contradictory effects of certain variables on duration judgments. When one adds to this confusion the misleading and vague terminology used to describe effects found using different duration judgment methods, the net effect is apparent chaos. When careful distinctions are made, though, somewhat orderly relationships emerge.

2.8 Experienced Duration: Awareness of Passing Time

In addition to the experiments already described, many others have been conducted examining experienced duration. Let us consider some of the more suggestive findings and reasonable hypotheses regarding experienced duration. Some theorists have attempted to explain experienced duration by postulating an internal clock, or pacemaker, mechanism that generates regularly-spaced "pulses". Most of these models are implicitly based on the discrete-moment hypothesis, which is inferior to other moment hypotheses for reasons discussed earlier in this review (Section 2.1). The best-known model of this kind is Treisman's (1963). He proposed a counter that records the number of pulses between two events, one defining the start and another the end of a time period. The total number of pulses is then deposited in a store, which can be accessed by a comparator (decision mechanism) in making a duration judgment. In my opinion, this kind of model obscures a

number of aspects of the cognitive processes mediating experienced duration. It also is subject to the same kind of criticism to which other internal-clock hypotheses are subject, since it fails to explain adequately the effects of information-processing manipulations on experienced duration.

There are a number of older studies of experienced duration that are difficult to explain by referring to an internal-clock mechanism. The most extensive of these was Lochlin's (1959) study of experienced duration of a 2-minute period spent performing one of 16 different kinds of tasks. He concluded that "time may seem long during an interval because the activity is boring, because attention is being paid to the passage of time, because the activity is unfamiliar, or because [the subject] is relatively passive" (p. 16). Loehlin's review of previous studies generally supported his conclusions about the importance of these factors.

More recently, Hicks and his colleagues (Hicks *et al.*, 1976, 1977) have used quantitative variations in information-processing activities to investigate hypotheses about experienced duration. Summarizing their findings, as well as those of others, they concluded that:

> Events on which [experienced duration] is based require attention (processing capacity) for storage. Stimuli requiring no processing can increase experienced duration by increasing the number of events in storage. Stimuli requiring processing can decrease experienced duration because fewer of the events defining duration are stored.
>
> (Hicks *et al.*, 1977, p. 443)

The proposal is reminiscent of that of Thomas and his colleagues regarding experienced duration of very short intervals (see Section 2.3). A problem with this kind of hypothesis is that it does not adequately specify the nature of the "events defining duration". In other words, when a person attends to the "passage of time itself" (James, 1890, p. 626), what are the momentary contents of consciousness? Surely attention to clocks should not be equated with attention to time, and in most experiments subjects do not have access to clocks anyway. A proposal that may represent an initial move in the direction of greater specificity is that attending to the passage of time means attending to changes in cognitive context—that is, certain aspects of the contents of consciousness. This hypothesis is clarified following a discussion of remembered duration.

2.9 Remembered Duration: Awareness of Past Time

A wide variety of factors have been found to affect remembered duration. However, hypotheses have tended to focus on a single kind of

variable and to attempt a parsimonious explanation in terms of processes presumably causing an effect of that variable on remembered duration. What is needed is an hypothesis that integrates all reliable findings in a coherent way. Block and Reed (1978) recently discussed four kinds of hypotheses that seem to have some generality—"informational", "attentional", "event-memory" and "contextual-change" hypotheses. To some extent these are overlapping hypotheses, since they all recognize that we must consider processes involved in encoding information during a duration, storing information between the time of encoding and the time of retrieval, and retrieving information at the time the duration is remembered. However, the relative emphases differ.

Informational and attentional hypotheses emphasize information-processing activities during encoding. Informational hypotheses propose that the most important consideration is the amount of information presented and processed during the duration. Support for this kind of hypothesis comes from Vroon's (1970) findings that if overt responding to presented information was not required, remembered duration lengthened when there was a greater amount of information presented; but if overt responding was required, remembered duration shortened when there was a greater amount of information processed. Attentional hypotheses propose that the most important consideration is the selectivity of attention required by the information-processing task (Underwood, 1975). For example, Underwood and Swain (1973) found that a prose passage which required more attention for analysis was remembered as longer in duration than one which required less attention. One weakness of informational and attentional hypotheses is that they must rely on other hypotheses for an explanation of the role of memory storage and retrieval processes in remembering duration. It is not obvious how a person remembers the amount of information presented and processed or the amount of attention demanded by the information-processing task performed during the duration.

Event-memory and contextual-change hypotheses emphasize memory retrieval processes, in addition to encoding and storage processes. Event-memory hypotheses propose that the most important consideration is the process of covert retrieval of memory representations of stimulus events that occurred during the duration. Ornstein's (1969) "storage size" hypothesis is the most well known event-memory hypothesis. It asserts that remembered duration is a cognitive construction based on a covert assessment of "the size of the storage space" of representations of stimulus events "*remaining in storage*" (p. 104, his italics). The hypothesis was proposed in order to explain his findings that remembered duration lengthened with an increase in the number

of stimulus events, the complexity of a stimulus or a sequence of stimuli, and the assumed complexity of coding of a stimulus.

The contextual-change hypothesis is similar to the storage-size hypothesis, except that it maintains that encoding, storage and retrieval of contextual information—rather than stimulus information—is the critical factor. The basic proposal is that remembered duration is a cognitive construction mediated by a covert assessment of the remembered amount of change in cognitive context during the duration (Block, 1978; Block and Reed, 1978). The four kinds of hypotheses were tested by Block and Reed, and they interpreted the results of their two experiments as consistent only with the contextual-change hypothesis. In their first experiment, a duration spent processing information at a "deep" (semantic) level was not remembered as longer than one spent processing information at a "shallow" (structural) level, even though the former task increased memory for stimulus events and presumably demanded more attention. In their second experiment, a duration spent alternately performing shallow and deep processing was remembered as longer than one spent processing information at a single level, even though the amount of information presented and processed was equivalent in the two conditions. The contextual-change hypothesis explains both of these findings by assuming that a unique cognitive context is associated with each kind of information-processing task (Underwood, 1977); when different kinds of tasks are performed, the cognitive context changes accordingly. In addition, several studies (Block, 1974, 1978; Block and Reed, 1978) obtained both duration judgments and memory judgments regarding the contents of the duration. The results indicated that retrieval processes involved in remembering stimulus events that occurred—such as those involved in judgment of number of events, recall or recognition of events and assignment of recognized events to the correct duration—do not mediate remembered duration. Since the contextual-change hypothesis does not emphasize memory for stimulus events, these findings are not unexpected.

The contextual-change hypothesis emphasizes change in aspects of the cognitive context, which are presumably part of the contents of consciousness. These contextual aspects probably include conspicuous environmental stimuli, internal sensations, characteristics of the task being performed and cognitive and affective reactions to the task (cf. Hintzman *et al.*, 1973). One model of memory asserts that experiences are encoded in a propositional format (Anderson and Bower, 1973). In this model, contextual aspects are assumed to be encoded directly in propositions, but new propositions are encoded only when some change occurs. Such a change might be a result of awareness of new

incoming information, new contextual aspects, or both. Ordinarily these two kinds of causes are related, since processing information usually produces changes in affective reactions, "cognitive strain" and other contextual aspects. The encoding, storage and retrieval of non-contextual information, such as concerning stimulus events that occurred during a duration, may play a role in remembered duration if the accessibility of contextual associations in memory is affected. However, the evidence suggests that the primary emphasis must be on encoding, storage and retrieval of contextual information.

To illustrate the integrative nature of the contextual-change hypothesis, consider how it might explain the effects of some variables on remembered duration. When the number of stimulus events presented during a time period is increased, a person attends to the more rapid change of contextual elements correlated with "cognitive strain" (cf. Hintzman *et al.*, 1973), and remembered duration is lengthened accordingly. A similar explanation is offered to explain the lengthened remembered duration of a time period containing a more difficult stimulus detection task (Underwood and Swain, 1973). However, if a person must actively generate a rapid sequence of responses, there is little residual processing capacity (attention) for encoding contextual changes, and remembered duration is shortened (Vroon, 1970). When a more complex stimulus is presented, contextual elements associated with different interpretations of the stimulus change more frequently (cf. Block, 1974), and remembered duration is lengthened. Finally, the first of two equal durations is remembered as being longer, perhaps because contextual elements correlated with affective reactions such as boredom change more rapidly at the start of a new experience, such as an experiment (Block, 1978; Block and Reed, 1978; Hintzman *et al.*, 1973).

A contextual-change hypothesis on remembered duration also has implications for hypotheses on experienced duration. Perhaps references to attention to time itself that are found in the literature on experienced duration can be understood in terms of attention to changes in contextual aspects of consciousness. Performing a task that requires relatively little information processing allows a person to allocate more attention to encoding contextual aspects. In addition, such a task produces relatively large changes in contextual aspects involving emotions such as boredom. On the other hand, performing a difficult information-processing task seems shorter in experienced duration because fewer contextual aspects are attended to and thereby encoded. To state this proposal somewhat differently, a relatively idle, "empty" duration seems long in passing because of increased attention to changes in contextual information. It seems short in retrospect—especially after a delay—because there are fewer retrieval routes to contextual information as a result of the relative lack of memories of stimulus events. Opposite effects are found for a relatively busy, "filled" duration for exactly opposite reasons. It remains to be seen whether the contextual-change hypothesis can succeed in integrating phenomena of experienced and remembered duration in the way described here.

2.10 Temporal Perspective: Past, Present and Future Time

The concept of "temporal perspective", "temporal horizon" or "temporal orientation" has been used to refer to all-encompassing philosophical and metaphysical viewpoints on time. Various theorists have described the concept somewhat differently. Fraisse (1963) characterized it as "the way in which we behave in relation to three aspects of time: the past, the present, and the future" (p. 153). Ornstein (1969) referred to it as "philosophical, social, cultural constructions of the world and their effects on the interpretation of time experience" (p. 23). Gorman and Wessman (1977) defined it as "the degree to which a person, group, or society conceptualizes events removed from the present situation" (p. 228). From a cognitive viewpoint, an important point is that the contents of consciousness ordinarily consist of remembrances of past events, responses to present events and anticipations of future events. It is usually difficult to separate these components, since the normal performance of any task depends on all three of them. However, individual and cultural differences in cognition must be acknowledged. Some people and some cultures place relatively more or less emphasis on each of the three components, and resulting differences in the overall conception of time may be substantial. Furthermore, an individual's temporal perspective changes dramatically as he or she experiences certain altered states of consciousness, since memory, information-processing and planning functions are altered.

In psychological literature on time, questions about temporal perspective of most people in ordinary waking consciousness have been addressed mostly by those concerned with developmental, personality, and social factors. Few cognitive psychologists have been concerned with these kinds of issues, although a basic understanding of cognitive processes involved in temporal perspective would seem to be a pre-requisite to an understanding of individual differences in cognition. Little can be said, however, about relationships between temporal perspective and cognitive aspects of temporal experience discussed in this review.

As a pre-requisite to an understanding of altered temporal perspective,

LeShan's discussions of normal temporal perspective are particularly useful. Most humans are assumed to operate most of the time from a metaphysical viewpoint he called the "Sensory Reality" (LeShan, 1974) or "sensory modes of being" (LeShan, 1976). Regarding temporal perspective, the basic laws, or limiting principles, are that every event has a cause which occurs before the event; that events in the past can be remembered but not changed; and that events in the future can be anticipated and influenced (LeShan, 1976, 88–91). Ornstein (1977) called this the "linear mode", in which "time is directional, a duration carrying us from the past into the future" (p. 103). Many people would not be aware of the possibility of other realities or modes of being regarding time unless altered states of consciousness were experienced. It is to temporal experiences in certain altered states of consciousness that we now must look for an understanding of the experience of alternate realities.

3 Temporal Experiences in Altered States of Consciousness

3.1 Approaches to Time in Altered States of Consciousness

Any reasonably comprehensive discussion of relationships between time and consciousness must consider temporal experiences associated with altered states of consciousness. There are two main reasons why this is important. First, a full understanding of temporal experiences in "ordinary" waking consciousness may not be possible without considering implications from experiences of "non-ordinary" states of consciousness. Second, any discussion of differences between altered states of consciousness and ordinary waking consciousness or of differences among various altered states of consciousness must include an account of alterations in temporal experience.

Although attempts have been made to identify discrete states of consciousness, a definitive listing seems remote. In fact, some definitions of the concept of altered states of consciousness in terms of continuous, quantitative variations obviously preclude such a listing, which assumes that there are discrete, qualitatively different states. At present, we can only speak of certain general categories of altered states of consciousness, with each category being distinguished by the use of certain techniques or the presence of certain conditions. Although it is probably a mistake to equate techniques or conditions and altered states of consciousness, given our present lack of understanding of altered states it is easiest to organize a discussion around general kinds of techniques or conditions. This review discusses several of the more

common categories of altered states of consciousness. Within each category, only those aspects of temporal experience that have been studied experimentally are discussed. In general, few studies have investigated changes in experiences of simultaneity, succession and very short durations; while many studies have investigated changes in the psychological present, longer duration experiences and temporal perspective.

3.2 Sleeping and Dreaming

Researchers have attempted to answer several related questions about temporal phenomena associated with sleeping and dreaming. One question concerns processes underlying judgments of the duration of dreamless sleep periods, which are generally associated with the absence of rapid eye movements. It is generally agreed that the remembered duration of dreamless sleep periods is not related to the experienced duration of such periods, since there is usually no awareness during non-rapid-eye-movement periods. Studies (Noble and Lundie, 1974) in which subjects were awakened at various intervals after sleep onset reveal some degree of accuracy in judging the duration of non-rapid-eye-movement periods, although the absolute error is considerable. Since only brief fragments of mental activity are sometimes reported upon awakening from even long non-rapid-eye-movement periods, it seems that people make inferences about duration based on other cues. Such cues ordinarily include external stimuli; but in the absence of any change in external stimuli, people rely on internal cues noticed upon awakening, such as general feelings of restedness or fatigue, stomach and bladder sensations and the apparent recency of pre-sleep events (Boring and Boring, 1917).

Some people claim to be able to awaken at any pre-selected time. Five studies conducted over 40 years ago (Tart, 1970) lend some support to this possibility, although they reveal nothing about the underlying processes. Tart investigated some subjects who believed that they could successfully awaken at any pre-selected time. Most of them reported doing so on six experimental nights at home. He then instructed three of the more successful individuals to awaken at various times while sleeping in the laboratory. The results confirmed a substantial ability in these subjects. There were no obvious physiological correlates of successful awakenings, such as sleep stage upon awakening. One confounding effect, however, was a substantially increased frequency of awakening. Interestingly, one person who in this case apparently misunderstood or forgot the pre-selected time of 01.23 hours, awoke at 02.22 hours, about a minute after mumbling in his

sleep, "Wake at 2:23"! Zung and Wilson (1971) used a more representative sample of subjects, and they found about 32% awakenings within ± 10 minutes of a pre-selected time between 02.00 and 05.00 hours. This accuracy is equivalent to the accuracy of waking estimates of comparable durations (Webb and Ross, 1972). In general agreement with Tart's findings, successful awakenings were independent of prior sleep stage, as well as the particular pre-selected time. In an attempt to explain their findings, Zung and Wilson proposed a "specific arousal system" that is unrelated to the 90-minute sleep cycle of alternating rapid- and non-rapid-eye-movement periods. In my opinion, their findings suggest the operation of subconscious (dissociated) information-processing mechanisms. The processes that underlie this phenomenon are still unknown, and it is also not known why only relatively few individuals apparently are able to awaken consistently at any pre-selected time. It might be revealing to study the temporal abilities of such persons in ordinary waking consciousness. It is possible that they simply represent an extreme portion of a normal distribution of temporal abilities.

Other investigators have studied the experienced duration of dream periods, which are generally associated with rapid eye movements. Although many people apparently believe that dreams last only a few seconds, electrophysiological records show that rapid-eye-movement periods last up to 1 hour. In one study (Dement and Kleitman, 1957), subjects were awakened either 5 or 15 minutes after the onset of rapid eye movements, and they were over 80% accurate in discriminating between the two time periods. In another study (Dement and Wolpert, 1958), subjects who had been showing rapid eye movements for a few minutes were exposed to an external stimulus, such as a spray of cold water, and then were awakened after a certain interval. In 10 instances in which the stimulus was incorporated into an ongoing dream, "the amount of dream action in the interval between the modifying stimulus and the awakening did not vary far from the amount of action that would have been expected to take place during an identical time in reality" (p. 550). Of course, it is possible, and perhaps even common, for an "ordinary" temporal sequence of events to be distorted, reversed or telescoped in dreams (Sturt, 1925), and some dreams may seem "timeless" (Cohen, 1954). It is not known to what extent these effects are produced by memory retrieval processes upon awakening, but it is unlikely that temporal distortions during dreams can be entirely explained in this way. One intriguing explanation is suggested by evidence indicating that in most people there is both greater activation of the right cerebral hemisphere and greater independence or reduced communication between the two hemispheres during rapid-eye-movement sleep (Bakan, 1977–78). Since the right cerebral hemisphere seems to be less involved in the analysis of temporal sequences than the left hemisphere, distortions of temporal sequences in dreams are understandable. Ordinarily, however, sequences of dream events are remembered upon awakening as having occurred in approximately "real-time", and processes involved in experiencing and remembering duration of dreams are probably not radically different from those mediating experienced and remembered duration of awake periods. In other words, awakened persons probably rely on retrieval of aspects of dream content in much the same way that awake persons rely on retrieval of certain aspects of conscious content in judging duration.

3.3 Daydreaming

Like nocturnal dreaming (i.e. rapid-eye-movement) periods, daydreaming periods tend to recur in an approximately 90-minute cycle in adult humans. This cyclic variation in consciousness apparently involves changes in present-centredness as well as duration experience. Recent work on daydreaming has begun to clarify the nature of these changes. For present purposes, "daydreaming" is defined as any conscious activity that is not related to immediate external information-processing demands. This definition emphasizes that daydreaming is stimulus-independent or task-irrelevant mentation. Daydreaming draws attention away from processing incoming information, so that consciousness shifts toward reconstructing the past or anticipating the future, often in ways involving considerable fantasy. One effect of this different orientation of attention seems to be a shortening of duration experience. To my knowledge, the only study investigating the relationship between daydreaming and temporal experience is that of Wheeler (1969). He found that subjects who reported more stimulus-independent mentation, especially of an emotionally positive nature, during a boring signal-detection task tended to remember the task duration as shorter than did other subjects. One possible explanation is that the daydreamer is encoding fewer changes in contextual information, either because certain elements of the cognitive context (such as those involving feelings of boredom) are changing less rapidly or because less attention is being allocated to existing changes. It is also possible that memories of daydream content become less accessible once consciousness has returned to task-relevant information, perhaps for reasons similar to those underlying state-dependent retrieval effects. Regardless of the ultimate explanation, daydreaming may be beneficial in tolerating long periods of repetitious, monotonous activity

(such as assembly-line work) because of the shortening of duration experience it apparently produces.

3.4 Sensory Deprivation and Sensory Overload

During the past 20 years, there has been some interest in possible alterations in temporal experience resulting from what is usually called "sensory deprivation". There are a number of older anecdotal reports given by people isolated in caves and other remote environments, many of which suggest that a shortening of duration experience accompanies isolation. Virtually all of the experimental evidence has been obtained by researchers primarily concerned with sensory deprivation rather than temporal experience, and they have made little effort to comment on the broader implications of their findings. Some psychologists primarily interested in temporal phenomena have attempted to relate sensory deprivation studies of temporal experience to the old controversy about the relative effects of filled and unfilled intervals (Doob, 1971, 117–118). It is apparent that only in a very narrow definition of an unfilled, or "empty", interval—one devoid or nearly devoid of changes in *external* stimuli—can a period of sensory deprivation be said to represent an "empty" interval. All subjects, in fact, report that conscious mental activity continues during most of the deprivation period, and electrophysiological recording supports such introspective reports. Nevertheless, it is quite reasonable to determine whether gross reductions in external stimulus information affect temporal experience. Of particular relevance here are introspective reports and empirical findings indicating that many subjects experience altered states of consciousness, especially under certain conditions and durations of sensory deprivation.

Different kinds of environments have been used in sensory deprivation research, but the most commonly used are the isolation room or cubicle and the water-immersion tank. Forgays and McClure (1974) found that experienced duration—measured by repeated production of 30-minute intervals—was longer during a period spent in a tank than during a period spent in a cubicle. Unfortunately, as in many sensory deprivation studies, a non-deprivation control was not used, so no conclusions could be made about changes in duration experience produced by sensory deprivation relative to more ordinary environmental conditions.

It is, however, usually concluded that experienced duration is shortened in sensory deprivation relative to more normal environmental conditions (Doob, 1971). The actual experimental evidence is meagre and inconclusive. Banks and Cappon (1962) reported that the duration

of a period of "reduced sensory input" was underestimated more than that of a period spent reading or filling out questionnaire forms; but they did not describe the "reduced sensory input" environment, indicate what temporal judgment method was used or report the mean judgments. Vernon and McGill (1963) obtained both prospective and retrospective estimates of duration of a sensory deprivation period up to 96 hours long. Prospective estimates—repeated productions of 60-minute intervals—averaged about 81% of the actual duration. Retrospective estimates—verbal estimates of the total time period—were also underestimates, averaging about 92% of the actual duration. Unfortunately, no firm conclusions about relative duration experience are possible, since no control condition was used. To my knowledge, no well-controlled study comparing temporal experience in sensory deprivation and more normal environmental conditions has been conducted. The shortening of duration experience in sensory deprivation must be considered to be a hypothesis that needs to be adequately tested.

In spite of the lack of any definitive conclusion regarding relative effects of deprivation, duration judgments have proved to be useful to some sensory deprivation researchers. Murphy *et al.* (cited by Myers, 1969) reported a significant negative correlation between the degree of overestimation of the first 4 hours of deprivation and the number of hours of deprivation endured. The "early release" subjects gave a mean verbal estimate of 7·7 hours, while the "long staying" subjects gave a mean estimate of 5·1 hours. Surprisingly, both types of subjects verbally over-estimated the duration. Regardless of this inconsistency with other findings, it appears that duration judgments can be used to predict endurance of sensory deprivation.

A related question is whether duration experience is altered during "sensory overload" conditions, which produce some of the same effects as sensory deprivation conditions. One report (Ludwig, 1972) suggested that "disturbances in sense of time" may occur and that the effect may be related to alterations in consciousness experienced by some subjects. However, the reported evidence on temporal experiences consisted entirely of excerpts of retrospective accounts given by three subjects. Further research is clearly needed on the effects of sensory deprivation and sensory overload, with the use of a more normal environmental condition as an appropriate and necessary control and with greater use of a variety of temporal judgment methods.

3.5 Hypnosis

The term "hypnosis" is used here to refer to a range of altered states of consciousness that a sufficiently suggestible person may be enabled to

experience as a result of the use of any of a number of different techniques. Let us first consider temporal experience in a typical hypnotic state—that is, one induced by customary techniques, but with no specific suggestions regarding temporal experience. Some early investigations (Cooper and Erickson, 1959) suggested that duration is judged more accurately during hypnosis than during "ordinary" waking consciousness; however, many of the experiments lacked a proper control condition. In contrast, some well-designed studies found no significant difference. For example, Stalnaker and Richardson (1930) asked subjects to produce durations of 1, 2 and 3 minutes during both a hypnotic "trance state" and an ordinary "waking state". There were no significant differences in mean estimation error, even though it was suggested to subjects that their estimations during hypnosis would be more accurate. There was also no significant lengthening or shortening of experienced duration during hypnosis. More recently, Tebēcis and Provins (1974) found no significant difference between hypnotized and non-hypnotized subjects in production of a 131-second duration. To my knowledge, no one has systematically investigated the remembered duration of a period of hypnosis. Since some people show partial amnesia for events that occurred during hypnosis—an effect that may be an example of a state-dependent retrieval effect—it is possible that the remembered duration of a hypnotized period would be shortened compared to a non-hypnotized period. When a suggestion is given to hypnotized subjects that they will not be able to remember events that occurred during hypnosis after being aroused from it, some subjects show a dramatic amnesia effect. Given such a suggestion, subjects would be expected to report a greatly shortened remembered duration of the hypnotic period.

A number of studies have investigated effects of specific "time-distortion" suggestions on temporal experience and behaviour. In their pioneering work, Cooper and Erickson (1959) gave deeply hypnotized subjects the suggestion that a short duration (e.g. 10 sec) would seem like a very long one (e.g. 1 h). They were told that sufficient time would be available for the completion of an activity, such as designing a dress, which ordinarily would require much more clock time. Subjects often reported completing the task, saying that the duration seemed greatly lengthened (e.g. "about an hour"). Cooper and Erickson claimed that these subjects actually experienced the duration as much longer than it really was. They also suggested that hypnotic time-distortion might be of practical benefit to a person wishing to engage in creative mental activity in an area of interest. Barber and Calverley (1964) challenged these assertions, claiming that details of the suggested mental activity might actually be constructed by the subject after the period of hypnosis, not during it. They compared hypnotized subjects given time-distortion suggestions, non-hypnotized subjects given similar suggestions, and non-hypnotized control subjects given no time-distortion suggestions. Both groups receiving the suggestions agreed that time seemed to go slowly during a 5-minute period, and both differed significantly from the no-suggestion control group. The difference between the hypnotized- and waking-suggestion subjects' retrospective duration estimates was not statistically significant, although mean estimates were 89·1 and 46·9 minutes, respectively; both were significantly greater estimates than the control subjects' mean estimate of 4·2 minutes. Barber and Calverley concluded that the induction of an apparent hypnotic trance state is not necessary to produce the time-distortion phenomenon. However, there appear to be effects of hypnotic time-distortion suggestions beyond what is implied by Barber and Calverley. Zimbardo *et al.* (1973) measured the behavioural consequences of hypnotic suggestions of altered personal tempo, which can be considered to be a manipulation of experienced duration. When it was suggested that they would experience time as either slowing down or speeding up, hypnotized subjects showed substantial effects on a behavioural response measure, while role-playing and control subjects did not. It seems reasonable to assert that experienced and remembered duration may be modified by suggestions given to a hypnotized person. Unfortunately, little or nothing is known about how cognitive processes are altered by such suggestions.

The practical consequences of hypnotic time-distortion suggestions have also been studied. Cooper and Erickson (1959) reported that hypnotic time-distortion produced a marked enhancement of learning ability; that is, memory for information processed under hypnotic time-distortion increased. In contrast, Barber and Calverley (1964) found a decrement in learning ability during hypnotic time-distortion. More recently, Krauss *et al.* (1974) conducted a well-designed experiment in which subjects attempted to learn a 60-word list. Hypnotized subjects who were allocated 3 minutes for the task and given the suggestion that it would seem like 10 minutes recalled about as many words as non-hypnotized subjects who were actually allocated 10 minutes. Both of these groups recalled more words than a control group given 3 minutes for the task. Krauss *et al.* suggested that "a hypnotic time-distortion procedure might . . . increase the ratio of effective time to nominal time in free-recall learning" (p. 143). Further research is obviously needed in order to resolve controversies about the use of hypnotic time-distortion as an aid in learning and creating.

Hypnotism has also been used to observe the consequences of altered temporal perspective (Aaronson, 1972; Zimbardo *et al.*, 1971). Aaronson's

experiments are the most extensive. In them, hypnotized subjects and non-hypnotized simulators were given the suggestion that one or two of the three temporal categories—past, present and future—either did not exist or was expanded. The behaviour and retrospectively reported experiences of hypnotized subjects under each condition were used to make inferences about the role played by each temporal category in normal temporal perspective. (It should be noted that non-hypnotized simulators often behaved differently from hypnotized subjects, so the results cannot be entirely explained in terms of demand characteristics.) The present is associated with "aliveness" and "attention to ongoing stimulation" (p. 307). Eliminating the present produced immobility, sleepiness and withdrawal; expanding the present produced emotionally positive reactions characterized by greater attention to ongoing events. The past gives "meaning and inhibition" to the present (p. 308). Eliminating the past produced confused, regressive behaviour, as well as loss of self-identity in the extreme case; expanding the past produced introverted disengagement from ongoing activities, although positive emotions dominated. Finally, the future is "the source of ambitions, goals, and anxiety" (p. 309). Eliminating the future reduced anxiety as well as motivation; expanding the future produced positive emotional states ranging from happiness to mystical euphoria. Aaronson concluded that "every mode of orienting to time has its existential consequences" (p. 310). These studies are valuable in pointing to the possibilities of different temporal perspectives, as well as suggesting how certain psycho-pathologies may be able to be understood and treated when viewed as disorders of temporal perspective.

3.6 Psycho-active Drugs

When discussing effects of psycho-active drugs on temporal experience, there is a tendency to refer to standard pharmacological categories of drugs and to make the simplifying assumption that all drugs within a given category induce a similar state of consciousness in all users. Actually, there are many variables that affect the nature of a drug-induced experience. The focus here is on typical experiences, drawing on both phenomenological reports and experimental observations of a variety of people. Reviews of relevant literature include those by Orme (1969), Ornstein (1969) and Doob (1971); these sources may be consulted for additional references.

It is frequently concluded that duration experience is altered by a wide variety of drugs. However, there is some disagreement on effects of specific drugs, with inconsistencies both between subjects and between studies. It is possible that some drugs increase the variability of temporal experience and behaviour. Orme (1969) concluded that "the work on the effects of drugs on time estimation is unsatisfactory" (p. 86). Nevertheless, duration experience is usually reported to be lengthened under the influence of stimulants (such as amphetamine and caffeine) and psychedelics (such as marijuana and LSD), while it is usually reported to be shortened under the influence of sedatives and hypnotics (such as secobarbital and alcohol) and tranquilizers (such as chlorpromazine). Some drugs produce relatively dramatic alterations in awareness of time and lengthening or shortening of duration experience, while other drugs produce only slight changes.

Although the specific physiological effects of some drugs are not yet understood completely, many drugs which alter duration experience probably have an effect on both autonomic and central nervous systems. Fischer (1971) proposed a "perception-hallucination continuum" of increasing ergotropic arousal (hyperarousal) and a "perception-meditation continuum" of increasing trophotropic arousal (hypoarousal). In his proposal, such drugs as psychedelics lead to a state of hyperarousal and cause lengthened duration experiences similar to those in creative, psychotic and ecstatic states; while such drugs as minor tranquilizers lead to a state of hypoarousal and cause shortened duration experiences similar to those in meditative states (such as Zen satori and Yoga samadhi). The controversy about internal-clock and cognitive approaches has been especially prominent in discussions of drug effects. Hyperaroused states can be described in terms of an acceleration of an internal clock, an increase in the rate of mental events, or both; hypoaroused states can be described in opposite terms.

Some drugs, most notably the psychedelics, apparently produce qualitatively different temporal phenomena at high doses than they produce at low or moderate doses. Effects at higher doses are often characterized as ineffable. Attempts to describe these kinds of temporal experiences include: loss of awareness of time, feelings of eternal or infinite time, awareness of only the present, feelings of archetypal time and feelings that time has slowed down so much that it has stopped (Anonymous, 1969; Hoffer and Osmond, 1967). According to Ornstein (1977), "the best the verbal-logical mode can do for these experiences is to term them *timeless*" (p. 108, his italics). Such phenomenological reports suggest that duration experience and temporal perspective might be intimately connected. Radical changes in duration experience may precede and, perhaps, cause radical changes in temporal perspective. Similar alterations in temporal perspective occur in mystical experiences (Pahnke and Richards, 1966), which are discussed in Section 3.7. These similarities support Fischer's (1971) notion that

there is a similarity between extreme hyperaroused and hypoaroused states. Ornstein (1977) hypothesized that large doses of psychedelic drugs can "overwhelm the linear construction [of time] and allow 'an infinite present' to exist" (p. 109). This proposal is examined in more detail in the following sections of the present review.

3.7 Meditation and Mystical States

Temporal experiences resulting from meditation can be discussed in general terms without making distinctions among the varieties of meditation techniques. Indeed, different meditation techniques may ultimately produce similar alterations in consciousness. Further, some meditative states are similar to mystical states, in which there are "experiences of union with supernatural power" that occur "during a period of mental emptiness" (Zales, 1978, 254–255; Deikman, 1963, 1966). Mystical experiences are commonly reported by some practitioners of meditation, although a wide range of activities, such as physical exercise and scientific or artistic work, may promote mystical experiences.

Meditation typically produces a decreased amount of spontaneous mental activity, and it is commonly reported that the experienced duration of a meditation period is shortened compared to physical time. Attention to the passage of time is usually greatly minimized or absent, perhaps because concentrative meditation techniques involve attending to a single stimulus, such as a mantra or a physical movement. If an inexperienced meditator is unsuccessfully engaged in a struggle to concentrate, however, the experienced and remembered duration of the time period may be lengthened (Deikman, 1963).

A remarkable alteration in temporal experience of advanced meditators occurs in the state of samadhi, which is variously described as an experiencing of "voidness", "no-thingness" or "blankness" in which there is a paradoxical "pure" awareness without thoughts or "ego-involvement" (Capra, 1975; Naranjo and Ornstein, 1971). There is a qualitative change in temporal perspective in the state of samadhi, a change which is similar or identical to that described in both mystical experiences and psychedelic drug-induced experiences. This altered mode of temporal perspective has been characterized by the terms "timeless" and "eternal", where both terms refer to a shift in temporal perspective outside the ordinary range of duration experiences. There is a similarity with descriptions of the "Clairvoyant Reality" (LeShan, 1974) or "clairvoyant modes of being" (LeShan, 1976), in which the following laws, or limiting principles, operate: "Divisions of time, including divisions into past, present, and future, are errors and illusion. Events do not 'happen' or 'occur,' they 'are'" (LeShan, 1976, p. 92). Ornstein (1977) called this the "nonlinear mode", and he said, "In this mode, all action occurs in an infinite present. There is no attribution of causality or construction of sequence. All events occur simultaneously" (p. 111). A cognitive explanation of this kind of qualitative shift in temporal perspective might assume that ordinary human temporal perspective is stabilized by certain contents of consciousness (cf. Tart, 1975, 63–69)—reconstructions of past events, responses to present events and anticipations of future events. When there is a decrease or an elimination of these contents of consciousness during samadhi, ordinary temporal perspective is disrupted and replaced by a temporal perspective that may be more ontogenetically "primitive." Ordinary temporal concepts, which were learned during socialization with the development of the ego, cease to be maintained.

Capra, a "high-energy" (particle) physicist, identified similarities between the temporal perspective described by some mystics and the space–time views of some modern physicists (especially those instrumental in developing relativity theory). He said that:

> Because of the awareness that space and time are intimately connected and interpenetrating, the world views of modern physics and of Eastern mysticism are both intrinsically dynamic views which contain time and change as essential elements.
>
> (Capra, 1975, p. 173)

In comparison with the mystical experience of "timelessness", Capra asserted that the "space–time of relativistic physics is a similar timeless space of a higher dimension" (p. 186). Furthermore, the emphasis in Eastern mystical traditions on becoming free from the bondage of karma by transcending time is reflected in the "liberation from time" of relativistic physics, which may view interconnections between events (e.g. interactions of sub-atomic particles) as acausal. Capra's synthesis points clearly to the importance of investigating statements made by some explorers of altered states of consciousness. After all, it seems that certain viewpoints on the nature of physical reality must be at least partially credited to the much earlier Eastern mystical traditions.

3.8 Cerebral Hemispheres, Altered States of Consciousness and Temporal Experiences

Ornstein (1977) reviewed evidence suggesting that the two cerebral hemispheres are specialized to process information in different ways. He interpreted the evidence as indicating that the left hemisphere of most humans operates in a more linear way, processing information

more sequentially; while the right hemisphere operates in a more holistic way, processing information more simultaneously. Several recent studies of experienced duration of very brief stimuli (Avant and Puffer, 1978; Polzella *et al.*, 1977) have explored the normal functioning of the two hemispheres in ordinary waking consciousness, but no broad implications can be drawn from these studies at present. Some older research, however, has clear implications for some of the issues discussed in this review. For example, Efron (1963) compared discrimination of temporal sequence in normal subjects and subjects with left-hemisphere damage. The relatively poor performance of subjects with damage in the left hemisphere supported his hypothesis that "temporal analysis of sequence . . . is performed in the left hemisphere" (p. 423). Based on this and other evidence, Ben-Dov and Carmon (1976) proposed a two-stage model of hemispheric asymmetry in information processing. In the first stage, the left hemisphere resolves temporal information, while the right hemisphere resolves spatial information. In the second stage, the left hemisphere codes information by extraction (analysis) of features, while the right hemisphere codes information by integration (synthesis) of features. In short, several theorists have proposed that the left hemisphere is ordinarily more intimately involved in temporal experience than the right.

Other theorists (e.g. Bakan, 1977–78) have suggested that the relative contribution of the hemispheres to conscious experience shifts from the left to the right hemisphere during certain altered states of consciousness. If this is the case, we can begin to appreciate the dramatically different temporal experiences and perspectives mediated by the functioning of the two hemispheres. The left hemisphere apparently plays the major role in "ordinary" temporal experiences by analysing events and temporal sequences of events. The right hemisphere apparently plays the major role in temporal experiences in some altered states of consciousness by synthesizing atemporal interconnections between events and by enabling humans to experience the timelessness of existence. An understanding of both modes of temporal functioning seems to be an essential pre-requisite to an understanding of consciousness.

4 Summary and Conclusions

Temporally-defined sequences of events permeate human consciousness, and temporal experiences originate in certain aspects and processes of consciousness. An internal-clock approach cannot adequately explain diverse influences on temporal experience, but a cognitive approach has few apparent drawbacks. The present review clarifies and extends a cognitive approach to understanding and explaining the origins of human temporal experiences in both "ordinary" and altered states of consciousness.

Experiences of simultaneity and successiveness, which form the basis of the notion of a psychological moment, do not reflect the operation of a pacemaker mechanism. Instead, such experiences are apparently derived from aspects of cognitive processes, although the nature of the processes remains obscure. Dynamics of sensory information storage may mediate very short duration experiences and underlie the notion of an indifference point. Both unconscious, pre-attentive processes and conscious, post-attentive processes are involved in very short duration experiences. The psychological present is a phenomenon that apparently originates in the maintenance of information in short-term memory. Outside the range of the psychological present, intervals between events are probably experienced as a result of a comparison of previous and present contextual aspects of consciousness. Longer duration experiences can be explained in terms of the encoding, storage and retrieval of changes in contextual information throughout an entire duration. The experienced duration of a time period might be affected mostly by processes involved in encoding contextual changes, while remembered duration might be affected mostly by processes involved in storing and retrieving contextual changes. The "ordinary" temporal perspective of most humans may arise as a result of conscious reconstructions of past events, responses to present events and anticipations of future events.

Temporal experiences may be altered in several categories of altered states of consciousness. The duration of sleeping and dreaming periods is usually able to be judged in a fairly veridical way, but distortions of temporal sequences and durations may occur in some dreams. The experienced and remembered duration of daydreaming periods is usually shortened. A shortening of duration experience may occur in sensory deprivation conditions, although the evidence is meagre. In hypnosis, specific time-distortion suggestions apparently can substantially modify duration experience, and suggestions regarding each of the three temporal categories—past, present and future—can alter temporal perspective and behaviour. Alterations in duration experience and temporal perspective typically accompany the use of certain psycho-active drugs, and psychedelics may produce an experience of "timelessness". Similar experiences occur in mystical states, which may result from meditation and a variety of other techniques and situations. Differences in the functioning of the two cerebral hemispheres may underlie the linear and nonlinear constructions of time.

In the future, theorists should pursue a unified cognitive approach to temporal experience in ordinary and altered states of consciousness, an approach that is sketched in the present review.

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