Acta Psychologica 133 (2010) 170–179

Contents lists available at ScienceDirect

Acta Psychologica

journal homepage: www.elsevier.com/locate/actpsy

The effects of sex, age, and interval duration on the perception of time

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ARTICLE INFO

Article history:
Received 1 August 2006
Received in revised form 6 November 2009
Accepted 13 November 2009
Available online 16 December 2009

PsycINFO classification:
2320

Keywords:
Age
Sex
Time perception
Temporal orientation

ABSTRACT

The present experiment examined the interactive effects of sex, age, and interval duration on individual's time perception accuracy. Participants engaged in the duration production task and subsequently completed questionnaires designed to elicit their temporal attitudes. The overall group of 100 individuals was divided evenly between the sexes. Five groups, each composed of 10 males and 10 females, were divided by decades of age ranging from 20 to 69 years old. The specific time estimation task was an empty interval production procedure composed of 50 trials on each of four different intervals of 1, 3, 7, and 20 s, respectively. The presentation orders of these intervals were randomized across participants but yoked across the sexes within each of the respective age groups. Analysis of the production results indicated significant influences for the sex of the participant while age did not appear to affect estimates of these short durations. Temporal attitudes, as reflected in responses to time questionnaire inquiries, did however exhibit significant differences across age. The contending theoretical accounts of such sex and age differences are considered and explanatory accounts that present a synthesis of endogenous and exogenous causal factors are discussed in light of the present pattern of findings.

1. Introduction

From earliest human history, the problem of time has represented a frustrating puzzle for all of philosophy and science (e.g., Augustine, 397; Fraser, 1987; Russell, 1915). The need for an understanding of time has pervaded the science of psychology from its very inception through the present day concerns of cognitive and neurosciences (see Dennett & Kinsbourne, 1992; Harrington, Haaland, & Knight, 1998; Michon, 1985; Michon & Jackson, 1985; Poppel, 1997). Yet time perception has persistently failed to establish any meaningful position within general theories of behavior. Previously, this shortfall was attributed to the inability of time perception researchers to link their specific theories directly with more mainstream psychological issues such as memory and attention (Adams, 1964). However, as Block (1990) has trenchantly noted: 'time can no longer continue to be ignored by psychologists who propose models of non-temporal behavior, because non-temporal behavior does not exist.' Many reasons persist as to why time perception still fails to occupy a central role in contemporary psychological science. However, perhaps the most obvious obstacles remain the vast differences that are observed between individuals in their perception of even the most common intervals of duration (Doob, 1971; Rammsayer, 1997).

When asked to estimate even a brief interval of time in the order of a few seconds, there is a remarkable range of responses that accrue across different individuals. This is seen generally as a problem, since we frequently wish to derive general or nomothetic principles that hold across all people (Eagleman et al., 2005). To some, this behavioral variability proves to be a source of great frustration. For others, individual variation is the path through which one understands the essence of behavior itself (cf., Cronbach, 1957). However, even when we tackle this issue of individual variation head-on, we still seek commonalty on some level in order to identify potential systematic sources of effect across sub-groups of individuals. In line with this concern, the present work examines the impact on response capacity of two characteristics that are commonly used to group individuals together, namely their sex and their age.

With respect to sex differences in time estimation, there are a number of extant results which have served to confirm the presence of significant sex difference which were observed spectacularly by MacDougall (1904) at the turn of the 20th Century (cf., Delay & Richardson, 1981; Hancock, Vercruyssen, & Rodenburg, 1992). In contrast to these positive reports, others have indicated no sex differences in time estimation (e.g., Getsinger, 1974; Roeckelein, 1972). Even within those studies that have observed significant sex differences there remain potentially disturbing

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doi:10.1016/j.actpsy.2009.11.005

inconsistencies. For example, some reports demonstrate that females underestimate durations with respect to males (e.g., Axel, 1924) while others show exactly the opposite effect (e.g., Harton, 1939). Much of this confusion is the result of a misunderstanding of the nature of the different methods used to assess time perception (see also Hornstein & Rotter, 1969). When these methodological differences are resolved, the vast majority of studies show a consistent pattern (and see Block, Hancock, & Zakay, 2000) that is, when using the production technique, females underestimate brief intervals of time with respect to males. It should, however, be carefully noted here that this general statement actually says nothing about absolute levels of accuracy of estimates themselves as the respective accuracy levels tend to vary across differing studies.

The consistency of sex differences is further clarified by the detailed evaluation of studies that reported negative findings. Such an analysis reveals the very interesting trend that the negative reporting studies rely overwhelmingly on a score derived from a single response from each individual. In contrast, studies that use multiple trials have almost ubiquitously found reliable sex differences. Thus, Block et al. (2000) in their formal meta-analysis of this overall area of research, found that both trial and estimation methods were amongst the most significant modifying variables (and see also Bindra & Waksberg, 1956; Clausen, 1950; Guay & Salmoni, 1988, for discussions of time estimation methods).

A number of other influences can also modulate the presence or absence of a sex difference in time estimation. For example, the size of recorded sex differences appears to vary according to the sensory modality that is used to present the target interval of concern (Roeckelein, 1972). Also, the time-of-day at which performance is measured (Hancock et al., 1992) and the ego strength of the individual involved (Getsinger, 1974) appear to further modulate the degree of difference reported. In previous work, we (Hancock, Arthur, Chrysler, & Lee, 1994) have also demonstrated that the presence or absence of light in the testing environment differentially affects how men and women estimate brief intervals of time. In sum, there appears to be a consistent but often small effect for sex on the estimation of brief intervals of time that is tempered by a variety of interactive influences.

If sex differences account for some of the individual variation in time perception, another factor that has been proposed as an important influence is a person's chronological age. With respect to age effects, the overall picture is less certain than that for the sex of the individual (see Block, Zakay, & Hancock, 1998; McCormack, Brown, Mylor, Darby, & Green, 1999). In looking to understand the overall area, Block (1990) identified three main aspects of time perception, namely succession, duration, and temporal perspective. These three aspects differ in terms of the absolute time intervals involved. Often, succession is concerned with differences in the order of milliseconds while duration tends to focus on intervals of seconds, through minutes, up to hours. Temporal perspectives frequently references periods as long as years or even a whole lifetime (Hancock, 2010). The nature of the current experimental findings on age and time perception is thus considered in light of this tri-partite differentiation of relevant measurement intervals (and see Block et al., 1998).

It has frequently been proposed that there are strong effects of age on one's temporal perspective and the well-known subjective acceleration of time with aging is often cited as support for this effect. Support for such an assertion comes from sources as diverse as poetry (Campbell, 1802), introspection (Cohen, 1967; Nitardy, 1943), biochemical analysis (DuNouy, 1937), and experimental (Bull, 1973) as well as synthetic approaches (and see Hancock, 2002). There are a number of differing theoretical interpretations of this phenomenon of speeded time perception with age (see Janet, 1877; Lemlich, 1975). The specific causal structure of this phenomenological acceleration has yet to be articulated fully. The effects of aging upon succession and simultaneity are even less clear. The consensus in the gerontological literature is of a progressive slowing of responsivity with age (Birren & Schaie, 1990). Therefore, we might suspect a progressive diminution in ability to judge the fine-grain temporal succession of events with age. However, this is a problematic assertion in the face of known individual differences in capability across chronological age. Also uncertain are the specific effects of age on duration estimation (cf., Rammsayer, Lima, & Vogel, 1993; Surwillo, 1964), especially brief intervals of the order of seconds (but see Craik & Hay, 1999; Poppel, 1988; Rammsayer, 2001).

Together, age and sex have been shown to interact in affecting performance on some forms of temporal task such as simple and complex reaction time (Fozard, Vercruyssen, Reynolds, Hancock, & Quilter, 1994). It is likely that any mechanism or mechanisms that underlie speeded reaction time also influence time perception. Consequently, the present work examined the effects of both age and sex in conjunction on the production of brief intervals as well as assessing temporal attitudes of these self-same individuals. There are some findings that have been previously reported on the combined influence of age and sex (see Bull, 1973; Espinosa-Fernandez, Miro, Cano, & Buela-Casal, 2003). Bull (1973) for example, examined these influences but only at durations that well exceed the brief number of seconds used in the present work. In contrast, Espinosa-Fernandez et al. (2003) have reported on the estimate of one specific interval (i.e., 10 s) which is directly comparable with the range of the presently selected durations. Although comparisons are here drawn between the current findings and this previous outcome, it is still the case that a full picture of the combinatorial sex and age effects on the estimation of brief temporal intervals has yet to be unequivocally established.

Solving the riddle of the vast individual differences in time estimation will obviously depend upon the further articulation of the influence of specific person-related factors. However, it is not only the variations intrinsic to the individual tested that have proved the sole barrier to the integration of time perception into the heart of psychological science. As well as such inter-and indeed intra-individual variability, we remain at present unsure whether there is one central mechanism or potentially several discrete, connected mechanisms involved in the production of and perception of temporal intervals ranging from seconds to minutes and on to months, years and the full length of a lifetime (see Hancock, 2010). While it is reasonable to postulate that memory-based effects have a stronger influence as the perceived interval increases, we are still seeking to understand the perception of brief intervals in and around what William James (after E.R. Clay) termed the 'specious present' (see James, 1890). One can argue that this contention centers around which appropriate physical interval it is that connotes the experience of the present moment, or what Gray (2009) has recently termed the 'saddle' of temporal experience. If there are a number of discrete contributions to the perception of the present moment then assessment across the intervals that have been proposed to represent the potential bounds of this saddle should reveal such thresholds as discontinuities in the pattern of outcome responses. It is this proposition that is explored therefore as part of the present experiment. Thus, given the foregoing observations, the purpose of the present experiment was to evaluate the effects of sex and age on the ability to produce response across a range of short duration intervals from 1 to 20 s and to compare such responses with those from questionnaires designed to elicit attitudes toward longer intervals of time. The theoretical foundation of the work is centered on the search for a unified endogenous temporal mechanism which is purported to vary systematically across individuals of different age and sex (see also Poppel, 1988; Treisman, 1963) and brief intervals of time in the order of seconds in duration.

2. Experimental method

2.1. Experimental participants

To investigate the foregoing propositions, 100 adults were solicited as volunteer participants in the present experiment. They were recruited from the faculty, staff, and students of a large university in the mid-west of the United States. All were in professed good health at the time of testing. There were 10 men and 10 women in each of the five age groups, namely: 20–29; 30–39; 40–49; 50–59; and 60–69 years of age, respectively. The means and standard deviations of age for each group, divided by the sex of the participant are given in Table 1. All experimental data were collected by a single, male experimenter.

2.2. Experimental procedure

Participants were seated at a table that was located in a 8′ by 6′ blacked-out room. On the table was a response box connected to a digital timer that was located at the experimenter's station in an adjacent room. The response box had two buttons on it, one of which started and one of which stopped a millisecond timer. Participants were free to move the response box on the table-top so that it was in a comfortable position for them. After completing a participant agreement form, a written explanation of the procedure was provided to each participant to read and sign. Following a verbal review of the procedures, each participant was asked to remove their watch or any other form of timekeeper in their possession. The lights in the room were extinguished (see Hancock et al., 1994) and the experimenter exited the room. Verbal communication, as necessary, was possible between the rooms while still maintaining the darkened conditions. Each participant was given 10 practice trials, without feedback, in which they were asked to estimate a 10-s period using the time estimation method known as the production procedure for empty intervals (Bindra & Waksberg, 1956; Clausen, 1950; Doob, 1971; Guay & Salmoni, 1988). The signal to begin the procedure was given and the participant pressed the left of two response buttons to start the interval and the right button to terminate it when they determined that their estimation was equivalent to the stated target interval. Participants were asked to pause briefly before initiating the next trial. After completing these initial practice trials, participants were asked to estimate four specific time intervals of 1, 3, 7, and 20 s in duration, respectively. These four target intervals represent a natural logarithmic progression that bracket the temporal thresholds that have been proposed to represent the duration of the experience of the present moment. These are, the boundary of brief intervals at 10 s (Allan, 1979), the range of the immediate present at 3 s (Poppel, 1988), and the duration of conscious intention at 6 s (Iberall, 1992; Iberall, 1995).

Participants completed 50 consecutive trials at one of the four intervals before proceeding to the next interval. The order of presentation of the different time intervals was randomized, except that within each age decade, the sequence in which the respective durations were presented were matched across sex so that one male and one female were yoked with respect to a particular presentation order. Participants were requested to change to the next interval only when the previous block of 50 trials had been completed. Participants were also asked to take a slightly longer pause during the transition from one interval to the next. Following each trial, the time estimate to the nearest millisecond was displayed to the experimenter who subsequently recorded it on a personal computer for later analysis. After each trial recording had been confirmed, the timer was reset by the experimenter. Participants were not given any feedback concerning their performance during any of the trials, a restriction which also included the practice trials. The opportunity to take a short break was offered to each participant following the completion of each of the four blocks of trials. This opportunity was very rarely taken. Upon completion of the four sets of intervals (being 200 trials in total) participants were asked to fill out a number of questionnaire and paper- and pencil-based tests designed to assess their attitudes toward time. Among these tests was a general demographic questionnaire as well as the more formal approaches of the lines test (see Cottle & Pleck, 1969) and the time reference inventory (see Roos, 1964; Roos & Albers, 1965). Details of the findings from these tests in relation to the specific characteristics assessed are presented in the results below.

Table 1
Mean and standard deviation of ages of the sample group by sex.

Decade	Males	Females
20–29	23.5 (2.37)	23.1 (1.91)
30–39	33.5 (2.88)	35.0 (2.63)
40–49	43.5 (2.27)	44.3 (3.65)
50–59	55.4 (3.10)	54.1 (3.18)
60–69	66.1 (2.85)	66.3 (2.63)

3. Results

3.1. Produced durations

In the present analysis, there were two between-participant factors and two within-participant factors. The between-participant factors were sex and age, while the within-participant factors were the length of the estimated interval and a block within trials factor. There were two levels of sex (male vs. female) and five levels of the age factor (being the discrete decades between 20 and 70 years of age, respectively). The 50 total trials at each interval were divided into 10 blocks of five trials each. This was in order to stabilize the trials factor so that the effects of the primary dependent variables could emerge more clearly from this repeated number of observations (and see Liu, Mayer-Kress, & Newell, 2004). As noted earlier, the lengths of the estimated intervals were 1, 3, 7, and 20 s, respectively. There were six dependent error measures derived from participant responses. The first dependent measure was constant error (CE) which represented the deviation of each score from the target interval. The second dependent measure was absolute constant error (ACE), which was the absolute value of these CE scores. The third dependent measure was variable error (VE) which was the variability around the mean response and this was derived as the square root of the individual responses minus the mean response divided by the number of responses. This formula is the same as that for the calculation of a standard deviation of a population. In addition to these primary dependent measures, two other derived error scores were calculated. The first was absolute error (AE), which was the average absolute deviation, regardless of direction, between the participant's time estimations and the target time. The second was Henry's error measure (E) which represents the square root of the summed value of the squared CE scores and the squared VE scores (see Schmidt, 1988). The latter score represents the overall accuracy in responding, and is a measure of the spread of the responses about the mean. A low score for E indicates responses that are clustered about the mean, and a larger value of E indicates that the responses are clustered further from the mean. The final dependent measure was the coefficient of variation (COV), calculated as the standard deviation score divided by the mean score. Together, these measures provide a portrait of the individual's response in terms of variability and central tendency with respect to each target duration.

3.2. Constant error (CE)

The analysis of variance results for the constant error (CE) showed one significant main effect only. This effect was for the block factor and indicated that there was a systematic increase in constant error across the 10 blocks recorded, $F(9, 810) = 11.416$, $p < .001$. This pattern of increase in estimates for which feedback has not been provided has been observed previously in time perception studies and is known generally as the 'lengthening' effect (and see Doob, 1971). This lengthening effect was thus confirmed by the present results. Beyond this single main effect were a number of higher order interactions and these are considered of superseding concern. Neither the four-way interaction nor any of the three-way interaction proved significant, although, the interval by block by sex interaction came very close to traditional levels of acceptance ($p = .054$). There were however, three, two-way interactions. There was an interval by block interaction, $F(27, 2430) = 7.144$, $p < .001$, which indicated that the lengthening effect became progressively more evident with the increase in the target duration, see Fig. 1. For the 1- and 3-s intervals, there was little change in the degree of CE across trial blocks. However, for the 7-s interval and especially for the 20-s interval, there was clear evidence of an increase in CE over the trial blocks. In essence, this interaction represents a meta-lengthening effect, suggesting that lengthening of the response in time estimation does not occur solely across trials but occurs also as function of the duration estimated. More detailed analysis using an individual trial-by-trial comparison confirmed this overall effect that is shown in Fig. 1.

Of particular concern with respect to the express goals of the present experiment are the two interactive effects involving participant sex. The first of these represented a significant interaction between the sex and the length of the estimated interval, $F(3, 270) = 2.869$, $p < .05$. Fig. 2 illustrates this interaction. It shows the present form of the error score (CE) converted into a time distortion ratio (TDR) for the purposes of clarity of exposition, as recommended by Block et al. (2000). For the 1-s interval, females exhibited a greater positive error than males. However, as the target interval increased, females showed a progressively more negative time distortion ratio, representative of an undershooting of the target interval. The significant interaction arose from the fact that the males largely exhibited the opposite effect showing a progressive increase in the time distortion ratio with the increase in target duration beyond the 1-s interval. The second interactive effect involving sex was that for trial blocks, $F(9, 810) = 2.654$, $p < .01$. As can be seen in Fig. 3, the males had a consistent positive constant error across the progressive blocks, while females had a consistent negative constant error. Even with this difference, each of the sexes did exhibit some degree of lengthening effect across blocks, although this effect was more pronounced for males as compared with the female participants. There was no main effect for age, nor any marginal or significant interactions involving the age of the participant for the constant error of the estimates recorded.

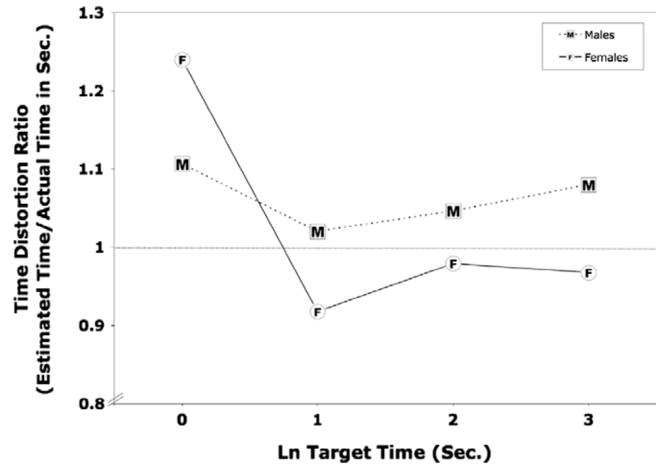

Fig. 2. Interaction between-participant sex and the interval of the estimate with respect to the time distortion ratio, calculated as the estimated duration divided by the target duration. The base axis has been transformed to a logarithmic expression for the purpose of illustration. The interaction arises from the evident decrease for females between the 1-s interval and each of the others, while the time distortion ratio for males stays fairly constant across the four time estimation intervals.

3.3. Absolute constant error (ACE)

Constant error (CE) includes the summation of responses that both overshoot and undershoot the target duration. Thus, CE represents the mean of the total number of responses. However, it is

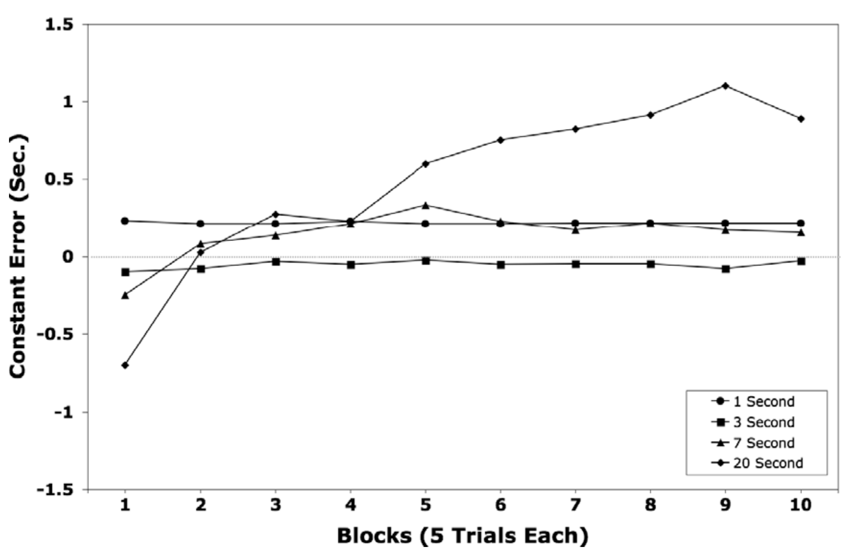

Fig. 1. The interaction between trial block and target duration on constant error. As is evident from the illustration, the constant error for the one and 3-s intervals changes very little over trial block. However, there is clear evidence of an increase in constant error for the 7-s interval which was again further magnified in the results for the 20-s interval. This evidence confirms the lengthening effect over multiple trials and indicates a modifying influence for duration on this effect.

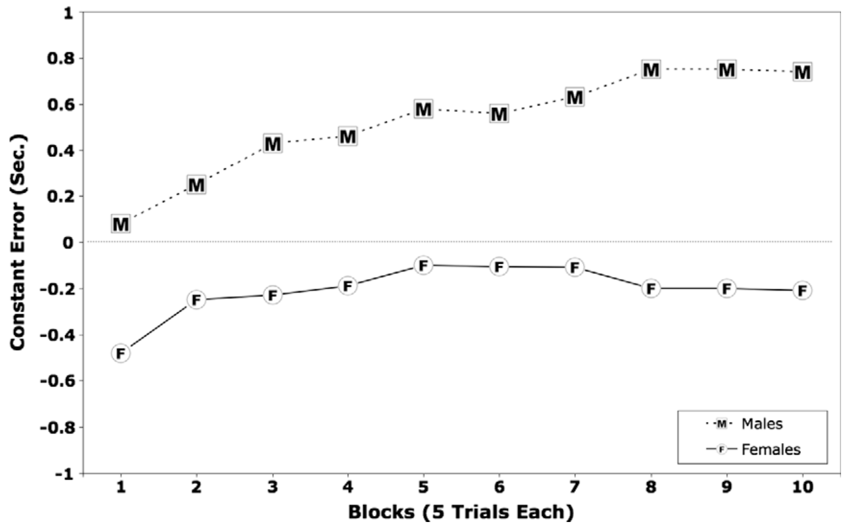

Fig. 3. Interaction between sex and trial block. While both sexes generate a lengthening effect, it is larger for the male compared with the female participants. As can also be seen, despite the lengthening, the constant error for the female participants was always short of the target, while the constant error for the males was always positive and growing, indicating estimates exceeding the target times.

possible to take the absolute value of these respective positive and negative deviation scores to provide a summary picture of how the independent variables influence the degree of overall deviation from the target value, regardless of the direction of that error. Analysis of variance results for this measure, termed absolute constant error (ACE), are given in Table 2. This measure showed very similar effects to those for CE in terms of the interaction of block and interval and that for interval by sex. Also, like CE, there is a main effect for trial block similarly showing an increase in the overall deviation of response with progressive trials. However, unlike the CE measure, ACE also provided two main effects, one for the interval of the estimate and one for the sex of the participant. With respect to the interval effect, not unexpectedly, the absolute constant error level increased with the length of the target interval. With respect to the sex effect, the males had a lower ACE value than the female participants. This result indicates that on average females were less accurate with respect to the target duration than their male counterparts. As with the results for CE, there were no main effects or interactive effects involving age for the absolute constant error (ACE) measure.

Table 2
Results of the mixed analysis of variance for absolute constant error.

Source	SS	DF	MS	F	p
Sex	502.393	1	502.393	5.201	0.025
Age	319.832	4	79.958	0.828	0.511
Sex × age	209.933	4	52.483	0.543	0.704
Error	8692.928	90	96.588		
Interval	14,905.089	3	4968.363	116.572	0.000
Interval × sex	383.591	3	127.864	3.000	0.031
Interval × age	411.005	12	34.250	0.804	0.647
Interval × sex × age	240.454	12	20.038	0.470	0.931
Error	11,507.533	270	42.620		
Block	38.463	9	4.274	4.813	0.000
Block × sex	1.340	9	0.149	0.168	0.997
Block × age	22.419	36	0.623	0.701	0.907
Block × sex × age	18.544	36	0.515	0.580	0.978
Error	719.183	810	0.888		
Interval × block	45.150	27	1.672	2.015	0.001
Interval × block × sex	3.562	27	0.132	0.159	1.000
Interval × block × age	76.774	108	0.711	0.857	0.852
Interval × block × sex × age	64.761	108	0.600	0.723	0.985
Error	2016.673	2430	0.830		

3.4. Variable error (VE)

While the two measures discussed so far represent reflections of central tendency, or how accurate responses were with respect to the target, the measure of variable error reflects the degree of distribution in the recorded estimates. The results for VE are very clear in that there were no interactive effects and the only significant main effects were for participant sex and interval length. There was no block factor in this analysis since the present VE scores were derived from all the trials performed by each participant in each condition. The significant effect for interval length was again an unsurprising finding in that variable error grew consistently and significantly with the length of the estimated interval itself, $F(3, 270) = 27.671$, $p < .001$. With respect to the sex of the participant, females (VE = 0.225 s) proved to have a significantly higher level of VE than their male (VE = 0.177 s) counterparts, $F(1, 90) = 5.02$, $p < .05$. As with the results for central tendency, there were no significant effects involving age in the VE results.

3.5. Absolute error (AE)

There are a number of additional derived error measures that seek to reflect a concatenation of both mean and variable error. The most common of these is absolute error (Newell, 1976). The analysis of variance of the absolute error (AE) scores is given in Table 3. These results indicate that there were two, two-way interactions between interval and block, and interval and sex. There were three main effects for block, interval, and sex, respectively. The block effect again illustrated the 'lengthening' phenomenon over trials in which AE grew across the successive 10 blocks of five trials each. AE also increased with interval so that, again unsurprisingly, greater absolute error was observed as the target time increased. Finally, females made significantly greater absolute error than their male peers. The results for absolute error confirmed those for the mean and variability measures and like those measures, AE also showed no main or interactive effects for age.

An alternative, and more controlled, method of deriving a compound error measure of both variability and central tendency is through the use of total variability (E), sometimes referred to as Henry's measure, or Henry's E (see Schmidt, 1988). This measure is computed by taking the square root value of the sum of CE squared plus VE squared. This is a more conservative compound

Table 3
Results of the mixed analysis of variance for absolute error (AE).

Source	SS	DF	MS	F	p
Sex	511.235	1	511.235	5.453	0.022
Age	310.182	4	77.545	0.827	0.511
Sex × age	196.710	4	49.177	0.525	0.718
Error	8438.286	90	93.759		
Interval	15,434.996	3	5144.999	124.754	0.000
Interval × sex	388.817	3	129.606	3.143	0.026
Interval × age	399.465	12	33.289	0.807	0.643
Interval × sex × age	234.308	12	19.526	0.473	0.929
Error	11,135.137	270	41.241		
Block	31.737	9	3.526	4.250	0.000
Block × sex	2.085	9	0.232	0.279	0.980
Block × age	20.104	36	0.558	0.673	0.930
Block × sex × age	15.699	36	0.436	0.526	0.991
Error	672.071	810	0.830		
Interval × block	35.998	27	1.333	1.744	0.010
Interval × block × sex	5.176	27	0.192	0.251	1.000
Interval × block × age	73.361	108	0.679	0.888	0.786
Interval × block × sex × age	55.597	108	0.515	0.673	0.996
Error	1857.998	2430	0.765		

measure than absolute error since the precise contribution of each component error is clearly evident. These results followed the pattern of those derived for AE and indicated a significant effect for the interval estimated, $F(3, 270) = 23.09$, $p < .001$, and a significant effect also for the sex of the participant, $F(1, 90) = 3.99$, $p < .05$, thus confirming the pattern previously exhibited for the other compound measure.

3.6. Coefficient of variation (COV)

The final reflection of objective response that was calculated was the coefficient of variation. This measure was derived by dividing the standard deviation scores by the mean scores. This analysis further confirmed the same pattern for both variable error (VE) and total variability (E). That is, there were significant effects again for interval and for participant sex. The coefficient of variation systematically decreased with the length of the interval, $F(1, 90) = 67.137$, $p < .001$. However, the coefficient of variation was greater for females compared with their male counterparts, $F(1, 90) = 9.776$, $p < .01$.

3.7. Summary of production findings

The findings for the time production responses in the present experiment generated a clear outcome. There were significant effects for the sex of the participant in the reflections of central tendency as confirmed by both the CE and ACE findings, respectively. As well as these differences in central tendency, there was a comparable effect for sex in response variability as reflected in the VE scores. These collective differences are further confirmed in the compound measures of response error which were reflected in AE and Henry's E. While the effects for participant sex are clear, the lack of any significant findings for age was equally evident. With respect to the interval of the estimate, there are strong, expected, and consistent effects over trial block that confirmed a 'lengthening' effect over multiple trials. In a number of measures, this lengthening effect interacted with the sex of the participant. Such interactions often represented a proportional difference since the size of the difference increased with the length of the target interval.

The mean of the actual estimates by males across all durations was 8.27 s, while the comparable value for the summed mean estimate for females across all durations was 7.55 s. This compares with a target mean of 7.75 s. These mean data confirm the pattern observed by Block et al. (2000) in which females underestimate produced intervals compared with males. It is often, and unfortunately the case, that inquiry is made as to whether males or females are more 'accurate' with respect to target intervals. From the results of the present experiment on the average, female responses proved more accurate overall than those of their male peers as a group. However, statements about relative accuracy need to be expressed very carefully since this overall accuracy difference can be easily overturned by considering the estimates of males and females at any one particular target interval. Therefore, the central question must be a comparison across groups. The consideration of 'accuracy' with respect to an arbitrary 'interval' should be considered, at the present time, to be of secondary concern.

What is now possible is a direct comparison of the present results with the most interesting, and directly comparable findings of Espinosa-Fernandez et al. (2003). In seeking to evaluate the potential interaction between age and sex on time estimation, they used a slightly larger age range, from 8 to 70 years old, with a sample of 140 participants, evenly balanced between the sexes. These individuals were asked to estimate 10 s, 1 min, and 5 min, in which trials of different duration were interpolated within each other. Briefly, they found an interaction between sex and age but no main effect for either variable independently. The interaction resulted from the highly divergent estimates of men and women in the highest age group. Like Espinosa-Fernandez et al. (2003), the present results also showed no main effect for age in the production estimates. However, unlike their reported results, there was a sex effect in the present findings. One most probable reason for this disparity lies in the methodological difference in the way the data were collected. In the experiment by Espinosa-Fernandez and her colleagues, there were 25 total estimates of 10 s but these were interspersed with the three estimates of 1 min and one estimate of 5 min, respectively. Thus, there were never more than 10 consecutive estimates of 10 s before an interruption. In contrast, in the present experiment there were 50 consecutive, uninterrupted trials before any situational change was made. As has been documented, there is an obvious lengthening effect as trials proceed and that effect interacts with participant sex. Therefore, it may well be possible that the different outcome for sex between these two studies arise from this important methodological difference. This observation serves to reinforce how important variation in methodology is in understanding the pattern of outcome results in this general area (and see Block et al., 2000).

3.8. Questionnaire analysis

As well as the objective reflections of response, each participant was asked a variety of questions concerning their characteristics and attitudes toward time. Results from the general survey questionnaire confirm that produced estimates were unaffected by whether persons habitually wore a watch, considered themselves punctual, or perceived themselves as often being late for meetings. There was some indication that participation in activities in which time was a factor did have an influence on the production of a 1-s interval. Participants who did take part in timed activities ($N = 57$) had a lower mean estimate of 1 s, i.e., 1.084 s and a lower standard deviation 0.302 s compared to the mean 1.295 s and standard deviation 0.607 s of those who did not ($N = 43$). Unfortunately, this effect did not extend to the other time intervals evaluated and at present it is unclear whether this represents a systematic effect or is, in contrast, simply a serendipitous finding. The combination of fingers used to start and stop response did not significantly affect any of the produced durations. Five different strategies were distilled through which participants sought to estimate the duration, these were; counting, finger tapping, foot tapping, picturing a clock, and no specific strategy. However, none of these strategies differentially influenced the production of durations. Whether individuals identified themselves as competitive or not, also did not further appear to influence produced intervals.

3.8.1. The lines test

Among the more formal approaches to assessing subjective temporal perspective was the use of the lines test, originally used by Cottle and Pleck (1969). In this procedure, the participants are presented with a horizontal line and instructed to mark on the line the location of their birth, their death, and the boundaries of the present (and see also Hancock, 2010). The latter is defined as the point where the past ends and the present begins and the point where the present ends and the future begins. This procedure creates six variables which are; (i) life space, which is comprised of (ii) personal past, (iii) personal present, and (iv) personal future. The next division is represented by; (v) the historical past or time before birth; and the final division is; (vi) the historical future as time after death. As the line is fixed in length, historical time (both past and future) is inversely related to life space. The line is a prescribed length and hence the variables reflect the distance along those lines. Present data on the lines test, derived from the current sample of individuals, were subjected to an analysis where the between-participant factors were age and sex. There were no significant main or interactive effects upon historical past, present, historical future, or life space. However, there were significant effects for age on personal past and upon the personal future. For the personal past there was a significant effect of age, $F(4, 83) = 5.097$, $p < .001$, which showed that personal past increased with age up to the age 60–69 group when it actually then reduced in the present sample. The increase in personal past with age is thus generally consistent with expectations, with the present exception of the oldest age group that was tested here. It is interesting to note however, that a similar but non-significant inversion also occurs in the production intervals. With respect to the personal future, there were consistent significant, effects, $F(4, 83) = 3.741$, $p < .01$. There was a direct decrease in the perceived length of personal future with age. There was no age effect upon the length of the perceived present. In the terms given by Block (1990), there appear to be no obvious age effects upon the perception of immediate duration but there is evidently an age effect upon time perspective. These findings differ somewhat from those of Cottle and Pleck (1969). However, this difference is unsurprising given that their sample were school-children ranging in age from 12 to 18 years old. Our findings do conform with those of Bull (1973) which is important since he used three groups; young (19–23), middle aged (43–55), and old (65–80) years, with 30 participants in each group evenly split between the sexes. Bull (1973) also found no sex or sex by age interaction effects but he also reported positive age effects for personal past and personal future only.

3.8.2. Time reference inventory (TRI)

The time reference inventory, originally developed by Roos (1964), was administered to the participants (see also Roos & Albers, 1965). The version used in the present experiment was composed of 12 statements, selected from the original 30 items, five of which were negative, five positive, and two neutral. A typical statement being: "*I believe the happiest time of my life is in the [past, present, future]*," where the individual then estimated the age at which that had retrospectively or would prospectively occur. Scores for each of the 12 selected items were then derived for past negative, past positive, and past neutral events, as well as future negative, future positive, and future neutral events. These data were then subject to analysis. There were significant main effects for age on past negative $F(4, 71) = 24.824$, $p < .001$, future negative, $F(4, 35) = 3.677$, $p = .01$, past neutral $F(4, 33) = 8.282$, $p < .001$, and past positive events, $F(4, 69) = 18.035$, $p < .001$. Unfortunately, not all participants responded to each set of questions and some items were left blank. These non-responses were not included in the analysis.

The main effect for age on past negative events was to distance past negative events from the older individuals. The main effect for future negative events was the converse. That is, the older the individual the closer the negative future events were perceived to be. Thus, these two sets of data are in direct accord and consistent with that which might be anticipated. Past neutral events also increase with age. Past positive events also increased significantly and systematically with age. In essence, the data are consistent that the older the individual, the more they perceived that the major events of their lives were in the past. This is true for both positive and negative life events. These overall results confirm the importance of the influence of age on time orientation, upon which interestingly, the sex of the participant does not appear to exert any significant effect.

4. Discussion

Since the structuring of the discussion of time perception can be made effectively by considering the individual phenomena of succession, duration, and temporal perspective (Block, 1990), this division is used here as the basis for considering the present results. Fundamentally, the present experiment addressed only two of these three elements, being duration and temporal perspective, respectively, and discussions of the findings are parsed accordingly.

4.1. Sex differences in duration perception and time perspective

Up until recently there has persisted in the literature a degree of contradiction concerning the magnitude and direction of sex differences in the perception of short duration intervals. Over the decades, numerous investigations have reported significant sex differences (see Axel, 1924; Bell & Watts, 1966; Carlson & Feinberg, 1970; Goldstone, 1968; Greenburg & Kurz, 1968; Gulliksen, 1927; Hornstein & Rotter, 1969; Martin, Shumate, & Frauenfelder, 1981; Rammsayer & Lustnauer, 1989; Yerkes & Urban, 1906). These almost ubiquitously show that females overestimate time intervals relative to males when using verbal estimation, while underestimating such intervals compared to males when using the production technique (Bindra & Waksberg, 1956). However, there are also several experiments that have reported no differences (Baldwin, Thor, & Wright, 1966; Geer, Platt, & Singer, 1964; Gilliland & Humphreys, 1943; Loehlin, 1959; Montare, 1985; Smythe & Goldstone, 1957; Swift & McGeoch, 1925) as well as the suggestion that others reporting no significant differences have failed to find their way into the literature. Periodic reviews of these disparate findings failed to differentiate between the methods chosen to record temporal estimates (e.g., Gilliland, Hofeld, & Ekstrand, 1946). This was a highly problematic omission since verbal estimation and production, which are the two most commonly employed assessment methods, are inversely related (see Hornstein & Rotter, 1969). Without this methodological distinction it can easily appear that no sex differences exist in this capability. Nor is the distinction of the method alone the only problem. When considering the number of trials upon which the results of each experimental study were founded, it is evident that those reporting no difference overwhelmingly use evidence from just one single trial. Those reporting positive effects predominantly use multiple trials (e.g., Hancock et al., 1994). These methodological differences, including trial frequency have been identified as crucial modifying influences in a formal meta-analysis of such sex differences by Block et al. (2000). When such factors are accounted for, then the collective outcome shows strong evidence of a consistent sex difference in the perception of brief intervals of time.

The results of the present experiment confirm this positive sex difference in the perception of duration with one of, if not, the largest sample sizes (and data sets, i.e., participant number by trial frequency) that were ever to be employed (but also see Espinosa-Fernandez et al., 2003). Most previous experiments have also examined only raw performance scores. However in the present experiment, sex differences were confirmed via analysis of a number of primary and derived error scores. Significant differences were recorded in both measures of central tendency and measures of variability. The fact that sex differences here were largely consistent across the four respective durations is also a matter of particular interest. As noted earlier, a number of theorists have suggested distinct differences between the behavioral interpretations of the various short intervals of time represented in the present work. Thus 1 and 3 s are postulated to occur in within the horizon of the immediate present (and see James, 1890), while 20 s is an interval often considered beyond short-term, time perception (Allan, 1979; Poppel, 1988). Consequently, the proportional gain in the difference between the sexes observed here implies a continuous function. Such continuity would favor an explanation founded upon a controlling mechanism. Such results then need to be addressed by those who propose theoretical differentiations between the respective time horizons which purportedly parse these brief duration intervals. In addition to the idea of a continuous mechanism, the proportional growth in the difference between the sexes also implies an accumulative temporal mechanism. Such a pattern of results seems to favor the accumulation type model as proposed for example in the influential work of Treisman (1963). In contrast to these findings for duration production, there was no evidence of any consistent sex differences in temporal perspective as assessed by a number of questionnaire instruments. This contrasts in part with earlier observations (see Cottle, 1976), although in general the evidence for sex differences in such prolonged temporal perspectives remains to be more thoroughly explored (and see Hancock, 2010).

There are two primary, contrasting explanations that have been advanced for sex differences in the perception of duration when they have been observed. These explanations have focused on the primacy of either endogenous or exogenous influences, respectively. The endogenous account favors the notion of a differential frequency of some form of "internal clock" that is itself responsive to a level of general cortical arousal perhaps mediated by differences in basal metabolic rate and/or body temperature (see Gibbon & Malapani, 2002; Hancock, 1984; Treisman, 1963; Treisman, 1984). Observed sex differences could thus be explained as a different average frequency of this 'internal clock' across males and females. This approach has particular value since such average frequency differences may be considered as dependent upon known sex difference in core body temperature and thus the subsequent link to metabolic rate. This would then account for both the sex effect and the temperature effect on time estimation through the use of one single, common 'internal clock' construct (and see Hancock, 1993; Treisman, 1984). It is through this idea of a common mechanism that linkages may also be made to observations on other related performance capabilities such as reaction time change across sex (see Fozard et al., 1994). Indeed, sex differences in lifespan longevity might themselves therefore also be contingent on this same common mechanism (and see Hancock, 2010). The natural extension of this argument is that perhaps a much greater amount of the variance observed between all individuals is contingent upon this variation in body metabolic rate.

In contrast, the exogenously-oriented explanation of such effects has emphasized the progressive and changing role of women in society over the decades of the past and present century (Gilliland et al., 1946). This account is founded fundamentally upon the idea that time perception is a learned ability. As an explanation of the evolving pattern of effects and non-effects, it was first promulgated as a result of the fact that many early studies did find substantive differences (e.g., MacDougall, 1904), while subsequent work apparently showed little or no effect (Gilliland & Martin, 1940). However, this account largely represents a post hoc re-statement of the overall pattern of results. The logical extension of this argument into the present era ought to imply that a further, progressive extinction of such sex effects should be seen in the most recent studies. This is because the manifest role of women in society has changed most dramatically in the immediate past decades. This social learning interpretation, which was first offered by Gilliland et al. (1946), is clearly not supported by these more recent findings (and see Block et al., 2000), although the idea of temporal perception as a learned ability remains an attractive one (see Fox, Bradbury, Hampton, & Legg, 1967). Problematically, this role-based explanation never really specified exactly by what mechanism social change exerted such influence. Implicitly, the argument proposed that women more and more engaged in time-regulated activities as they entered the modern workplace. As there are many intrinsic oscillations that might form the basis of such learned timing, it could be argued that women were socialized into choosing a common time base with men as they experienced the equivalent working environments. An information-processing account of this nurture effect could, in contrast, emphasize differential attention between the sexes (and see Coull, Vidal, Nazarian, & Macar, 2004). However, no sufficiently rigorous theoretical statement as to this social effect has ever been made so as to allow for specific testing of this exogenous, changing social role proposition.

4.2. Age differences in duration perception and time perspective

In the present experiment, there was an age-related difference in time perspective as represented by response to the questionnaire inquiries. There is a long tradition of evidence that reflects this age effect in a number of facets of behavior. Among the very first, DuNouy (1937) noted that the rate of wound-healing (cicitrization) varied directly with the functional age of the individual. The relationship for such healing rates followed a proportionate rate so that the healing time of the 20-year old was half that of the 40-year old. This change in the physiological indication of functional aging has been linked to the apparent phenomenological acceleration of time with age. It has been frequently observed that the subjective experience of time changes across the lifespan (e.g., Lemlich, 1975). Both physiological and subjective reflections of the difference in temporal flow with age appear to be related to a proportion of baseline effect in which events (both behavioral and physiological) can be scaled to the current age the person has reached (Hancock, 2002; Hancock, 2010). Whether, in these circumstances, functional age represents a better baseline compared to chronological age is still in contention (see also Perbal, Droit-Violet, Isingrini, & Pouthas, 2002). The present findings on aging and temporal perspective appear to confirm this global 'memory-based' effect. However, this age-related change in temporal attitude is one that might also be linked to the known diminution of metabolic rate with age.

The present results did not show an effect for age on the production of short intervals up to 20 s in duration. This is interesting since Bull (1973) did find such age effects for each of the three periods he investigated, being 30, 60, and 120 s, respectively (see also McGrath & O'Hanlon, 1968). There are a number of potential reasons for this disparity. First, the intervals investigated here and by Bull do not directly overlap. However, the difference between 20 and 30 s does not appear to be so substantive, either in practical or theoretical terms as to rely on this difference as a certain explanation of the present divergence. In reality, the divergent findings are much more likely to result from the sampling range of the age of the individuals involved in the respective studies. Further, through the solicitation of participants from among a university environment, the present sample is itself inherently slanted toward those with a higher average IQ, there being evidence that the resilience that goes along with such a healthier and more intelligent sample directly affects the functional aging of the individual (Polyukhov, 1989). Thus, the present outcome may be somewhat atypical of the overall population (cf., Block et al., 1998; Espinosa-Fernandez et al., 2003). While the original expectation was that age would indeed have some systematic effects on the perception of short duration intervals, there remained a high degree of heterogeneity in the present age results. Overall, the conclusion from the present results is that age seems to play a minor role while sex plays a small but significant role in the estimation of brief intervals of time.

5. Summary

The present work has sought to distinguish the discrete and interactive effects of age and sex as they affect the perception of brief duration intervals as well as more long-term temporal perspectives. Clearly, sex exerts a relatively small but consistent effect on the perception of brief durations. Somewhat surprisingly, chronological age showed no systematic influence on the perception of these brief intervals of time up to a period of seconds. However, age does exert strong and consistent effects on the expressed attitudes toward more extended intervals of time. The sex of the individual, in contrast, had a much lesser impact on the attitude toward these more prolonged time horizons. As we look to clarify why there remain such large differences between individuals in their approach to several faces of temporal perception involved with succession, duration, and temporal perspective, it is helpful to establish some degree of nomothetic basis from which such idiographic propensities can be approached. The results reported in the present work serve to elucidate some pieces of this on-going puzzle.

Acknowledgments

We are very grateful to Drs. Eric Arthur and Aaron Duley for all their efforts in relation to the production of this work. Further, we very much appreciate the informative comments of the anonymous reviewers of this work and the guidance, direction, and suggestions of the action editor, Professor Albert Postma.

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