AQ: Please provide an abstract to this Chapter, as all other chapters have one.

Chapter 6

The wrong tree: time perception and time experience in the elderly

J. H. Wearden

Introduction

A prominent psychological feature of ageing is changes in the experience of time. People report that "Christmas comes round quicker every year" as they age, yet "Time lies heavy on their hands," and days may seem to crawl by, in a way they never used to when the person was younger. The two statements together appear at first sight baldly contradictory: the former implies increased rate of the passage of time with ageing, while the latter suggests time seems to drag as we get older. As will be seen later, modern research in the Psychology of time perception may be able to reconcile these apparent paradoxes, and begin to give us some insight into the ways that time experience might change with increasing age.

The perception of time is a Cinderella who never attended the ball. The number of active workers worldwide remains very small (at the time of writing a few tens of people), and funding for basic research is impossible (in the United Kingdom) or very difficult (elsewhere) to come by. Nevertheless, the few workers that there are in this field show extraordinary productivity, and the last 20 or 30 years have seen a mini-"Golden Age" in the study of time perception in humans, with many fundamental processes being elucidated for the first time, and major discoveries made.

The present chapter is intended to perform a number of different functions. First, it will introduce some basic ideas from contemporary time Psychology, and show how some of these ideas have been applied to the study of some aspects of timing in the elderly. To anticipate slightly, it will become clear that explanations of timing based on some sort of "internal clock" have been recently dominant. Following on from this, a second part will specifically discuss the question of what changes in time experience and behavior might be

06-Spco-chap06.qxd 04/02/05 3:36 PM Page 135

occasioned by changes in the "speed" of this internal clock, with a particular focus on any slowing of clock speed that might occur with ageing. The third part of the chapter takes a more radical turn, and essentially argues that most work conducted up until the present time (including work such as Wearden, Wearden, & Rabbitt, 1997), interesting though it may have been, is inappropriate to come to grips in a satisfactory way with important questions about time experience in the elderly, and that new areas, developed from some recent theoretical arguments and developments in time Psychology, need to be explored if a proper understanding of time experience and ageing is ever to be achieved. Much of the work on time perception in the elderly, interesting though it may have been has, according to this view, been "barking up the wrong tree," and some suggestions for a more appropriate location are given.

Prospective timing: a model and some age effects

A distinction central to modern time Psychology is that between *prospective* and *retrospective* timing, although the distinction was introduced only fairly recently in the long history of time perception by Hicks, Miller, and Kinsbourne (1976). Prospective timing involves time judgments made when experimental participants are alerted in advance that duration is an important feature of the procedure. Most common laboratory tasks are of this type (e.g. "hold down this button for one second," "I'm going to present two tones and I want you to tell me which lasted longer"). In contrast, retrospective timing involves a time judgment made when the participant is unaware that a question about time is going to be asked (e.g. "how long is it since you started reading this paragraph?").

Contemporary time researchers are (virtually) unanimous that confusing these two is fatal to any proper progress (although they were routinely mixed up until recently, see the work reviewed in Fraisse (1964) for example), and that they are explained by different psychological mechanisms. I will discuss retrospective timing in more detail later (as well as adding a third type of time judgment to the existing list of two), but first I will introduce some ideas and research related to prospective timing.

AQ: Please update Wearden (in press).

Figure 6.1 shows the dominant contemporary model of prospective timing (dominant in the sense that all alternative models are either variants of it, or reactions against it), the *scalar timing* model (SET) of Gibbon, Church, and Meck (1984), which is in some ways an elaborated version of an earlier model by Treisman (1963) (for a discussion of the development of this type of approach see Wearden (in press a) and for recent reviews of the use of SET as an explanation of human timing see Allan (1998) and

06-Spco-chap06.qxd 04/02/05 3:36 PM Page 136

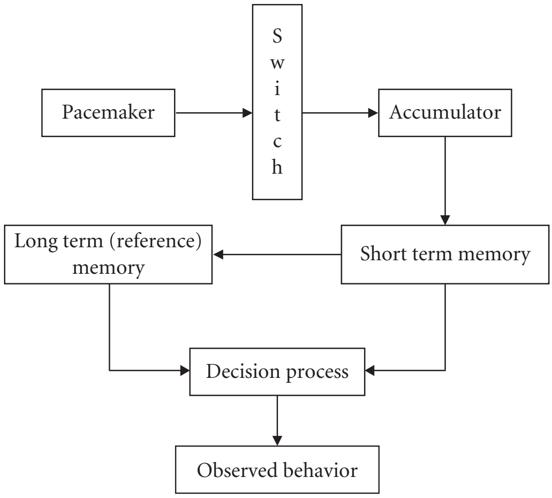

Fig. 6.1 Outline of the timing system proposed by scalar timing theory (or scalar expectancy theory: SET).

Wearden, 2003). SET derives time judgments and timed behavior from the sequential operation of processes at three levels. "Raw" representations of duration are generated at a clock level by a pacemaker–accumulator clock. This sort of (hypothetical) clock consists of three connected parts: a pacemaker that produces pulses or "ticks," an accumulator that stores the ticks produced during some time period, and a switch that connects the two. So, for example, when a stimulus is timed, the switch closes, allowing pulses to flow from the pacemaker to the accumulator, and when the stimulus goes off, the switch opens, cutting the connection. The accumulator thus contains the number of pulses accrued during the stimulus, and this number is used as the "raw material" for time judgments. Although pacemaker–accumulator clocks are hypothetical in the sense that no brain mechanism corresponding to them has (yet) been found, the operation of the such clocks can be mathematically specified, so very precise predictions about what sort of time representations such clocks can produce can be made (see Gibbon et al. 1984, & Wearden Edwards, Percival, & Haworth, 1998, for discussions of the mathematics of pacemaker–accumulator clocks).

AQ: Please check , Wearden, et.al (1998) has not been listed in the reference list.

The next level of the SET system involves two sorts of memory: a working memory for duration (essentially the contents of the accumulator, and in some recent versions of SET the working memory is conflated with the accumulator), and a reference memory storing "important" times, such as standards needed for the particular task used. A final level involves a decision process, and it is only after the operation of all three levels that a time judgment is made.

06-Spco-chap06.qxd 04/02/05 3:36 PM Page 137

AQ: Please note the change we have made from "Derby" to Darby in para "The task . . . " according to reference list.

The task of *temporal generalization* (Wearden, 1992), which has been used with elderly people by Wearden et al. (1997) and by McCormack, Brown, Maylor, Darby, and Green (1999), illustrates the operation of the model. In the normal version of temporal generalization, the participant receives a few presentations of a "standard" duration (e.g. a tone 400 ms long), and must remember this standard. Next, comparison durations (e.g. tones from 100 to 700 ms long) are presented in a random order, and the participant's task is to decide whether each comparison had the same duration as the standard (by making a YES or NO response), with feedback as to performance accuracy usually being given. The resulting behavior can be presented in the form of a *temporal generalization gradient*, the proportion of YES responses plotted against stimulus duration.

SET explains performance on the task as follows. Presentation of a stimulus causes the switch connecting the pacemaker to the accumulator to close, and "ticks" accumulate until the switch opens again when the stimulus goes off. The accumulator contents are then transferred to working memory, which then contains a raw representation of stimulus duration, coded in terms of the number of ticks stored. At the start of the experiment the identified standards are stored in reference memory, which contains a representation of what the standard (400 ms in our case) "feels like." When a comparison stimulus is presented, the number of ticks in working memory is compared with a sample drawn from reference memory, and if the two are "close enough," according to some decision process, the participant makes the YES response, otherwise he or she responds "NO."

In order to generate behavior, clock, memory, and decision processes are all involved, so if some intergroup difference (e.g. between elderly participants and younger controls) is found, this could be due to differences at any of the three levels of the SET system. However, SET produces mathematical specifications of the operation of each part of the system, so computer modeling can be used to identify the cause of between-group differences more precisely subject, obviously, to acceptance of the assumptions of the model.

In the case of temporal generalization, the standard treatment (deriving from Wearden, 1992) assumes, in a slightly simplified form, that (a) all the durations are timed on average accurately, (b) the reference memory is represented as a Gaussian distribution of values, with an accurate mean and some variance, which can vary between groups, with a sample being drawn from this distribution on each trial, and (c) the comparison process is based on a threshold (which can also vary between groups, that is, different groups can be more or less conservative about saying that a comparison duration is the standard).

Wearden et al. (1997) used temporal generalization in a wider study of prospective timing in the elderly. In their work, sampling was used to avoid the

06-Spco-chap06.qxd 04/02/05 3:36 PM Page 138

usual age/IQ confound, so data could be analyzed in terms of either age or IQ. The standard used was a 400 ms tone, and comparison durations ranged from 100 to 700 ms in 100-ms steps. The first interesting finding was how "normal" performance of the elderly groups (60–69 and 70–79 years) was, compared to that of students. In all cases, the temporal generalization gradient peaked at the standard (so on average the 400 ms comparison was identified, correctly, as the standard more than any other comparison value), and was asymmetrical, with durations longer than 400 ms being confused with it more than durations shorter by the same amount. This asymmetry is almost always found, and is explained by the decision processes used (Wearden, 1992, in press).

AQ: Please update Wearden.

Wearden et al. (1997) found an age difference between groups, with slightly flatter generalization gradients in the 70–79 year-olds than the 60–69 year-olds. Modeling suggested that the difference was due to greater variability of reference memory in the older subjects. When the same population was divided into three IQ bands, differences between the IQ groups were more marked, but once again the main difference between groups was due to memory variance, with higher variability in the lower IQ groups.

The results of Wearden et al. suggested that prospective timing in the elderly was associated with greater variability of reference memory (or, perhaps, in variability of raw timing processes themselves, see Wearden (in press b) and below) than timing in young people, but was essentially very similar in nature, and a similar conclusion from temporal generalization was reached by McCormack et al. (1999). However, differences in timed behavior between old and younger people are not always found.

AQ: Please check Wearden (in press) has not been listed.

A second task used by Wearden et al. (1997), and by McCormack et al. (1999), was *bisection* (see Wearden, 1991, for the original method). Superficially, this task resembles temporal generalization. People are initially presented with two standards, one short (e.g. 200 ms) and one long (e.g. 800 ms), identified as such. They then receive a range of stimulus durations (e.g. from 200 to 800 ms in 100-ms steps), and have to classify each presented duration in terms of similarity to the short or long standards, with a SHORT or LONG response being produced. The resulting behavior can be plotted as a psychophysical function, the proportion of LONG responses (judgments that a presented duration is more similar to the long than the short standard) plotted against stimulus duration. This produces a monotonically increasing function of ogival shape going from near zero LONG responses when the stimulus with the same duration as the short standard is presented to nearly 100% when the longest stimulus duration occurs. The psychophysical function can be analyzed to yield a number of measures of performance (see Wearden & Ferrara, 1995, 1996), and task performance can be explained by a number of

06-Spco-chap06.qxd 04/02/05 3:36 PM Page 139

different models (see Wearden, 2004). Among the performance measures that have attracted attention are the *bisection point* (the stimulus duration giving rise to 50% LONG responses), and the *Weber ratio* (essentially a measure of the slope of the psychophysical function, which assesses timing sensitivity).

Wearden et al. (1997) found no age or IQ effects on bisection point (see also McCormack et al. (1999) for a similar result) and, furthermore, the performance of our elderly or low-IQ participants was virtually identical to that of undergraduate students 50 years younger, and (presumably) with higher average IQs. Figure 6.3 of Wearden et al. also suggests that temporal sensitivity did not differ between age and IQ groups either, as the different psychophysical functions superimposed almost perfectly, but Weber ratios were not calculated. It should perhaps be mentioned, however, that bisection is not immune to "developmental" effects, as differences in performance of children of different ages can be consistently found (Droit-Volet & Wearden, 2001, 2002).

The discrepancy between finding consistent age and IQ effects on temporal generalization but not bisection is puzzling, to say the least. A reader might predict that age and IQ effects would be at least as marked on bisection, as people have to remember two standards rather than one (which might be supposed to be more demanding, and is, see Jones & Wearden, 2004), so if the bisection standards in reference memory have increasing variance with increasing age or decreasing IQ, behavioral effects should be obtained, yet are in fact absent. A complete discussion of this result is inappropriate here, but the obvious conclusion is that participants are not using the "standards" in bisection in the same way as the standard in temporal generalization, and there is other evidence for this (e.g. Allan, 2002; Wearden & Ferrara, 1995).

More generally, this generalization/bisection comparison in the elderly may tell us more about how timing tasks are performed (an interesting topic, but not the central focus of the research) than it does about timing processes in the elderly *per se*. In addition, the bisection result shows that age (and IQ) effects on timing are not always obtained. A further complication in timing studies is that a multiprocess theory like SET offers many possibilities for psychological variables, other than "timing ability," which may differ between young and older participants. Attentional effects are well-known in timing (see Lustig, 2003, for a review) although how they should be best understood remains controversial, and age-related differences in memory and decision processes may also play a critical role.

I will discuss some prospective timing studies, which relate to the "speed" of the internal clock later, but before leaving the topic one fairly consistent result needs to be mentioned. Consider the task of temporal generalization described above. When the standard is presented, SET assumes that it is normally stored

06-Spco-chap06.qxd 04/02/05 3:36 PM Page 140

on average accurately in reference memory (although the storage may involve the introduction of variability to the representation). So, for example, 400 ms is stored as on average 400 ms, and so on. Some data suggest developmental trends not only in the *variability* with which standard durations are represented, but also in the *average* value stored.

McCormack et al. (1999) studied temporal generalization in children of 5, 8, and 10 years (as well as adult groups), and found that the younger groups of children behaved as if they were storing the standard as shorter on average than it really was. This trend disappeared in the older children. Droit-Volet, Clément, and Wearden (2001) found a similar result using children of 3, 5, and 8 years: here, modeling assumed that the youngest children were remembering the standard on average as 83% of its real duration, whereas the oldest children exhibited a much smaller "distortion" of the average, or no distortion at all. The claim that young children remember standard durations are shorter than they really are is controversial, and was not obtained by Droit-Volet (2002), but the bulk of evidence, including new data, seems to support it (see McCormack, Brown, Smith, & Brock, 2004).

The obvious question is this: if children store standards as shorter than they really are, and young adults store them veridically, do older adults store durations as *longer* than they really are? Wearden et al. (1997) and McCormack et al. (1999) effectively assumed in their Modeling that this was not true. However, inspection of their data shows that temporal generalization gradients in the older groups were more skewed to the right than those in younger populations (i.e. older people tended to confuse stimuli *longer* than the standard more with it than younger groups did, although all groups produced asymmetrical gradients), and one obvious suggestion is that the standard is being remembered as (slightly) longer than it is. Other evidence for this comes from a study of absolute identification of duration by McCormack, Brown, Maylor, Richardson, and Darby (2002).

In fact, the suggestion of temporal memory "distortion" in the elderly is supported by earlier work with rats. Meck, Church, and Wenk (1986), and Lejeune, Ferrara, Soffié, Bronchart, and Wearden (1998) both studied aged rats, and younger controls, on a "peak interval" task. To simplify the procedure slightly, lever-presses are reinforced with food but only at some time, *t*, after the onset of a signal. Essentially, the animals should learn that food is available at time *t*, and the procedure enables the measurement of their responding at times both shorter and longer than *t*, on the critical "peak" trials. After considerable training, the response rate of the animals increases from near zero early in the interval to a peak at or near *t*, then declines at longer times, with the overall response versus time curve resembling a Gaussian

06-Spco-chap06.qxd 04/02/05 3:36 PM Page 141

function. Curve-fitting can be used to determine when the response peak occurs, and this peak location is assumed to be an index of the average value of the animal's reference memory of *t* (see Lejeune et al. (1998) for details). Both studies found that, at least in most cases, the older rats behaved as if they remembered *t* as being longer than it actually was.

Slowing down the clock and the problem of "reference"

The attentive reader will have noted that the possibility that the pacemaker of the internal clock hypothesized by SET slows down with increasing age has not so far loomed large in this chapter. Suppose that the pacemaker does slow down: what are the consequences of this for timing behavior? SET proposes a pacemaker of a Poisson type, that is, a process which generates ticks at random but at some constant average rate. SET furthermore usually regards the rate of this pacemaker as sufficiently rapid so that the Poisson process makes only a small contribution (which is usually ignored) to the total variance of timing. So, in normal circumstances, the actual speed of the pacemaker (which I will just call "clock speed" from now on), is of no importance in timing.

However, internal-clock based theories like SET have long been interested in the possibility of changing clock speed by various manipulations. Early examples come from attempts to manipulate clock speed in humans by increases or decreases in body temperature (Wearden, 2003, 2004; see also Wearden & Penton-Voak, 1995, for a review). Work with animals has used drugs that increase or decrease dopamine levels (Meck, 1983), and recent work with humans has used a method introduced by Treisman, Faulkner, Naish, and Brogan (1990). With this technique, stimuli or timed responses are preceded by trains of repetitive stimulation (usually in the form of clicks or flashes), and evidence suggests that this stimulation increases clock speed. A complete account of the effects of repetitive stimulation, and other attempts to change clock speed, cannot be given here, but the reader is referred to Penton-Voak, Edwards, Percival, and Wearden (1996), Burle and Casini (2001), Droit-Volet and Wearden (2002: a demonstration of the effect in children), Wearden, Philpott, and Win (1999), and Wearden, Pilkington, and Carter (1999: a rare "slowing down" study).

AQ: Please check that Wearden, Pilkington, and Carter (1999b) has been changed to 1999.

Almost all the work on changing clock speed, whether by body temperature changes, drugs, or repetitive stimulation, has used a "state change" design, where, for example, timing behavior with a putatively speeded up or slowed down clock is compared with that obtained with a "normal" clock. In the classic drug experiments by Meck (1983), for example, rats, in some conditions, learned standard durations after saline injections, then were tested with these

06-Spco-chap06.qxd 04/02/05 3:36 PM Page 142

durations after amphetamine (which speeds up the clock) or haloperidol (which slows it down). The inverse experiments were also conducted by Meck: here, animals were *trained* under haloperidol or amphetamine, then *tested* with saline. In these experiments, rats have a "reference" developed in one state (drug or saline) and use this reference to judge comparisons timed in another state. Logically, if there were no state change, then clock speed differences would not be observed in behavior, even if present. Meck (1983) showed that this was in fact the case: rats' timing behavior was identical under amphetamine, haloperidol, or saline, with any differences in clock speed being revealed only when the state was changed (see Meck, 1996, for a discussion and review).

Experiments with humans have employed state change conditions logically similar to those used by Meck (1983): judgments made in one state make reference to standards learned in another one. For example, Droit-Volet and Wearden (2002), in an experimental *tour de force* for which the first author was solely responsible, tested children as young as three in conditions where standards in bisection were learnt with a normal clock, with comparison durations being sometimes presented after flicker, which "sped up" the clock. Wearden, Philpott et al. (1999) show the inverse effect: standards were learned with a speeded up clock, then comparisons were sometimes tested with a "normal" clock. In all cases, the participants behaved as if their clock had sped up or relatively slowed down in the appropriate manner.

AQ: Please check that Wearden, Philpott et al (1999a) has been changed to 1999.

To illustrate that some kind of reference is needed to interpret putative clock speed differences, consider the following simple thought experiment. We compare two individuals A and B. For A the internal clock "ticks" at 120/s, for B 80/s (the figures are, of course, imaginary and used only for illustration). Let us suppose that one clock second is represented by 100 ticks. If a stimulus 1 s long is presented, A will overestimate it (1.2 s), and B underestimate it (0.8 s). If, on the other hand, A and B are asked to produce 1 s, and do so by counting ticks, then A will "underproduce" reaching 100 ticks in 0.83 s (100/120), whereas B will "overproduce" 1 s as 1.25 s (100/80). The logic above derives from sketchy and questionable accounts of how verbal estimation and production are performed but, more importantly for present purposes, depends critically on the idea of a "common reference" (100 ticks = 1 s), used by *both* A and B. It assumes that neither A nor B can learn, as a result of everyday experiences, or events presented during the experiment, that 1 s = 120 ticks for A and 80 for B. In experiments where the clock is "speeded up" (e.g. Penton-Voak et al. 1996), participants can establish a "common reference" from state-change conditions, and results are as predicted above: with a faster clock estimations increase but productions decrease. If A and B are a young person and an older one, there can be no state change, so the problem of where the "common reference" comes from remains.

Logically, contemporary internal clock theories appear to forbid the detection of *absolute* clock speed, and allow effects to be manifested only *relatively*, in state change designs, where a "reference" established in one state is used for comparisons in another one. At first sight, this seems to shut the door on timing behavior in the elderly being explained in terms of changed clock speed compared with younger people, as for example, a person cannot be given the standards on temporal generalization when 18, and tested on the comparisons when 78. In all timing tasks comparing, for example, elderly participants with student controls, comparisons are between-subject so no clock-speed effect can be detected, without some "common reference."

Suppose, for example, that participants are required to hold down a button for 1 s, with accurate performance-related feedback being given after each response. Even if the clock in one group "ticked" at *m* per second and another group at *n* per second, the participants could just learn to respond after different numbers of ticks. This suggests that feedback would reduce age, or IQ, effects if these were based on putative clock-speed differences, and it does (see Wearden et al. 1997, figure 6). It may further suggest that "recalibration" of time judgments to take account of clock speed differences may be easy to achieve.

The above discussion suggests that "clock speed" explanations of ageing effects in timing need to be approached with considerable scepticism, as in most cases even if clock speed differences were present they may not affect time judgments. Is there any way out of this quasi-Einsteinian trap, which seems to forbid the detection of absolute clock speed, just as absolute velocity cannot be measured without a "reference?" The conservative answer is "no," but subject to certain assumptions (which may not be correct) progress might be made.

AQ: Vanneste et al (2001) has not been listed. Please check.

Vanneste, Pouthas, and Wearden (2001), for example, used the idea of "internal tempo," derived from Denner, Wapner, and Werner (1964). This very simple method asks participants to tap at a "speed which is comfortable for them" for a short period of time, and the resulting intertap interval defines that individual's "internal tempo," a measure which is supposed to be related directly to internal clock speed (see Vanneste et al. 2001, and Boltz, 1994, for discussion). Vanneste et al. found that elderly participants (mean age 69) had slower internal tempi than younger ones (mean age 26), a result that can be considered to reflect slower internal clock speed in older people, subject to the assumption that spontaneous tapping reflects internal clock speed directly. Vanneste et al. also tested their participant groups on a "continuation tapping"

06-Spco-chap06.qxd 04/02/05 3:36 PM Page 144

task introduced by Wing and Kristofferson (1973). Here, people initially receive a periodic signal, and have to tap in synchrony with it. Then the signal stops and the people are required to continue to tap at the same rate.

The synchronization period would be expected to abolish the young/old difference in timing behavior as even if the internal clock ticked more slowly in the elderly, as the internal tempo result suggests, the participants would compensate for this. This was the result obtained: no differences were found between the young and old group under the continuation tapping phase of the study, even when the "enforced" tap rate was faster than people's spontaneous tapping rates.

The data of Vanneste et al. suggest that some "uncalibrated" conditions, like performance without any kind of feedback or synchronization, might reveal clock speed differences, and this might tempt the reader into thinking that procedures like interval production without feedback might be useful, but this suggestion needs to be treated with the utmost caution. For one thing, we know little about where "references" come from in uncalibrated conditions: when a person is asked to hold down a button for 1 s, we have little or no idea how they do this without feedback (and the role of feedback itself is not understood). For another, some data suggest that the idea in a simple form may not give a coherent account of data

Experiment 4 of Wearden et al. (1997), which asked people to produce 1 s, proceeded in three phases: no feedback, feedback, and post-feedback. No age or IQ effects on mean time produced were found in the feedback or post-feedback conditions, but in the no-feedback conditions, the young participants (60–69) produced longer intervals than the older ones (70–79). Both produced intervals much longer than 1 s without feedback, although the older group's average production (about 1.5 s) was closer to the target. When intervals are produced, faster clock speed leads to *shorter* productions (Penton-Voak et al. 1996), so the conclusion here would be that clock speed is faster in the older participants, which contradicts the general idea of slowing down the clock with increasing age.

However, there are some data consistent with clock speed differences between elderly and younger people, if a common reference is assumed. Craik and Hay (1999), for example, found very large age effects in an experiment where older participants (mean age 72.2) were compared with undergraduates (mean age 22.2). Participants estimated or produced intervals of 30, 60, and 120 s. Both participant groups overproduced real times, but underestimated them. However, very marked age effects were found, with the older groups emitting productions much longer than the younger groups, and productions which were, furthermore, very much longer than the real time. Conversely, estimates produced by the older group were smaller than those produced by the younger one, and sometimes very deviant from real time (e.g. 120 s was estimated as around 40 s in the elderly).

If we assume a clock-speed difference between the groups, the results are consistent with the idea of slower clock speed in the elderly, which will lengthen productions and shorten estimations (as discussed above). However, the logic assumes some common reference for both participant groups, that is, both need to have some standard "clock second" or other unit, which is the same. This may seem at first sight rather implausible as it implies that older people have never, in the course of innumerable experiences with duration in their everyday life, learned to "recalibrate" to compensate for their lower clock speed. One possibility is that Craik and Hay's participants were using the common reference provided by chronometric counting at a subjective rate of 1 count/s. The experiment used long intervals where counting would be expected to be useful, and the procedure did not appear to prevent or discourage it. If, as Vanneste et al. (2001) the results of suggest, older people have slower spontaneous tapping rates than younger ones, then their rate of counting at a subjective rate of 1 count/s might be slower, so counting would produce a common reference, which would produce the effects obtained. When the stimulus finishes, the older people have counted to a smaller number of "seconds" than the younger ones, so report shorter estimates. When they produce some target interval, they count more slowly, so a longer time is needed to get to the "*n* seconds" required, and the interval produced is longer in older people than younger ones. This interpretation is speculative, but does supply a possible "common reference" for judgments in both the old and young people, without which demonstration of a clock speed effect seems impossible.

AQ: Vanneste et al. (2001) has not been listed. Please check.

Obviously, assuming that absolute clock speed can be detected in mean measures of timing behavior is exceptionally risky, but there may be another way to detect differences. Recall that "classical" SET assumed that pacemaker variance makes a negligible contribution to total timing variance, which is assumed to come from other sources, such as temporal reference memory. Some recent work has questioned this assumption, and some "twenty-first, century" SET tends to the view that the pacemaker of the internal clock itself is an important, or even the principal, source of variance, particularly in human timing. The arguments here are beyond the scope of this chapter, and the reader is referred to Wearden and Bray (2001), and Jones and Wearden (2003, 2004) for (rather technical) discussions.

Suppose that the pacemaker is an important source of timing variance. Virtually any quantitative pacemaker model will produce the mathematical result that *slower* pacemakers produce *greater* relative variance (e.g. variance that is expressed as a fraction of the mean). This is true of standard Poisson pacemakers, but also of variants discussed by Gibbon et al. (1984). In these cases, then, slower clock speed would be expected to result in more variable time judgments in, for example, the elderly compared with younger groups, rather than judgments which differed in mean, as calibration or feedback would eliminate these.

More variable timing performance in the elderly than in younger groups is in fact quite commonly found, consistent with this idea, although the result is not universal. For example, Wearden et al. (1997) found that variability in temporal generalization performance was affected by age and IQ, and was higher even in the high-IQ elderly than student groups (although the differences were small), see their table 1, p. 968. However, no effects were found in bisection. In the interval production study (their experiment 4), although feedback eliminated age and IQ differences in the mean times produced, some variability effects remained. Their figure 7 shows that, in general, the older group produced responses that were relatively more variable than the younger one, although the difference was not significant, but effects of IQ were significant and orderly, with the lowest IQ group producing the highest relative variance, and the highest IQ group the lowest.

In summary, the hypothesis that internal clock speed decreases with age is difficult to directly test, or directly refute, and only has limited usefulness as an explanation of age-related differences in average measures of behavior. On the other hand, it may explain why relative variability in timing behavior increases with age.

Retrospective timing and passage of time judgments

The remainder of this chapter does not review any previous empirical work with the elderly, but attempts to indicate what areas of timing research might be useful for the future. Research on prospective timing in the elderly has produced rather small effects, some of which are inconsistent, with even variability differences between groups not always being found. Effects obtained are hard to interpret, and many studies may be more illuminating about issues in time perception *per se* than they are about age-related changes. A further problem is that the issues investigated in prospective timing studies may have little relevance to the time experience of elderly people in their everyday lives. If we wish to come to grips with changes in time experience, we may need to diversify into studies of retrospective timing and what I call "passage of time" judgments.

06-Spco-chap06.qxd 04/02/05 3:36 PM Page 147

As mentioned above, retrospective time judgments are those made when an unexpected question about time is asked. Figure 6.2 shows data from a study by Hicks and Kinsbourne (quoted in Hicks, 1992). Ten groups of students examined a tartan pattern presented for from 8 to 54 s, and rated it for complexity and aesthetic value. For people in one condition (retrospective) this was the only task, whereas people in the prospective condition were told that the duration of presentation of the pattern should be estimated without counting. After the stimulus presentation, all groups were asked for a judgment of duration. Obviously, people in both the prospective and retrospective conditions showed increased estimates as actual presentation time increased, but the retrospective judgments diverged from the prospective ones at longer durations. However, it might be considered remarkable that retrospective judgments can be performed at all, given that no instructions about timing were given.

Hicks and Kinsbourne's study illustrates an important methodological nuisance in studies of retrospective timing, and that is that once the question about timing has been posed, no further retrospective timing can be measured, as people naturally suspect that time is the focus of the experiment, making the study subsequently prospective. In Hicks and Kinsbourne's experiment, each participant made a single time judgment, essentially participating in only one trial, a methodology that is common in retrospective timing studies (e.g. Block, 1992), but is obviously extremely wasteful of experimental time and effort. However, it is not necessary that each participant gives a single time judgment. Boltz (1994) played participants a short series of distinct auditory stimuli, without any timing instructions, then asked for retrospective time

AQ: Block, 1992 has not been included in Reference. Please check.

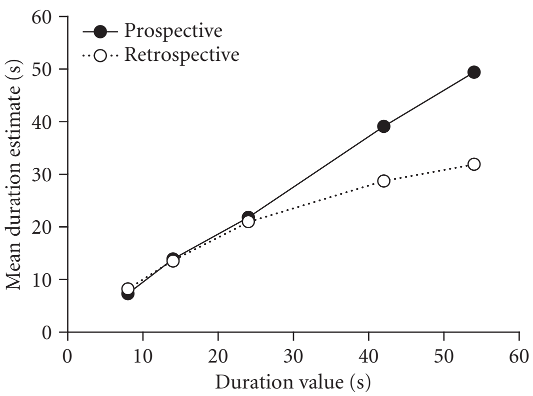

Fig. 6.2 Prospective and retrospective judgments of time from the experiment of Hicks and Kinsbourne. Judgments of the duration of presentation of a tartan pattern are plotted against the real duration of presentation for prospective and retrospective conditions.

06-Spco-chap06.qxd 04/02/05 3:36 PM Page 148

judgments, identifying the stimuli by their content, so did obtain more than one data point from each participant. Overall, retrospective timing studies use much larger participant populations than prospective ones, and collect far fewer data points per subject. Given variability in retrospective time judgments, obtaining statistical significance requires large subject groups, and the arduous nature of the organization and conduct of such studies makes them much rarer than studies of prospective timing and, according to a personal communication from the leading worker in this area (Richard Block of the University of Montana) is a deterrent to carrying them out at all.

How are retrospective time judgments performed? The general idea, deriving from Ornstein (1969), is some sort of "storage size" process. When the participant is asked, unexpectedly, to make a retrospective time judgment, they examine the amount of "memory storage" or "contextual change" during the period in question, and greater amounts of "storage" result in longer time judgments. In other words, retrospective timing is largely based on the amount of "memory-storage" or "information-processing" that has been carried out, and does not depend on internal clock processes in the way that prospective timing does.

Given that elderly people may show poorer memory performance or slower rates of information-processing than younger people, retrospective time judgments would seem to be an area ripe for fruitful investigation, but no study appears to have been done, possibly for the practical reasons outlined above.

Prospective and retrospective timing are commonly distinguished, but I wish to add a third type of time judgment, one that may be particularly useful in studies with elderly people: what I will call "passage of time" judgments. What these are and how they differ from retrospective judgments can be illustrated with reference to a study conducted at Manchester, the grandly-titled "Armageddon" experiment.

The procedure in a slightly simplified form was as follows. A person either watched 9 min of the film "Armageddon" (a virtually violence-free action film), or waited for 9 min in a simulated "waiting room" condition. At the end of this period, the person was asked to judge how quickly time seemed to pass compared with some subjective "normal" condition. The normal result of "time passing quickly when you're enjoying yourself" was found: people rated the passage of time during "Armageddon" as faster than normal, and the "waiting room" time as slower than normal. Note that this implies that the "Armageddon" period was *shorter* than the waiting period (as time passed subjectively quicker in a period that was physically the same), although no judgment of duration was required. Next, both groups read a novel for 10 min, to separate out the two phases of the experiment, then a retrospective

06-Spco-chap06.qxd 04/02/05 3:36 PM Page 149

time judgment of the previous 9-min period was required. Now, the results were as the storage-size theory predicted: the "Armageddon" period was judged as *longer* than the waiting room period. This result is reminiscent of the paradoxical statements about time experience in the elderly quoted at the start of the chapter, but in reverse: a time period (Armageddon) seems to fly when participants were in it (passage of time judgment), but is judged as relatively long after it has finished (retrospective time judgment).

Studies of passage of time judgments and retrospective timing may enable us to understand changes in time experience with increasing age, changes that are sometimes distressing to elderly people and which greater scientific understanding may help us to alleviate. As mentioned above, such studies are currently completely lacking. What kind of research might it be interesting to do?

The right tree: Toward a new chronogerontology

As mentioned above, the general explanation for our ability to make retrospective time judgments is that we can use the amount of information-processing, or number of items perceived, or remembered, as the basis for judgments of the duration of that period, what from now on I will just call "storage." However, an obvious and persistent difficulty is defining just how much "storage" has occurred. In fact, no study of retrospective timing so far published has done this in a precise way, and most depend on a manipulation as follows: Participants in retrospective conditions are divided into two groups, and receive tasks A or B. An example might be sorting playing cards into red or black (A), or into suits or some more complex arrangement (B). B is putatively more difficult than A, so requires more "information-processing." After tasks A or B have proceeded for some time period, the experiment stops and a retrospective judgment of the duration of A or B is required. In general, more "difficult" tasks produce longer retrospective judgments (see Block, 1992, for discussion).

In the case of the elderly, slowing down of average information-processing rates, and increased intersubject variability in information-processing rates, imply that retrospective timing studies might not only produce large age effects, but also might offer a way of observing more precisely links between "storage" and retrospective time judgments than is possible with younger participants alone. For example, if we have some task A carried out by an elderly group and younger controls for some time period, we might be able to measure (a) the rate of information-processing by individuals during A, (b) subsequent cognitive judgments of events in A, such as the number of items recalled, and (c) link both of these measures to a retrospective time

06-Spco-chap06.qxd 04/02/05 3:36 PM Page 150

judgment. Experiments such as this, and others employing procedures manipulating information-processing during A, might put possible relations between "storage" and retrospective judgments on a firmer footing than ever before.

However, although experiments of the type outlined above would be very useful, an additional consideration for retrospective time judgments is another problem of "reference." As people age, not only might their internal clock slow down, as discussed earlier, but information-processing rates and memory performance might also decline. However, this decline is gradual in most nonpathological cases, so even in retrospective timing, a person has the opportunity for "recalibration," over a long period of years. We might try to explain the "Christmas comes round quicker every year" effect as follows. Ordinarily, a year contains some amount of "storage" (X). As information-processing rates decrease and memory losses increase with ageing, the amount of storage in a year is less (possibly much less) than X, so the person is surprised that a year has passed, as much less storage has occurred than they expect. The key word here is, of course, "expect," because the obvious question arises of where this expectation comes from: in effect, a "storage" explanation of the "Christmas effect" implies that people are comparing the amount of "storage" in the last year with the amount stored in some other, probably much earlier, year when information-processing rates were higher, and memory losses smaller, effectively employing a "state-change" procedure. This is not impossible, but if people are adjusting to the fact that "less happens" in time periods with increasing age (because people process information more slowly, forget things more, or simply do fewer varied things because of physical limitations) then the "Christmas effect" would be expected to be reduced or even abolished. In general, we need to know much more not only about the cognitive processes on that retrospective time judgments are based, but also on the "reference" used for such judgments. Attributing some real-life timing effects in the elderly to age-related differences in retrospective, rather than prospective, timing may be an essential first step in understanding them, but neither the methodology nor theory of retrospective timing studies currently offer us a completely satisfactory explanation.

Passage of time judgments have been studied quite extensively in the elderly, but usually in a procedure (see Lemlich, 1975), which asks an extraordinary hypothetical question. For example, people are given some standard that represents the passage of time now (a line length or a number), then must rate the passage of time at various ages when they were younger. The usual finding is that people judge time to have passed more slowly when they were young, compared with now.

AQ: Lemlich, 1975 has not been included in reference list. Please check.

06-Spco-chap06.qxd 04/02/05 3:36 PM Page 151

Even if this procedure yields highly orderly data, it is clearly difficult to know exactly what is being measured here. A more useful line of research, in my view, would be to obtain passage of time judgments from real-life situations (judgments which, ideally, were taken simultaneously with, or just after, the events), and try to understand what influences these. Some work by Zakay (1992) may help to do this. The basic structure of Zakay's approach is illustrated in Figure 6.3. Zakay's model was not initially applied to the study of passage of time judgments, but seems an excellent starting point for it.

According to Zakay, some real-life situation is judged by the participant on the basis of past experience or expectation, in terms of two-dimensions: temporal relevance (how important time is in the task), and temporal uncertainty (how much uncertainty the participant has about the time of event occurrences, or their duration). The outcome variable in Zakay's model is "temporal awareness": if this is high, then the passage of time seems very slow (time seems to "drag"), whereas if it is low, then time can seem to "fly." A situation judged to have very low temporal relevance will induce little temporal awareness, and the passage of time will be subjectively rapid (although a subsequent retrospective time judgment may be long). A high level of temporal relevance can be associated with high or low level levels of temporal uncertainty. Even if the time of some event is critical, then temporal awareness is reduced if uncertainty is reduced (by providing cues as to when the event will occur, for example, or in conditions where things "run like clockwork"). High levels of temporal relevance coupled with high levels of temporal uncertainty produce a high level of temporal awareness, where a person focuses continually on the passage of time, which consequently seems very slow.

Consistent with these ideas, "waiting room" situations produce high temporal awareness, and consequently time seems to drag in them, because (a) time is

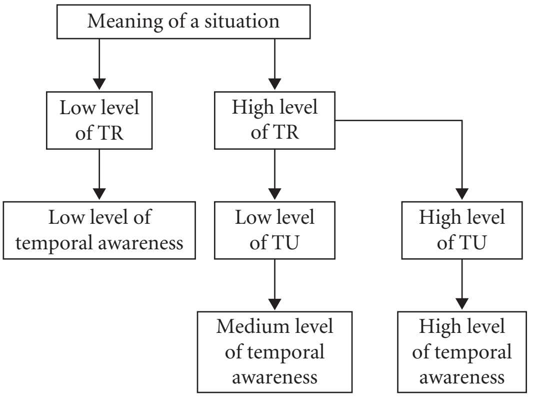

Fig. 6.3 The "temporal awareness" model of Zakay (1992), see text for details. TR = "temporal relevance"; TU = "temporal uncertainty."

06-Spco-chap06.qxd 04/02/05 3:36 PM Page 152

highly relevant, when waiting for a train or plane, for example, and (b) the exact moment when the train, or plane, arrives can be uncertain, particularly in error-prone transport systems such as the UK-railways at the time of writing.

Zakay's model only gives a starting point, and needs to be elaborated. An important variable might be the amount of attention allocated to temporal and nontemporal aspects of situations (see Brown, 1997, for a review of research). If a person can maintain attention on something other than the passage of time (watching an exciting film, for example), then temporal awareness may be reduced, and time may seem to fly during the time period. To give a personal example, a recently-purchased portable DVD player reduces my temporal awareness during train journeys practically to zero (to the extent of engendering a potential risk of missing the station).

There are many reasons to think that passage of time judgments in the elderly might be a fruitful field of study. For one thing, difficulties in maintaining task attention with increasing age may reduce the capacity for "distraction" away from the passage of time in the elderly. In addition, temporal uncertainty may be higher in the elderly because of increased variability of time representations (caused by slower clock speed or otherwise), or by general memory difficulties such as impairments of prospective memory (Rendell & Craik, 2000). Both reduced ability to focus on nontemporal aspects of situations and increasing temporal uncertainty may increase temporal awareness in older people, thus giving rise to the feeling of "dragging" time sometimes reported.

My general suggestion is that studies of retrospective timing, and passage of time judgments, in the elderly are necessary if we are to gain any proper insight into the subjective distortions of time that accompany old age. Conducting such studies is not, however, easy, and the need for large subject populations may mean that such work can only be performed by research groups which have access to hundreds of elderly participants, and the resources necessary to carry out the studies in any reasonable length of time. Unlike prospective timing research with student participants, which has mostly proceeded using small subject groups, tested easily and at minimal cost, making any serious inroads into understanding the time experience of the elderly will require the allocation of considerable time, effort, and resources. However, the goal of understanding changes in human time experience with ageing may be elusive without such research.

References

Allan, L. G. (1998). The influence of the scalar timing model on human timing research. *Behavioral Processes,* **44**, 101–117.

Allan, L. G. (2002). Are the referents remembered in temporal bisection? *Learning and Motivation,* **33**, 10–31.

06-Spco-chap06.qxd 04/02/05 3:36 PM Page 153

Boltz, M. G. (1994). Changes in internal tempo and effects on the learning and remembering of event durations. *Journal of Experimental Psychology: Learning, Memory, and Cognition,* **20**, 1154–1171.

Brown, S. W. (1997). Attentional resources in timing: Interference effects in concurrent temporal and nontemporal working memory tasks. *Perception and Psychophysics,* **59**, 1118–1140.

Burle, B., & Casini, L. (2001). Dissociation between activation and attention effects in time estimation: Implications for clock models. *Journal of Experimental Psychology: Human Perception and Performance,* **27**, 195–205.

Craik, F. I. M., & Hay, J. F. (1999). Aging and judgments of duration: Effects of task complexity and method of estimation. *Perception and Psychophysics,* **61**, 549–560.

Denner, B., Wapner, S., & Werner, H. (1964). Rhythmic activity and the discrimination of stimuli in time. *Perceptual and Motor Skills,* **19**, 723–729.

Droit-Volet, S. (2002). Scalar timing in temporal generalization in children with short and long stimulus durations. *Quarterly Journal of Experimental Psychology,* **55A**, 1193–1209.

Droit-Volet, S., Clément, A., & Wearden, J. H. (2001). Temporal generalization in 3- to 8-year-old children. *Journal of Experimental Child Psychology,* **80**, 271–288.

Droit-Volet, S., & Wearden, J. H. (2001). Temporal bisection in children. *Journal of Experimental Child Psychology,* **80**, 142–159.

Droit-Volet, S., & Wearden, J. (2002). Speeding up an internal clock in children? Effects of visual flicker on subjective duration. *Quarterly Journal of Experimental Psychology,* **55B**, 193–211.

Fraisse, P. (1964). *The psychology of time*. London: Eyre and Spottiswoode.

Gibbon, J., Church, R. M., & Meck, W. (1984). Scalar timing in memory. In J. Gibbon and L. Allan (Eds.), *Annals of the New York Academy of Sciences*, 423: Timing and time perception (pp. 52–77). New York: New York Academy of Sciences.

Hicks, R. E. (1992). Prospective and retrospective judgments of time: A neurobehavioral analysis. In F. Macar, V. Pouthas, and W. J. Friedman (Eds.), *Time, action, and cognition: Towards bridging the gap*. (pp. 97–108). Dordrecht: Kluwer Academic Press.

AQ: Please check if the insertion in reference Hicks (1992) is Ok.

Hicks, R. E., Miller, G. W., & Kinsbourne, M. (1976). Prospective and retrospective judgments of time as a function of the amount of information processed. *American Journal of Psychology,* **89**, 719–730.

Jones, L. A., & Wearden, J. H. (2003). More is not necessarily better: Examining the nature of the temporal reference memory component in timing. *Quarterly Journal of Experimental Psychology,* **56**, 321–343.

Jones, L. A., & Wearden, J. H. (2004). Double standards: Memory loading in temporal reference memory. *Quarterly Journal of Experimental Psychology,* **57B**, 55–77.

Lejeune, H., Ferrara, A., Soffié, M., Bronchart, M., & Wearden, J. H. (1998). Peak procedure performance in young adult and aged rats: Acquisition and adaptation to a changing temporal criterion. *Quarterly Journal of Experimental Psychology,* **51B**, 193–217.

Lustig, C. (2003). Grandfather's clock: Attention and interval timing in older adults. In W. H. Meck (Ed.), *Functional and neural mechanisms of interval timing* (pp. 261–293). Boca Raton, FL: CRC Press.

McCormack, T., Brown, G. D. A., Maylor, E. A., Darby, A. & Green, D. (1999). Developmental changes in time estimation: Comparing childhood and old age. *Developmental Psychology,* **35**, 1143–1155.

06-Spco-chap06.qxd 04/02/05 3:36 PM Page 154

McCormack, T., Brown, G. D. A., Maylor, E. A., Richardson, L. B. N., & Darby, R. J. (2002). Effects of aging on absolute identification of duration. *Psychology and Aging,* **17**, 363–378.

McCormack, T., Brown, G. D. A., Smith, M. C., & Brock, J. (2004). A timing-specific memory distortion effect in young children. *Journal of Experimental Child Psychology,* **87**, 33–56.

Meck, W. H. (1983). Selective adjustment of the speed of internal clock and memory processes. *Journal of Experimental Psychology: Animal Behavior Processes,* **9**, 171–201.

Meck, W. H. (1996). Neuropharmacology of timing and time perception. *Cognitive Brain Research,* **3**, 227–242.

Meck, W. H., Church, R. M., & Wenk, G. L. (1986). Arginine vasopressin innoculates against age-related changes in sodium-dependent high affinity choline uptake and discrepancies in the content of temporal memory. *European Journal of Pharmacology,* **130**, 327–331.

Ornstein, R. E. (1969). *On the experience of time*. Harmondsworth: Penguin.

Penton-Voak, I. S., Edwards, H., Percival, A., & Wearden, J. H. (1996). Speeding up an internal clock in humans? Effects of click trains on subjective duration. *Journal of Experimental Psychology: Animal Behavior Processes,* **22**, 307–320.

Rendell, P. G., & Craik, F. I. M. (2000). Virtual week and actual week: Age-related differences in prospective memory. *Applied Cognitive Psychology,* **14**, S43–S62.

Treisman, M. (1963). Temporal discrimination and the indifference interval: Implications for a model of the "internal clock." *Psychological Monographs,* **77**, 1–31.

Treisman, M., Faulkner, A., Naish, P. L. N., & Brogan, D. (1990). The internal clock: Evidence for a temporal oscillator underlying time perception with some estimates of its characteristic frequency. *Perception,* **19**, 705–748.

Wearden, J. H. (1991). Human performance on an analogue of an interval bisection task. *Quarterly Journal of Experimental Psychology,* **43B**, 59–81.

Wearden, J. H. (1992). Temporal generalization in humans. *Journal of Experimental Psychology: Animal Behavior Processes,* **18**, 134–144.

Wearden, J. H. (1999). "Beyond the fields we know . . .": Exploring and developing scalar timing theory. *Behavioral Processes,* **45**, 3–21.

Wearden, J. H. (2003). Applying the scalar timing model to human time psychology: Progress and challenges. In H. Helfrich (Ed.), *Time and mind II: Information-processing perspectives* (pp. 21–39). Gottingen: Hogrefe & Huber.

Wearden, J. H. (2004). Decision processes in models of timing. *Acta Neurobiologiae Experimentalis,* **64**, 303–317.

Wearden, J. H. (in press). Origins and development of internal clock theories of time. *Psychologie Française*.

Wearden, J. H., & Bray, S. (2001). Scalar timing without reference memory: Episodic temporal generalization and bisection in humans. *Quarterly Journal of Experimental Psychology,* **54B**, 289–310.

Wearden, J. H., Edwards, H., Fakhri, M., & Percival, A. (1998). Why "sounds are judged longer than lights": Application of a model of the internal clock in humans. *Quarterly Journal of Experimental Psychology,* **51B**, 97–120.

Wearden, J. H., & Ferrara, A. (1995). Stimulus spacing effects in temporal bisection by humans. *Quarterly Journal of Experimental Psychology,* **48B**, 289–310.

AQ: Please check the insertion of place of location, is Ok in ornstein, R. E. (1969)

AQ: Please check the change of whole number 576 to 1-31 is ok in Treisman, M. (1963).

AQ: Wearden, J. H. (1999) has not been cited in text. Please include.

06-Spco-chap06.qxd 04/02/05 3:36 PM Page 155

Wearden, J. H., & Ferrara, A. (1996). Stimulus range effects in temporal bisection by humans. *Quarterly Journal of Experimental Psychology,* **49B**, 24–44.

Wearden, J. H., & Penton-Voak, I. S. (1995). Feeling the heat: Body temperature and the rate of subjective time, revisited. *Quarterly Journal of Experimental Psychology,* **48B**, 129–141.

Wearden, J. H., Philpott, K., & Win, T. (1999). Speeding up and (. . . relatively . . .) slowing down and internal clock in humans. *Behavioral Processes,* **46**, 63–73.

Wearden, J. H., Pilkington, R., & E. Carter (1999). "Subjective lengthening" during repeated testing of a simple temporal discrimination. *Behavioral Processes,* **46**, 25–38.

Wearden, J. H., Wearden, A. J., & Rabbitt, P. M. A. (1997). Age and IQ effects on stimulus and response timing. *Journal of Experimental Psychology: Human Perception and Performance,* **23**, 962–979.

Wing, A. M., & Kristofferson, A. B. (1973). Response delays and the timing of discrete motor responses. *Perception and Psychophysics,* **14**, 3–12.

Vanneste, S., Pouthas, V., & Wearden, J. H. (2001). Temporal control of rhythmic performance: A comparison between young and old adults. *Experimental Aging Research,* **27**, 83–102.

Zakay, D. (1992). On prospective time estimation, temporal relevance, and temporal uncertainty. In F. Macar, V. Pouthas, & W. J. Friedman (Eds.), *Time, action, and cognition: Towards bridging the gap.* (pp. 109–118). Dordrecht: Kluwer Academic Press.

AQ: Please check if the insertion in the reference Zakay D. (1992), is Ok.

06-Spco-chap06.qxd 04/02/05 3:36 PM Page 156