timing the future

the case for a time-based prospective memory

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Preface

Since millennia, people have pondered over the puzzle of time, its nature and its meaning. Among numerous Merriam Webster definitions of the word, one alludes to "events which succeed one another from past through present to future." That definition alludes to the recurrent ebb and flow of events that are ever new, in the Heraclitic sense, to some intrinsic stereotypy of the bodily internal rhythms as well as those of nature when a change or a spatial distance between events is defined as time. The word "tide" (from Old Germanic "tídiz") must have evolved into contemporary "time" applied also to evolutionarily programmed biochemical events, such as feast–famine and physical activity–rest cycles. The remnants of this tradition are in our calendar with the cycles of death (in the Fall) and recovery (in Spring). As in ancient Rome, our year begins with Januarius (the sacred month of Janus, the two-faced patron of beginnings and endings who saw the past and had his other face, turned to the future; he was also the deity-protector of portals, which as we know guide both ways). Nothing seemed more vital than having a glimpse of the future to cushion disquiet when awaiting the unknown. Timekeeping devices were produced as a way of organizing the world by planning a linear succession of affairs, predicting and thus hoping for controlling "an hour-glass and a scythe." Whatever we do (often labeled in the language of orienting response by "what" it is) is also defined spatially (as "where" we do it), but these two questions only become relevant when they are provided with a time-tag of "when." We often fall victims of mishandling the "when" regardless of how well the "what" and "where" are located. That alone explains the practical value of studies of the mechanisms of time-cued intentions.

In neuropsychology, the capacity for memory of future intentions is designated as prospective memory. Memory is considered prospective when it is provided from the outset with an explicit and mostly transitory retrieval "address" ("prospective trigger") either in a time-based format or as contextual or event-related cues. That specific reference determines how prospective memory is organized and how it is related to other cognitive functions. While remembering to implement intentions at a certain point in time is believed to merit an independent status in brain research, the pace of investigations in the area was surprisingly slow. In 2000, Ellis and Kvavilashvili asserted: "Although the first experimental study on prospective memory within cognitive psychology was conducted nearly 30 years ago . . . subsequent research in this new field grew steadily but somewhat slowly due to the efforts of only a handful of researchers." Five years later, in their Welcome to the homepage of the 2nd International Conference on Prospective Memory, its organizers write more enthusiastically that "since the 1st Conference in 2000, the field of prospective memory research has been booming." Our literature search of published papers appearing after 2000 in the Web of Science using the term "prospective memory" witnessed a steep proliferation of reports in this field reaching about 200 papers. Hardly a mark of a renaissance, this list assures that no longer is prospective memory area an emerging field struggling to achieve greater scientific respectability and independence.

The nature of time-cued prospective memory has received relatively little attention. In spite of its worth, it remains a mostly descriptive area of prospective memory research. Part of it belongs to the difficulty of the notion of time. The word is both an everyday patinated cliché and one of those grandiloquent terms that still ignites debates of physicists and philosophers. Neuropsychologists refrain from the transcendental aspects of timing the future in favor of a more pragmatic, task-related stance. These tasks are examined by the students of diverse disciplines of cognitive neurosciences, mostly those of time perception, memory for time and prospective memory. That is why the chapters in this collection deal with time perception and explore the ways time is used as a cue of prospective memory paradigms.

Surprisingly, the tradition of studying the effects of temporal distance from decision to outcome has strong methodological roots in economics (or behavioral economics) (e.g. "temporal discounting"). Temporal discounting scenarios increasingly inspire cognitive psychologists as well as health professionals whereas social psychologists, rather recently, model its more human face (e.g.

"temporal construal theory"). In the past, each group exhibited an attitude of "benign neglect" towards the other. That attitude has changed, also in large part because of the greater visibility of the prospective memory studies, so that it has become more feasible to provide psychological and neurobiological bridges between these areas.

In designing the book, we consciously omitted all "applied" illustrations of prospective memory in the conviction that the discipline is genuinely practical. In its different forms, prospective memory keeps our lives glued to the future when we need to shop, keep appointments, order prescribed drugs, meet a partner on the tennis court, pay the bills or need to come "on time" for a party. It is a part of our self-testing, error-monitoring, plan evaluation and other problem-solving behaviors. Total evasion of planning heralds a perilous withdrawal from reality — more so because prospective goal is a state, but prospective memory is the act of getting there. It says a lot about people's resolve, being in command of events, self-command, and self-restraint. Adequate prospective memory delays the prospects of cognitive disability or the need to move an elderly individual to a nursing home. That explains why the readership of this volume easily includes researchers and practitioners dealing with development and aging, social competence, pregnancy, manipulation of consumers' intentions, forecast of sales, marketing and advertising, and even those examining performance in a multitask environment of traffic operators. We hope that this publication will stimulate the reader's interest in the processes whereby people time the future.

It is a pleasure and a privilege for us to recognize all those who helped to produce this volume. Elaine Tham (now at Springer) was an enthusiastic midwife of the book. Terry Goldberg (now at Albert Einstein College of Medicine) gave it a formal welcome. Simon Goodman (Penn University), Richard Coppola (NIHM), and Leslie Hicks (Howard University), as well as our students on both sides of the Atlantic prompted stimulating discussions in the early phase of this project. The last chapter owes much to the generous comments of Arnold Wilkins (University of Essex, UK). Lia Kvavilashvili (University of Hertfordshire, UK) shared with us a sample of her slide presentation at the 2nd Meeting on Prospective Memory ahead of publication. Francois Lalonde helped in producing illustration materials. Alexandra Parmet-Myslobodsky proposed the design of the cover that was handsomely amended by Ian Seldrup our editor at World Scientific Publishing/Imperial College Press, who provided his hand and counsel all the way through. The project was partially supported by a sabbatical year from Bar-Ilan University for Joseph Glicksohn and a 2005

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Last, but not the least, Luzian Barr's moving story was an unwitting inspiration and a reminder of the powers of prospective memory. During WW2, he was deported to Germany from Poland. "If we are to remain alive," he heard his father mutter before the family was scattered in different concentration camps, "let us gather in the municipality of Łódz." Freed from the camp after the war — still a teenager — he made an arduous journey through the devastated post-war terrain of the two countries to reach, finally, his native city of Łódz. There, on the municipality steps he found the second survivor of his family, his older brother.

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Time Perception and Time-Based Prospective Memory

Peter Graf*[*] and Simon Grondin[†]

Introduction

In this chapter, we review experimental psychology research in two domains: time perception and time-based prospective memory (ProM). Intuition suggests that these domains are connected, that they involve at least some of the same high-level cognitive processes or mechanisms. In view of this intuition, it is surprising that only a small number of empirical investigations have focused directly on the processes or mechanisms that link time perception and time-based ProM. Why? In order to answer this question, in the first part of this chapter, we summarize recent empirical and theoretical work on time perception, and on how this ability changes across the adult lifespan. In the second part, we review empirical and theoretical work on time-based ProM and on how this cognitive function changes across the adult lifespan. In addition, we examine the manner in which time- and event-based ProM tasks have been defined, in order to identify where — under what kinds of study/testing conditions — time-related processes might be recruited in support of performance on time-based tasks.

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This chapter is a true team effort that was motivated by the desire to discover and delineate cognitive processes that are involved in both time perception and time-based ProM, and by the hope that it will lay the foundation for new collaborative research between these domains.

Time Perception

What are the major empirical and theoretical questions that motivate research on psychological time and time perception? To answer this question, we begin this chapter section with some observations on conceptual and method issues related to research on time perception. Next, we describe the dominant theoretical model of time perception, the internal-clock model, focusing especially on a recent information-processing version of it. Then, we use this model to guide the presentation of significant findings that have emerged from recent research, including from research on age related changes on temporal judgments.

Conceptual and Method Issues

The study of memory involves a retrospective component and a prospective component, and similarly, the study of time involves two components or research areas, one concerned with retrospective timing and the other with prospective timing. The distinction between prospective and retrospective timing concerns, respectively, situations where subjects/observers are informed in advance that they will have to make a time-related judgment versus situations where subjects/observers receive no prior warning about the need to make a time/duration judgment.[1]

In memory research, a vastly greater number of empirical and theoretical investigations have focused on retrospective memory than on ProM. By contrast, it is prospective timing that has received the most attention from time perception researchers in the past 30 years. Generally speaking, timing models developed to account for prospective judgments attempt to capture two fundamental features of temporal performance. One is related to the accuracy, or validity, of the time estimates provided by subjects, that is, it asks how closely related to physical time is subjective or perceived time. The other feature of performance concerns the variability of the perceived time estimates that have been obtained from a large number of trials.

Research is often centered on one or both or these two aspects of performance (i.e. accuracy and variability). The dependent variables used when addressing specific questions about accuracy or variability tend to be given different names, depending on the experimental method that is employed (e.g. verbal estimates, categorization, production and reproductions of intervals) as well as on the index adopted for expressing variability. The classical emphasis of time perception research has concerned the analysis of the ratio of the variability of estimated time to physical time (Weber fraction) or to the mean of the time-estimates (coefficient of variation).

Throughout the history of research on the psychology of time, a number of different independent variables have been targeted.[2] The most prominent among these are: the duration (length of time interval) under investigation,[3] the sensory modality used for marking time,[4] the nature of the cognitive demands made on subjects during an interval to be estimated, and the influence of participants' age.[5] Below, we will briefly review the research that bears either directly or indirectly on the last of these variables.

Theoretical Models

Some theoretical models of psychological time are based on the concept of a clock process, but others do not presuppose this type of construct.[3] Investigations of retrospective timing have been led by researchers with a traditional cognitive background. They held the view that subjective time is mediated by cognitive mechanisms. One classical example is Ornstein's model,[6] which deals with intervals longer than 10 s. This model postulates that the amount of storage space that needs to be allocated in memory for the purpose of estimating time varies directly with subjective duration. The availability of memory storage space is assumed to be determined by the number and complexity of stimuli to be processed during a given time period. By contrast Block and Reed[7] and Zakay and Block[8] argued that it is the number of contextual changes encoded into memory that determines the retrospective impression of duration.

A large number of different theoretical models have been proposed to account for subjects' performance on prospective timing tasks. Some models rely strictly on cognitive concepts without assuming the existence of a clock. For instance, Thomas and Weaver[9] describe time estimation in terms of an attention-based model. They assume that the number of stimuli to be processed during a given time period is inversely correlated with subjective duration because increasing attention to these stimuli leaves temporal processing with fewer, and possibly insufficient, attentional resources.

A very different way of thinking about time perception was introduced by M. Jones and collaborators (see Chap. 3 for a more complete description of their theoretical approach and how it may apply to prospective timing).[10,11] Jones and Boltz proposed a dynamic attending model.[12] In the context of ProM, this model is most interesting because it emphasizes the fact that sensitivity to the occurrence of future events might depend on the properties of past events. The occurrence of physical regularities within the flow of events in the environment is assumed to mark non-arbitrary (or coherent) beginnings and endings of several succeeding time spans which offer temporal predictability for forthcoming events. This predictability sets within an observer an attending attitude called a future-oriented attending mode. The accuracy of temporal judgments was assumed to depend on temporal coherence and on the capacity to synchronize the internal rhythmicity of attending, called attunement, with the appropriate external rhythm afforded by the environment. When sequences of events in the environment do not provide temporal coherence, an observer is forced to adopt an internal strategy, called an analytic attending mode, for dealing with such unpredictable event occurrences.

Before turning to the description of probably the most popular version of an internal clock, the pacemaker-accumulator device, the reader should note that animal timing and neuroscience offer many other timing models. For instance, Staddon and Higa proposed a pacemaker-free model where a cascade of interval timers is assumed to exist and where memory-strength decay determines specific time periods.[13,14] And most popular are pacemaker-free models that emphasize a neural network description or some oscillatory process.[15–17]

A Pacemaker-Accumulator Device. A long tradition in research on time perception has proceeded on the assumption that prospective timing is mediated by a unique or dedicated internal clock. This clock, often described as a pacemaker-counter or pacemaker-accumulator device,[18] is at the foundation of many theoretical models.[3] In general, these models assume that the pacemaker emits pulses that are accumulated in a counter, and the number of pulses that have been counted determines the perceived length of an interval.

According to this type of model, how does one explain the occurrence of errors in judging time? One central cause of error is often assumed to be the reliability of the pacemaker, i.e. errors are thought to be a property of the pulse emitter device. The mode of pulse distribution can be deterministic or stochastic, and the pacemaker rate of responding/signaling over a long time period may be fixed or variable. Differences in models are related to properties of the pacemaker.[3] Errors in timing may also occur because of variability in the latency of the onset or offset stages of responding, and in matching the internal signals with the physical dimensions of the intervals to be judged.[4] This source of error is more likely to have a small impact when intervals to be timed are relatively brief.

Other properties of the counter might also be a major source of timing error. Killeen and Taylor proposed the existence of a cascade of counters. If counting is hierarchical, as it is when decimal or binary systems are used, dropped counts can become increasingly costly when larger numbers are counted.[19] Killeen and Taylor noted that there should be a disproportionate error in timing each time the next stage in the counter must be set. These authors have demonstrated that the mean count registered should grow approximately as a power function of the duration of the to-be-timed interval.

An Information-Processing Theory. Probably the most frequently cited contemporary theoretical account that builds on the idea of a pacemaker-accumulator device is called the Scalar Expectancy Theory (SET).[20,21] Although it was developed primarily in order to explain animal timing data, this theory has been successfully applied to human time perception.[22] One very important feature of SET is that it acknowledges that sources of variance other than at the clock level exert a major influence on temporal performances.[23] The pacemaker-counter device is embedded in a larger information processing system, and thus is subject to errors that may be caused not only by the clock processes described above, but also by memory and decisional processes (see Chap. 2 for a discussion of the latter processes). In this version of the clock, the accumulation of the pacemaker's pulses into the counter is reported to be under the control of a switch mechanism, whose functioning is influenced by the amount of attention devoted to time processing.

SET has two fundamental properties. The first is that the mean representation of time for a series of temporal judgments equals real time. In other words, in the long run, subject produced estimates of target durations converge on the actual duration of targets. The second critical feature of SET is that the variability — often expressed as a one standard deviation unit — of time estimates or judgments increases linearly with the mean representation of time. The constant proportion between variability and the mean is said to be scalar, which is essentially known in psychophysics as Weber's law (i.e. the ratio of variability to mean time is a Weber fraction).

The availability of attentional resources is assumed to have a critical influence on the functioning of the switch mechanism.[24–26] Its role is central in accounting for the variability of time estimates and is most commonly invoked in order to explain the findings of investigations on perceived duration.[27,28] The dual-task strategy, classical in cognitive psychology, has been employed in multiple timing experiments. This strategy builds on the assumption that attention is a limited-capacity system. Therefore, if two tasks need to be carried out simultaneously, less attention will be available for each one. Brown and West showed that, in conditions where subjects were required to process multiple sources of temporal information, increasing the number of sources that had to be attended decreased the accuracy of timing.[29,30]

Somewhat along the same lines, the critical influence of attention on temporal information processing during the interval to be timed was demonstrated by Macar, Grondin and Casini. Their procedure was based on that used for analyzing attention-operating characteristics. Before each trial, a participant is asked to allocate a percentage of attention to each of two tasks to be performed simultaneously: a temporal task, which is to discriminate the length of the sensory signal, and a non-temporal task, which is to discriminate the intensity of the signal. When more attention was allocated to the temporal task, perceived duration was longer and better performance was observed in duration discrimination.[31,32]

These attentional effects can be readily accommodated by a pacemaker-accumulator model, if we assume the existence of a switch component that determines the access of pulses to the accumulator. The switch would be under the control of attention, with less attention to time resulting in a smaller transmission of pulses and in more variability.

Time Perception and Aging

Although there has been a great deal of research on time perception, only a relatively small number of investigations have focused on how this high-level ability (i.e. time perception) is affected by aging, and consequently, many important questions remain unanswered, especially questions on age-related changes in the variability of time estimates.[5,33] Because timing is so central to many simple tasks that need to be performed everyday (e.g. driving a car, carrying out a series of planned tasks), and because timing, as noted above, is so closely linked to memory and attention mechanisms (both of which are known to decline with aging), this section is dedicated to research on aging and time perception.

Overall, aging is accompanied by a decrease in the accuracy of estimating time, but this decrease appears to depend on the method adopted for conducting the investigation as well as on the range of the to-be-timed durations that are under scrutiny.

For very brief intervals (circa 50 ms), Rammsayer, Lima and Vogel reported no difference between age groups (mean ages = 25.1, 45.5 and 64.6 years old) in the ability to discriminate the relative duration of intervals marked by two brief auditory signals.[34] The mean difference threshold was about 17 ms in this experiment. However, Rammsayer reported that the discrimination of intervals of 1 s duration was poorer by older adults (70.4 years old) than by younger adults.[35] As well, in the same study, the reproduction of 1 s intervals, but not that of 15 s intervals, by older adults was longer than the reproductions by young adults.

In a task that required subjects to categorize a series of six tones on the basis of their duration (from 250 to 622 ms or from 622 to 1548 ms), McCormack, Brown, Maylor, Richardson and Darby reported that older adults (74.1 years old) performed significantly worse than young adults (19.5 years old).[36] The same authors reported that for a similar task involving 9 tones varying from 250 to 2039 ms, older adults (70.5 years old) made fewer correct responses than young adults, and the pattern of errors was different between the groups. When the pitch of nine tones had to be categorized, older adults (68.7 years old) made fewer correct responses than young adults, but both groups showed a similar pattern of errors. Based on these data, McCormack *et al.* concluded that older adults have a distorted memory representation for duration information.

The effects of age have also been examined in the categorization of intervals lasting between 3 to 6 s, and marked by auditory or visual signals.[37] In this experiment, the level of attention was manipulated: there were trials with only one stimulus presented in either modality (i.e. in the full attention condition), and trials where two stimuli, of different lengths and different modalities, were presented (i.e. in the divided attention condition). This manipulation was conducted in the morning (9 am) for half of the participants, and in the afternoon (4 pm) for the other half. The older adults (69.3 years old) showed larger effects due to the modality and attention manipulation than the young adults (20.1 years old): visually marked intervals were perceived as much shorter than auditory marked intervals, and sensitivity to time decreased in the divided attention condition. Moreover, sensitivity to time was higher and the modality effect was smaller when testing occurred in the afternoon rather than in the morning in both age groups, except that in the full attention condition, older adults tested in the morning showed better sensitivity to time for intervals marked by visual signals.