The Psychology of Time: A View Backward and Forward

P. A. HANCOCK
University of Central Florida

RICHARD A. BLOCK
Montana State University

We selectively review the progress of research on the psychology of time during the past 125 years, starting with the publication of the first English-language psychological journal, *The American Journal of Psychology*. A number of important articles on the psychology of time appeared in this journal, including the widely cited early article by Nichols (1891). The psychology of time is a seminal topic of psychological science, and although it entered a phase of decline and even moribund neglect, the past several decades have seen a prominent renaissance of interest. This renewed vigor represents the rebirth of the recognition of the centrality of the psychology of time in human cognition and behavior. Our selective overview highlights a number of strands of progress and how they have helped lead to the present, in which the cognitive neuroscience of time and timing in the brain is one of the most fervent and fertile modern areas of brain research. We also discuss some remaining challenges and potential lines of progress.

The psychology of time has had a unique history in psychological research. When the formal discipline of psychology emerged from its philosophical antecedents in the late 1800s, the study of time and its relationship to mental phenomena was central to the nascent enterprise (Nichols, 1891). James (1890) featured this centrality in the inherent structure of his classic work, *The Principles of Psychology*. In it, *time past* was a function of attention and memory, topics that have become perhaps the most explored and investigated of all psychological phenomena to date. The previous chapter in James's book, and thus central to both his perspective and theoretical discussion, was *time present*. It was in that chapter of the text that he featured what was then known about the perception of time. Clearly, James saw this issue as perhaps the central component of human psychological experience, and rightfully so. How people understand the nature of time in passing, and its relationship to time in prospect and to time in memory, is at the heart of the human experience. Thus, in James's view, time perception stood at a pinnacle.

It was only following this centrality that James went on to discuss future time, or time in prospect,

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in terms of planning and decision making. Of course, these latter topics have also burgeoned far beyond the assembled knowledge on the perception of time. Given this historical foundation, why did time perception devolve from its pinnacle of importance to the point at which Adams (1964) concluded that "time perception is a venerable, tired topic in psychology that interests very few active investigators any more because no one bothered to explore the mechanisms of time perception and how it might enter into meaningful interaction with other mechanisms" (p. 197)? Before we discuss the reason for this demise, we emphasize that the enthusiastic pursuit of time perception persisted during at least the first decade and a half of the 20th century, along with studies of the effects of rhythm (Dunlap, 1911, 1915) and provocative observations on the differences between the sexes (MacDougall, 1904; Yerkes & Urban, 1906), to name but two lines of study. But the study of subjective time perception largely died with the ascendancy of behaviorism, at least as far as psychology in the United States was concerned.

In looking to excise appeals to unobservable phenomena, Watson (1913) and his later acolytes strove for acknowledgeable respectability from the putative harder sciences for which the essence was direct, empirical observation. In consequence, the pursuit of issues that featured primarily subjective experience (e.g., anxiety, fatigue, or any reference to the crucial role of internal states) was minimized in importance. Here we see the graveyard of the youth of time perception, because time is the quintessential nonobservable. Unlike all other forms of sensory psychophysics, *time* refers to an evidently intangible quality. As Hancock (2011b) argued, this is what makes the psychology of time perception difficult to comprehend above all other dimensions of experience. This observation is true not simply for the psychology of time but for the study of time in general (e.g., Parker, Harris, & Steineck, 2010).

Although the North American study of time perception died in the crematorium of behaviorism, the European community, and especially French and German psychologists, kept the pursuit alive (Block & Zakay, 2001). Following the tradition of Vierordt (1868; see Lejeune & Wearden, 2009), Bergson (1889/1913), and Guyau (1890), a number of European researchers continued to study the apparently intractable nuances of time. Among these, François (1927) was perhaps the first to point up the important link between body temperature and the perception of brief temporal intervals, an effect independently identified by American physiologist Hoagland (1933). Research on the physiological influences on time perception has continued to the present, where it features very much in the neuroscience-based attack on this puzzle (Hancock, 1993; Rao, Mayer, & Harrington, 2001; Treisman, 1984). The French tradition persisted with the important work of Fraisse (1963, 1984), and the contemporary resurgence in time perception research has owed much to this European tradition (cf. Pöppel, 1988; Rammsayer, 1997a).

The Resurrection of Time

Shortly after Adams (1964) announced the death of the psychology of time, a number of studies began to appear to initiate its resurrection. Arguably the most emblematic of these was Ornstein's (1969) dissertation. Perhaps inspired by Huxley's (1954) popular text, Ornstein, among others, explored the nonlinearity of temporal experience, which had become most evident under the influence of mind-altering drugs such as LSD (cf. Fischer, Griffin, & Liss, 1962). This lead was taken up by clinical psychologists interested in the relationship between drug influences and more commonly occurring forms of mental illness (Orme, 1969). Time perception became a useful instrument for such explorations and reintroduced the perception of brief intervals of duration back into the mainstream of clinical efforts. However, it was also at about this time that the evaluation of interval perception also began to reemerge into the experimental world.

To give the impression that no experimental research had been conducted between the 1920s and the 1960s would be simply false. In fact, a series of reviewers surveyed the area at fairly regular intervals during the period from the 1930s (Weber, 1933) through the late 1940s (Gilliland, Hofeld, & Eckstrand, 1946) and early 1950s (Woodrow, 1951), and on into the 1960s (Wallace & Rabin, 1960). Much of this work was directed at a conundrum that has still to be satisfactorily resolved, namely, how the content of a specific interval influences the perception of the duration of that interval (e.g., Smith, 1969). Block and Zakay (2001) wrote an extensive review of that early and later history.

There are some crucial reasons why the psychology of time has proved to be such a difficult problem. The first is that in assembling the ongoing literature across the century, we can see that there was no principled fashion in which the content "filling" the interval was ordered. The typical investigation used a series of convenient activities—counting, crossing off the letter *w* on a page of text, listening to text, doing nothing at all, actively trying to estimate the interval, and so on—in which there was virtually no theoretical foundation for the chosen activity or activities. Surveying numerous introductions to such works makes paradoxical reading. Many authors make this point and then go on to select their own idiographic selection of tasks. Like Adams's (1964) earlier observation on the failure to integrate time perception with other processes, this principled failure to establish a theoretical taxonomy as to what connotes a task (which indeed still remains a contemporary challenge) inhibited progress. A second and very much allied question concerned the role of attention. In the late 1950s and early 1960s attention itself experienced a renaissance in the early dawn of the cognitive revolution (Broadbent, 1958). It was all very well presenting differing tasks, but how could one control the amount of attention a person paid to each respective task? This concern itself emphasizes the issue of individual differences and the problems that such interindividual and intraindividual variation posed, and still poses, to the whole area of time perception (Doob, 1971; Tien & Burnes, 2002). It is a topic we will comment on at the conclusion of our review. We should also note that chronometric methods of studying reaction time, which we do not review here, also became an important part of the nascent cognitive revolution starting in the late 1950s.

Modern behavioral researchers introduced the scalar expectancy theory (SET) of time perception in the 1980s, based largely on studies of animals such as rats and pigeons (for a review, see Church, 2003, and others). However, SET theorists largely ignored the role of attention in their formal models. The issue of attention was raised most pertinently in a revision of SET that explicitly included attention, the attentional gate model (AGM; see, for example, Zakay & Block, 1997).

The AGM was proposed partly from what has become to be known as the prospective–retrospective comparison. This comparison has been explored most extensively by Block and Zakay (Block, 1974; Block & Zakay, 1997; Zakay, 1993). In prospective conditions, a person is aware that he or she will be asked about the duration of an interval and therefore is expected to pay explicit attention to coding that duration. In contrast, in retrospective judgments, the person has not been forewarned about the need to estimate the length of any particular duration and so, presumably, pays less attention to the passage of time. In this way, one can seek to generate an explicit contrast of the effects of differing levels of attention, without the necessity to make the inferences as to which filling activities demand more or less attention. In part, this comparison can therefore also circumvent the persistent and thorny issue of individual differences (Woodrow, 1933). Indeed, the results of these comparisons show important and large effects as to whether a person does or does not know whether he or she will be asked to judge the accuracy of a duration for which there are a number of potential explanations involving the respective influence of memory and attention (Block & Zakay, 1997; Zakay & Block, 2004).

The Importance of Time

The present article advances the study of and the importance of time, not merely in psychological research but throughout science and indeed in all of human experience (Fraser, Haber, & Muller, 1971; Hancock & Warm, 1989). However, especially for experimental psychologists, time is critical because "psychological time can no longer continue to be ignored by psychologists who propose models of nontemporal behavior, because nontemporal behavior does not exist" (Block, 1990, p. xviii). Not only is this statement important for all of psychological research, it is especially relevant to the present journal and its celebration of its longevity of more than a century and a quarter of its existence. As we have seen, time perception has been featured in its earliest volumes (e.g., Nichols, 1891), but if we scan the most cited works ever to appear in the present journal, we find a most interesting outcome. From a Web of Science search, one of the most cited articles in *The American Journal of Psychology* concerns time estimation (Hicks, Miller, & Kinsbourne, 1976). Given the foregoing discussion, we can see both the paradox and the importance of the cited work. First, the paradox:

How is it that the oldest continuously published journal in all of psychology has one of the highest citation rates for an article in an area we have already described as neglected and at times moribund? Our answer derives from the fact that the work of Hicks et al. was central to the ongoing theme of time perception and the content of specific intervals that, to a degree, persisted throughout the 20th century. Thus, their work struck a chord at the juncture when time perception was especially beginning to reemerge onto the psychological scene. In particular, they asked how prospective and retrospective judgments of time varied as a function of the amount of information processed (e.g., Smith, 1969). Briefly, they found no systematic effects in the retrospective paradigm, in which the person was not aware of the necessity to estimate the duration of the interval. However, in contrast, they found that in the prospective paradigm, judged time was an inverse linear function of response uncertainty. This linked attention to the information content intrinsic to a particular interval in conditions where someone expected to be asked to estimate the duration experienced. Thus, Hicks et al. identified the crux of an ongoing major issue and reported results that illuminated both the empirical pattern of outcomes and the theoretical reasons why such a pattern may be produced. Although the whole area of time perception has moved on since the 1970s, this finding has proved an important and influential one and is still a central building block in a number of theories on time perception.

Time Flows On

In the four decades since Hicks et al. (1976) reported their findings, the psychological study of time perception has progressed on numerous fronts (e.g., Friedman, 1990). One sequence of investigations looked to use the opportunities opened up by meta-analytic techniques to attack the question of the influence of individual characteristics on the perception of brief intervals of time. Block, Zakay, and Hancock (1998) examined the effects of aging on time perception and developmental status on the estimation of the same range of short durations. In general, there were systematic effects for age and developmental status, as there were for the sex of the person making the respective estimates (Block, Hancock, & Zakay, 2000; Hancock, 2011a). More recently, this technique has been used to address the influence the nature of the content of any duration has on its perceived duration (Block, Hancock, & Zakay, 2010). Again, large differences emerged between the prospective and retrospective findings. Importantly, as the cognitive load of the filling activity (cognitive load) increases, the subjective-to-objective duration judgment ratio decreases in the prospective paradigm but increases in the retrospective paradigm. We interpret this as emphasizing the influence of attentional allocation in the prospective paradigm but memory retrieval in the retrospective paradigm. Both positions argue for the importance of information coding rate and its subsequent transfer to, and recall from, memory. Thus, time in passing (prospective estimation) and time in recall (retrospective estimation) are distinct issues. In addition to these quantitative techniques for summarizing large bodies of experimental data, the pure psychological exploration of timing and time perception has itself shown an important renewal in the last decade or two (cf. Block & Zakay, 2001; Grondin, 2008).

What is perhaps most challenging is the generation of new techniques through which to explore the sense of time. The traditional and historically most dominant techniques typically are verbal estimation, duration production, and duration reproduction (Bindra & Waksberg, 1956; Clausen, 1950; Guay & Salmoni, 1988), but each has some drawbacks (Siegman, 1962). For example, reproduction necessarily emphasizes memory for explorations of time in passing, but the reproduction method has some limited exploratory capacities. In contrast, verbal estimation and production require the person to reference standard temporal units (e.g., seconds, minutes), and thus the pure perception of duration is contaminated by the linguistic and semantic tags associated with traditional units of measured time (Zakay, 1990). Furthermore, we have often come to see the duration measured by the clock as the "correct" time, and so percepts that deviate from this declared target are necessarily seen as errors of estimation. Although this provides methodological convenience and a veneer of scientific respectability, such a perspective can mask certain important qualitative dimensions of differing human temporal experience (Hancock, 2011a). A challenge in sustaining the renewed interest in time perception will be the development of innovative

exploratory techniques, especially those that can be used in association with the time scales involved in various brain imaging techniques. Indeed, it is the cognitive neuroscience of temporal perception to which we now proceed.

Time and the Brain

In many ways, neuroscientists have taken much more notice of Block's (1990) imperative about the centrality of time than have contemporary psychologists, although this too is changing. With advances in brain imaging techniques, it became progressively more evident that spatial and temporal resolution of the respective advances traded off such, so improved spatial resolution was often accompanied by lower temporal resolution and vice versa. Highly detailed but static representations of brain configuration could lead to important insights, but these were inevitably frustrated by the absence of sufficient information as to the dynamic changes that were occurring on differing time scales. Thus, much interest in the temporal dimension was engendered purely by way of the functional limits of the methodological techniques through which important discoveries were being made. But the focus was not on the techniques alone. Many neuroscientists began to realize that understanding how the brain deals with the fundamental dimension of time is important. They joined with many researchers who had been pioneering such efforts for a number of years, if not decades (Buhusi & Meck, 2005). It is now evident that the brain necessarily deals with time on a number of differing scales—and in a number of different cortical areas, or modules—in relation to a number of differing functions (e.g., absolute timing, relative timing, rhythmic frequencies). Recently, we have argued that one might consider these differing requirements as a virtual battle for time in the brain (Hancock, 2010). These respective advances in understanding the neuroanatomy (Coull, Vidal, Nazarian, & Macar, 2004), neurophysiology, and neuropsychology of temporal processing represent a significant and growing literature (Wittmann & van Wassenhove, 2009).

The Future of Time

To summarize, the most important question to pose is, What is the future of time? If one believes in the application of Kondratiev's (1925/1984) "long wave cycles" to the pursuit of scientific knowledge, then the future of time perception research appears to be exceptionally bright. Having been sadly displaced from its initial centrality in the psychological sciences and, for some decades, consigned to the back drawers of the discipline, time perception has now come roaring back. The number of people in psychology and the greater neurosciences working on time perception issues has perhaps never been greater.

There are a number of persistent issues in the psychology of time that we see as crucial. Perhaps the most important concerns individual differences. For some researchers, individual differences are an unmitigated nuisance because they dilute the strong nomothetic trends that they are seeking out. For others, these differences are the source of their whole life's study (Cronbach, 1957). What is clear is that when you ask a group of people for an estimate of even a short duration, you get a remarkably large distribution compared with a number of other forms of psychophysical assessment (Doob, 1971; Rammsayer, 1997b). What remain unspecified are the exact sources of these large individual differences. Although the characteristics identified by Block and his colleagues account for some of this variation, there remain sources of variation that have yet to be identified. It is encouraging to see that such efforts have begun to burgeon in the past decade (Hancock, 2011a; Pos, 2006; Rammsayer, 2002; Zimbardo & Boyd, 1999, 2008). As noted earlier, perhaps there are potential resolutions to be had by refining the methods of measurement so that the tested person is not expressing his or her estimate in terms of necessarily learned temporal units (i.e., having to express their estimates in terms of semantic labels such as *seconds*). The next challenge concerns the demands of integration. Important discoveries are coming from research in the neurosciences (e.g., Eagleman et al., 2005; Harrington, Haaland, & Knight, 1998). The central question is how these insights at the level of neurophysiology express themselves in various behavioral outcomes. It is often the case that behavioral data are explained through reference to associated, underlying neural structures and functions. Such linkages often pass the level of necessity, and some reach the criterion of sufficiency, although few have been confirmed as exclusive relationships (Gibbon & Malapani, 2002). Understanding and elucidating

these polymorphic, isomorphic, and homeomorphic linkages between differing levels of description may be the most vital challenge for neuropsychology in the coming decades. This challenge is not confined to timing and time perception, of course, but is one primary and persistent goal of all such research. To conclude, research on the psychology of time is on the upswing (Block & Zakay, 2001; Grondin, 2010). Perhaps this is a recurring theme in which time expresses its resurgence near the commencement of each new century. Even if this blithe speculation is not so, the future of time looks especially bright at present.

NOTE

Address correspondence about this article to P. A. Hancock, Department of Psychology, University of Central Florida, Orlando, FL 32816 (e-mail: phancock@mail.ucf.edu).

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