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The effect of age and sex on the perception of time in life

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As a measure of their personal perception of time in life, 320 participants completed the Lines Test. Participants were asked to mark off on a line their perceived present life location between the endpoint anchors of birth and death. The percentage of the life span marked was compared with actuarial life expectancy to establish a quantitative degree of difference for each respondent. Results indicated a significant sex difference in which women across the age range investigated were more accurate as to their life location. Results also showed a significant age effect in which older participants consistently underestimated their life location to a much greater degree than their younger peers. A second investigation presented an amended version of the traditional Lines Test and scaled the actuarial life span to each participant's specific age. The pattern of findings was replicated by this procedure. Reasons for this overall pattern of results are discussed in terms of what is currently understood about the perception of short intervals of time and the perception of duration across the life span.

Perhaps the greatest of all challenges in psychological research is to find ways to render personal, private experience open to mutual, public inspection. When such private or inner phenomena concern a person's contemplation of the material world, there is potential for a direct mapping between that person's mental conception and any external object or dimension (Stevens, 1957). Psychophysical explorations of these direct links between internal state and external condition give us encouragement to believe that we can eventually understand each person's mental world through reference to our own corresponding social experience. However, when the private experience has no obvious material correlation in the real world, we are faced with a much more difficult problem. This situation pertains with respect to the study of time (see Gallagher, 2009). Time has been described as "perhaps the most fundamental dimension of human experience" (Cohen, Hansel, & Sylvester, 1954, p. 108). As a fundamental aspect of all existence, time occupies a privileged place in science and indeed in all of human knowledge (Kant, 1781).

If human beings learned to represent time as a direct chronometric record of events and could veridically project that chronometric capacity onto the future, then one would see an unvarying match between the social and personal constructs of time. In essence, each person would perceive the flow of time

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in synchrony with the clock on the wall and be able to estimate intervals of seconds, minutes, and hours almost precisely (Hancock, 2002). More formally, the exponent of the psychophysical curve would be unity. Interestingly, this statement is true for very short intervals of time, up to a number of seconds (Woodrow, 1951). However, it is clear from the pattern of existing data that this average relationship conceals very large individual differences (Doob, 1971). Problematically, it is also the case that the general relationship does not appear to hold for intervals of time beyond a matter of seconds. However, studies of the perception of extended intervals of time are often constrained to use particular socially labeled durations (e.g., a day, a week, a month). Thus, the accuracy of individuals' estimations in these terms is greatly influenced by the degree to which they have learned or internalized the duration of these socially fabricated intervals. A much more informative measure of long-term temporal perception should involve the primary markers that bracket each person's life. The evident markers in life are of course its beginning (birth) and, in prospect, its ending (death).

Within the general scatter of individual differences in temporal perception (Kirkcaldy, 1984) some regularities have emerged over the years of experimentation. For the estimation of short intervals, meta-analyses have revealed consistent effects for the sex of the participant (Block, Hancock, & Zakay, 2000). Here, females show larger subjective:objective duration judgment ratios but only for retrospective judgments of time. Also, there are significant influences for the age of the person tested (Block, Zakay, & Hancock, 1998), in which older people give larger verbal estimates and shorter productions of durations than younger people. Similar sex and age effects are also seen in other fundamental capacities, such as reaction time change across a person's life span (Fozard, Vercruyssen, Reynolds, Hancock, & Quilter, 1994; Perbal, Droit-Volet, Isingrini, & Pouthas, 2002; see also Halpern, 2000). The question addressed in the present set of investigations is how a person's perception of the time of his or her life itself changes across the life span. In particular, the work looks to explore whether there are consistent effects for sex and age in such long-term estimates and whether any patterns of response adduced are consistent with the patterns observed for the estimates of short-term intervals on the order of minutes and seconds.

STUDY 1

METHOD

Participants

The sample in the present investigation represented participants drawn from the population in the immediate vicinity of a large university campus. The sample was not strictly random because participants were recruited and evaluated by a number of different testers on an individual basis. There was no restriction on the age of people who were solicited for participation. The final sample consisted of a total of 320 participants who were equally split between the sexes. The average age for the sample was 35 years and 4 months. No effort was made to control any additional variation, and the confidentiality of participants' responses was ensured in accordance with the American Psychological Association (APA) treatment protocols for research data.

Procedure

Ten data collectors (five male, five female) were trained on the administration of the Lines Test (Cottle, 1976, 1977). The Lines Test presents a participant with a single line, in this case 10 in. long, across a single sheet of paper. The tester informs the participant that this line represents his or her own lifetime. At the left end of the line is a vertical mark that indicates birth. At the right end of the line is another vertical mark that indicates the participant's prospective death. Participants are asked to mark one vertical line anywhere they choose along the 10-in. line where they perceive themselves to be in their lifetime at the present moment. The tester then recorded the participant's self-declared age in years and months.

Individual testers were responsible for seeking out participants and soliciting their responses. After each tester had collected a total of 32 participants split equally between young and old and male and female, they provided the investigator with the marked data sheets for subsequent analysis. This collection phase completed the contribution of each individual tester. The investigator (who was also one of the testers and administered the training of the Lines Test to all other testers) then coded the collected data according to age of the participant (in months); sex of the participant (male vs. female); sex of the tester collecting the data (male vs. female; Rumenik, Capasso, & Hendrick, 1977); percentage of the lifetime perceived as having passed (as derived from the marked line); percentage of lifetime passed according to the contemporary actuarial tables for prospective life span, being 74.7 years for males and 77.4 years for females (U.S. Department of Health and Human Services, 2007); and the difference between perceived age and the latter actuarial age. The difference value formed the primary dependent variable for analysis. Finally, the ratio of the present estimated age compared with the actuarial age was also calculated and used in analysis.

RESULTS AND DISCUSSION

The overall data are presented in Figure 1, which shows the overlap of the difference estimates of the two sexes by age. The most obvious finding represented in these data is the very large inherent variability in estimates across participants. Thus, even at the same age, difference values can vary as much as 75%. Such variability does not appear to be contingent on the sex or age of the participant to any great extent. This finding may at first seem problematic. However, in actuality, individual differences are the predominant finding in all psychological studies of time estimation (see Doob, 1971). Of course, such individual variation can be viewed as a problem to be minimized or, in contrast, the heart of the issue (Cronbach, 1957). However, embedded in this large variability are a number of significant nomothetic trends that are revealed by formal analysis.

A preliminary analysis of the results indicated that the sex of the tester exerted no significant influence on the outcome scores. Therefore, the next step was to conduct a *t* test, and this analysis showed a significant effect for participant sex, $t(318) = -2.09, p = .037$. On average, the difference score for females between their estimates and their actuarial life expectation was −3.275%, whereas for males the comparable figure was −6.235%. Also, there was very little difference in the standard deviation scores between the two sexes, females = 12.925, males = 12.367. The main effect, although significant, was not particularly large, ac-

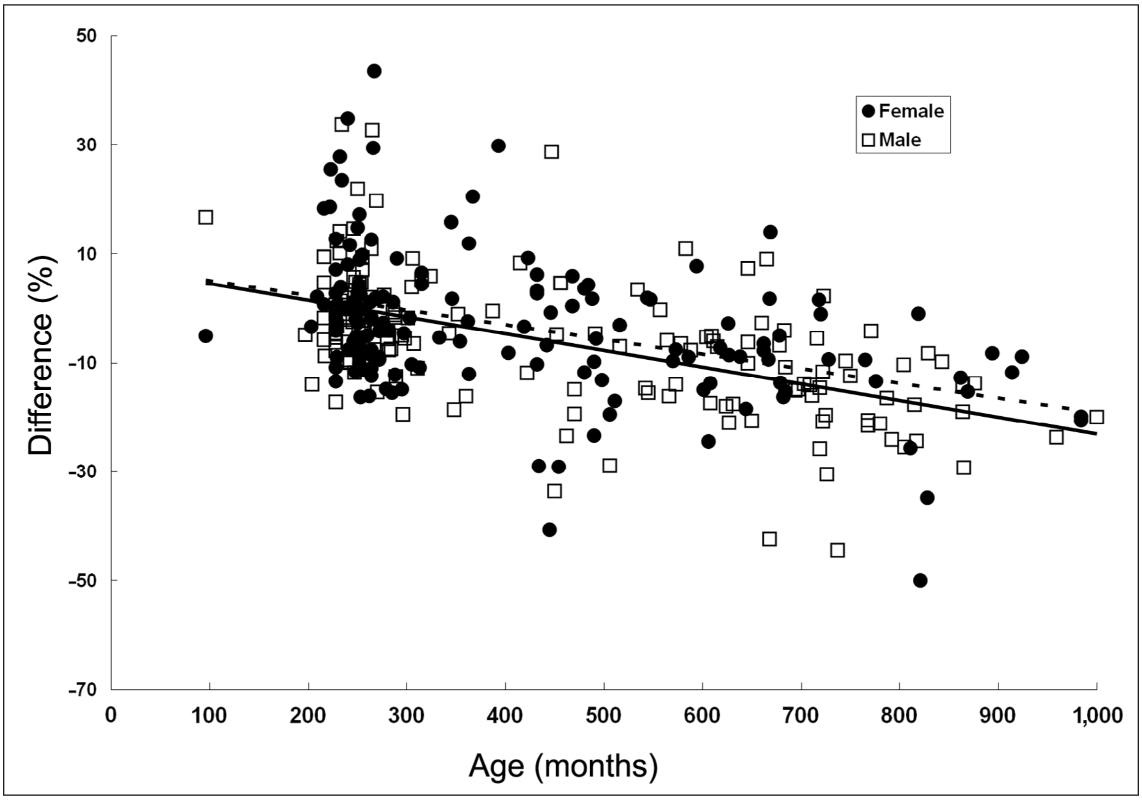

FIGURE 1. Participant age versus difference between perceived and actuarial life span expectation for males and females, Study 1. The dotted line represents the regression for female participants and is described by the equation $y = -.03(\text{age in months}) + 7.76$. The solid line represents the regression for male participants and is described by the equation $y = -.03(\text{age in months}) + 7.58$. These are not statistically different.

counting for only some (R^2 = 1.4%) of the variance observed. However, subsequent regression analysis permitted calculation of what is called the indifference interval. In the present circumstances this might more readily be defined as the life indifference interval. This life indifference interval represents the age at which males and females, respectively, provide a correct estimate of their actuarial life span. Because younger people tended to overestimate their actuarial age and older people to underestimate their actuarial age, there has to be an age when the respective regression lines for male and female participants cross zero. For females, this age is 24 years 0 months, and the comparable age for males is 20 years and 6 months. The average indifference interval for the whole sample was 22 years and 3 months. That this is near the design life expectancy of human beings as derived from allometric scaling principles (Thompson, 1917/1992) may be more than simple coincidence.

As is evident in Figure 1, the degree of underestimation increases across the life span for both males and females. Initially, we have to consider whether this effect could be an artifact of the characteristics of the Lines Test itself. For example, as the age of the participant approaches his or her actuarial life expectancy, there is a natural ceiling effect. This occurs because the actuarial age is a mean value expressed for each cohort and not adjusted to each person as an individual (see U.S. Department of Health and Human Services, 2007). Thus, a person who is older than his or her actuarial life span expectation almost inevitably provides an underestimated value. For this reason, no participant was evaluated who was older than his or her actuarial life expectancy. This limited any potential artifact as influencing the outcome as a result of the inevitable ceiling effect.

A subsequent regression analysis indicated a significant incremental effect for participant age, $F(3, 316) = 35.05$, $p < .001$, $R^2 = 0.25$, $\Delta R^2 = 0.236$, beyond any effect for the sex of the participant or the sex of the tester. Difference scores decreased as a function of increasing age, $b = -.03$, $SE = .003$, $\beta = -.49$, $t(316) = -9.97$, $p < .001$. The individual regression equation for males was difference = −.03 age + 7.58, and the comparable equation for females was difference = −.03 age + 7.76. Analysis demonstrated that this aging effect was by far the most influential factor, accounting for some 23.6% of the variance. Effects for the sex of the tester on these outcome results were marginal, and therefore this manipulation was omitted in the procedure that follows.

To this point, the dependent variable used to reflect a participant's response has been the difference score between his or her personal perception and actuarial life expectancy. In essence, this is a reflection of a general measure known in the performance literature as constant error. However, one could argue that there is another derived measure that may better reflect the relationship between these two variables (Eisler, 1996). This is the ratio of the perceived value to the actuarial life span. This measure is often used in the time perception literature and is called the duration judgment ratio (DJR) (Block et al., 2000). In order to evaluate such effects, a subsequent analysis was conducted using this ratio measure. As in the case of the difference score, preliminary analysis indicated that there was no significant effect of the sex of the tester on the duration judgment ratio, nor was there a significant effect of participant sex on this measure, $p > .25$ in each case. However, subsequent regression analysis showed a significant incremental effect for age, $\Delta F(1, 317) = 20.89$, $p < .001$, $R^2 = 0.07$, $\Delta R^2 = 0.06$. DJR decreased as a function of participant age, and the regression equation for this function was DJR = −.03 (participant sex) − .0004 (age in months) + 1.13. The coefficient for age here appears to be small because of the units of age used in the DJR derivation (Figure 2).

Although the pattern of findings in the present investigation are largely consistent, a number of objections to their validity may be raised on both methodological and theoretical grounds. For example, the results could be influenced by certain intrinsic characteristics of the Lines Test itself. The current version of the Lines Test provides endpoint anchors and subsequently asks participants to mark off their subjective perception of "now" on the line presented. In this circumstance, the endpoints may constrain how a participant chooses to respond. Particularly, as has been noted, if the respondent is an older adult, there is a limiting effect of the upper boundary. Thus, the absolute ceiling effect may spill over and influence the responses of those who have yet to reach their actuarial life expectancy. In consequence, it may be preferable to ask participants to create these endpoints on a continuum that allows

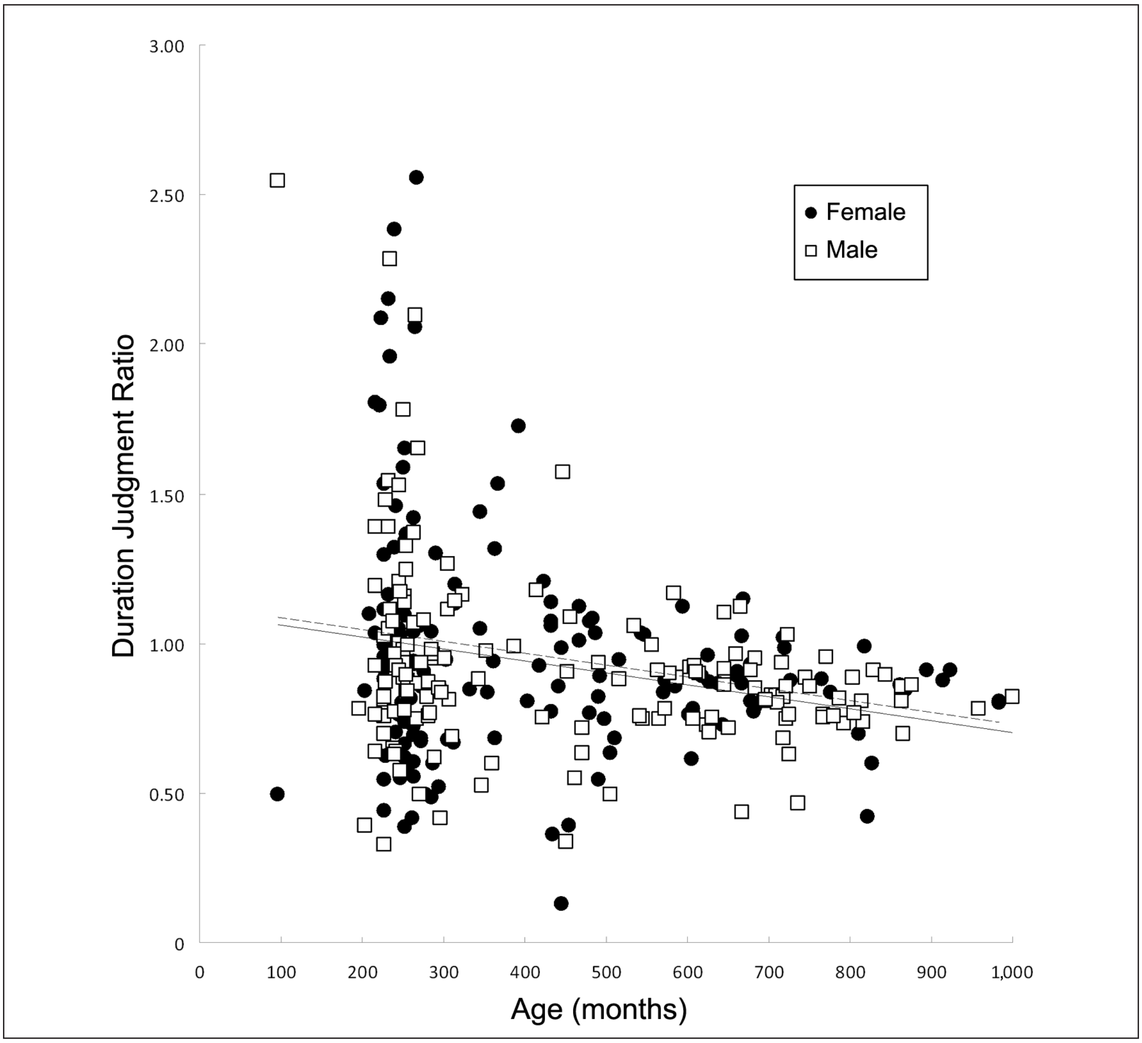

FIGURE 2. Participant age versus duration judgment ratio between perceived and actuarial life span expectation for males and females in Study 1. The dotted line represents the regression for female participants and is described by the equation $y = -.0004(\text{age in months}) + 1.13$. The solid line represents the regression for male participants and is described by the equation $y = -.0004(\text{age in months}) + 1.10$. These are not statistically different.

them free expression of these critical life events. Also, the calculations in this first investigation of actuarial life span were derived from a single value for males and a single value for females based on the life expectancy for the current cohort of participants. A more accurate, potentially different picture might emerge if participants were scaled to their own individual life expectancy. To this end, a second procedure was conducted that addressed these potential objections and acted as a further exploration of the robust character of the findings derived from the first procedure.

STUDY 2

METHOD

Participants

The sample in the second investigation was also a quasirandom group drawn from the same environs as in the first investigation. The sample in this case was recruited and tested by one single (male) tester. In the final sample, there were 132 total participants, equally split between the sexes. The average age for the sample was 38 years and 1 month. No effort was made to control any additional variation, and the confidentiality of participants was ensured as according to the APA treatment protocols for individual data.

Procedure

The procedure for the second investigation was similar to that for the first investigation but with the following small but critical amendment. The participant was presented with a single sheet of paper with a horizontal line of 10 in. drawn across the center of the sheet. At the midpoint of the line was a single vertical mark. Thus, rather than the end anchors being presented and the participant being asked to make his or her judgment with a single vertical line between the anchors, this technique presented a single vertical line representing the present, and the participants were asked to strike off one mark for their birth and a second mark for their prospective death. This information was then recorded together with the participant's sex and self-declared age in years and months. Because the sex of the coder had little substantive impact on the results in the first investigation, it was considered justified that only one single male tester collected all data for the second investigation. The same dependent measures of response were used here as in the first investigation.

RESULTS AND DISCUSSION

The results of this second investigation for the respective difference scores are presented in Figure 3. In this instance, a *t* test was first used to evaluate the potential presence of a sex effect in the overall data for the difference scores, calculated in the same fashion as in Study 1. This analysis indicated a significant difference between the sexes, $t(130) = 2.21$, $p = .029$. On average, the difference for females between their estimates and their actuarial life expectation was –7.262%, and for males the comparable figure was –13.878%. Again, although significant, the degree of

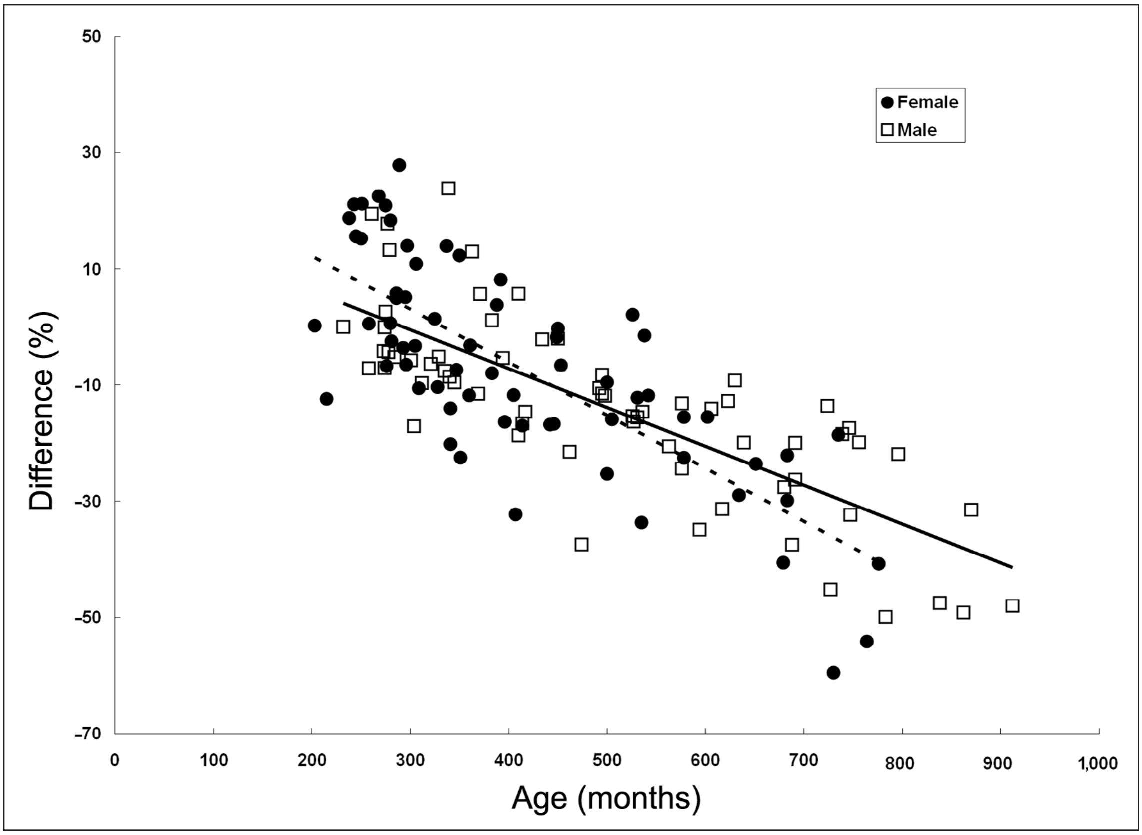

FIGURE 3. Participant age versus difference between perceived and actuarial life span expectation for males and females, Study 2. The dotted line represents the regression for female participants and is described by the equation $y = -.09(\text{age in months}) + 30.45$. The solid line represents the regression for male participants and is described by the equation $y = -.07(\text{age in months}) + 19.58$. These respective regression lines are statistically different.

the overall variance accounted for was relatively low, $R^2 = 3.6\%$. It may be observed that the absolute values of the differences for both males and females were larger in this second investigation than in the first investigation. However, the overall age of the sample in this second investigation was greater by almost 4 years. Thus, the variation in the absolute values for the difference scores between the two investigations can perhaps be attributed to this sampling variation. From the age distribution recorded, it appears to be the case that the student testers in the first investigation sampled at convenience, resulting in the testing of more of their younger peers as compared to the more balanced age distribution in this second investigation.

As with the first investigation, a subsequent analysis was conducted on the effect of age on the derived difference scores. Again, the present results confirmed the overwhelming impact of age. The regression of participant sex on the difference scores was confirmed to be significant, $F(1, 130) = 4.88$, $p = .029$, $R^2 = 0.036$. In addition to this effect, there was a significant increment in ΔR^2 for age, $\Delta F(1, 129) = 179.30$, $p < .001$, $\Delta R^2 = 0.561$, and for the interaction between age and sex, $\Delta F(1, 128) = 4.48$, $p = .036$, $\Delta R^2 = 0.014$. This analysis showed that the incremental influence of age accounted for 56.1% of the variance observed. As with the results from the first investigation, the younger the participant, the greater the propensity to overestimate his or her current life location compared with actuarial life expectancy. Similarly, the older the participant, the greater the propensity to underestimate his or her current life location compared with actuarial life expectancy. These data also allowed the calculation of an indifference interval, and in the present set of scores the mean indifference interval was 26 years and 0 months; the respective indifference interval for females was 27 years and 9 months, and for males it was 24 years and 3 months. The average life indifference interval in this investigation is almost exactly the length of the allometric design life span of human beings. That this figure varies with respect to the age identified in the first investigation appears to show that the life indifference interval is, to some degree, influenced by group sampling issues. However, this issue deserves more extensive experimental evaluation to determine whether life indifference interval is a meaningful measure or whether it is simply an artifact of the present investigational strategy. Overall, despite the changes in the data collection procedure and in the manner in which each participant's score was scaled to his or her own age (as opposed to the mean cohort age of Study 1), the results of the second procedure confirmed directly the pattern of findings derived in the first investigation.

As with the first investigation, a subsequent analysis was conducted on the DJR scores derived from the raw data (Figure 4). For the initial t test, there was an effect for sex that approached traditional levels of significance, $t(130) = -1.85$, $p = .067$. This marginal effect was resolved more clearly in the subsequent regression analysis. This showed a significant incremental effect for age, $\Delta F(1, 129) = 45.39$, $p < .001$, $\Delta R^2 = 0.25$, $R^2 = 0.28$. However, there was also a significant increment for the interaction of sex by age, $\Delta F(1, 128) = 8.31$, $p = .005$, $\Delta R^2 = 0.4$, $R^2 = 0.32$. To explore this interaction in more detail, subsequent regressions were conducted for each sex separately. For the males the regression weight was −.0007, whereas for females the comparable regression weight was −.002. This outcome indicated that the relationship between DJR and age was greater for female participants than for their male peers.

In addition to the difference and ratio scores, the present amended version of the Lines Test permitted the evaluation of three other resultant variables: the total length of the line that was marked off by the participant, the length of the line segment representing the past as marked off by the participant, and the length of the line representative of the future as marked off by the participant. In the first-order correlations, the two significant effects that emerged were between age and line segments for the future and past, respectively. That is, there was a significant negative correlation, $r = -.416$, $p < .001$, between age and the length of line marked for the future. However, there was also a significant positive correlation, $r = .299$, $p < .001$, with past line length, which indicated that the length of the previously experienced life span increased with age. Of course, these are naturally expected outcomes of the present procedure.

With respect to the length of the line marked as the experienced past, there was no significant effect for sex of participants; however, there was a significant increment in variance accounted for by the age of the participant, $\Delta F(1, 129) = 10.50$, $p = .002$, $R^2 = 0.095$,

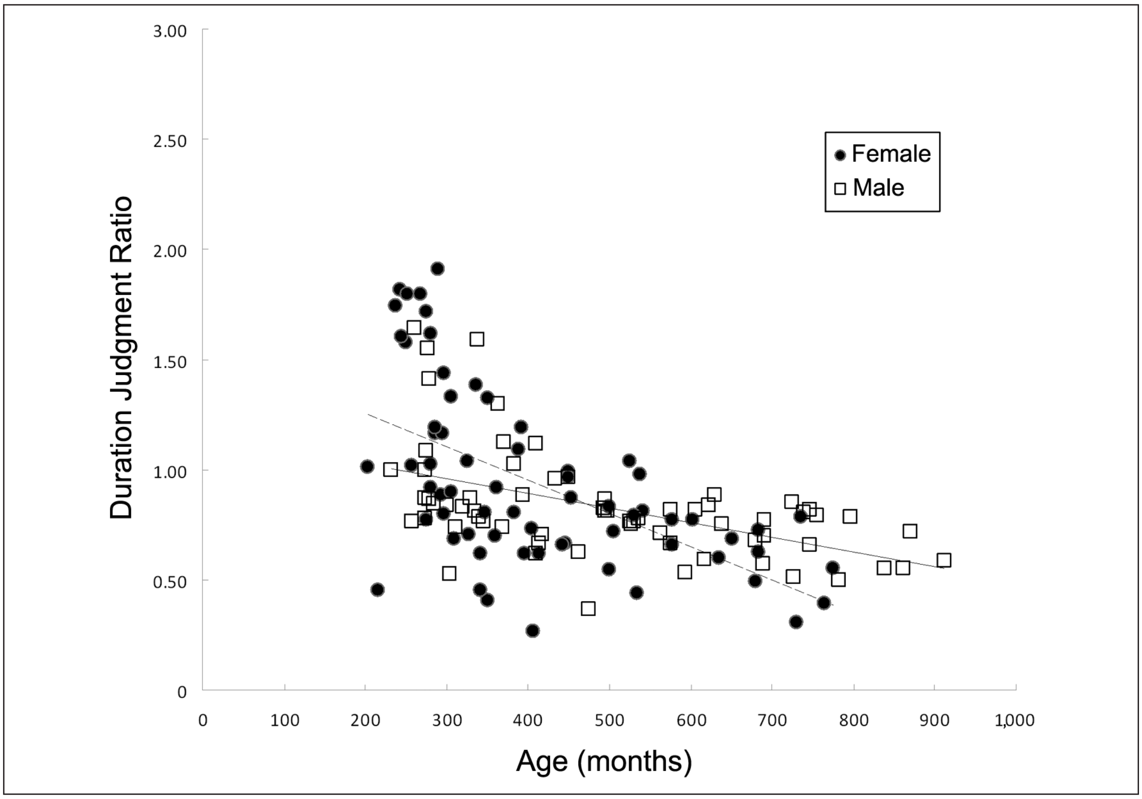

FIGURE 4. Participant age versus duration judgment ratio between perceived and actuarial life span expectation for males and females, Study 2. The dotted line represents the regression for female participants and is described by the equation $y = -.002(\text{age in months}) + 1.56$. The solid line represents the regression for male participants and is described by the equation $y = -.0007(\text{age in months}) + 1.16$. These respective regression lines are statistically significantly different from one another.

$\Delta R^2 = 0.074$. This indicated that as the participants grew older, the line segment for the past grew longer. This is not an unexpected outcome in relation to the present test. Indeed, it would be noteworthy if this were not so. The interaction between age and sex for this measure did not reach significance. For the line length representative of the future segment, there was a significant effect of sex, $F(1, 130) = 6.26$, $p = .014$, $R^2 = 0.046$. This showed that the line representative of the future segment was longer for females than for their male peers. Because there was no significant difference in the past line segment, this result indicates that females, on average, perceive that they have a greater prospective life span. There was subsequently a significant additional effect for age, $\Delta F(1, 129) = 22.17$, $p = .001$, $R^2 = 0.186$, $\Delta R^2 = 0.14$. As age increased, the line length for the future segment sequentially decreased. These results are logical and confirm the utility of the present technique, which can be directly compared to circumstances in which verbal estimates of time were elicited through the use of a visual analog scale (cf. Angrilli, Cherubini, Pavese, & Mantredini, 1997; Bschor et al., 2004). These findings also affirm the collective consciousness of aging in the sample tested. The interaction between age and sex was marginally significant, $p = .059$, but is not considered a particularly substantive influence in the present pattern of results. There were no significant effects or correlations between participant sex and the total length of line marked for the person's life span.

GENERAL DISCUSSION

Many experimental studies have looked at the effects of age on the estimation of brief intervals of time (e.g., Craik & Hay, 1999; Lemlich, 1975; Nitardy, 1943; Rakowski, 1979; Rammsayer, 2001). For example, Wittmann and Lehnhoff (2005) recently confirmed that the passage of time speeds with age, but they also noted the limited size of this effect. A recent meta-analysis of the collective findings concluded that age-related effects in the perception of short intervals were consistent and substantive, with older people producing shorter intervals of time for a standard set duration than their younger counterparts. Furthermore, this analysis also revealed that older people are more variable in their estimates than are younger people (Block et al., 1998; see also Carrasco, Bernal, & Redolat, 2001). In a similar manner, there have been numerous empirical evaluations of the effect of sex on the estimate of short durations (e.g., Eisler & Eisler, 1992; MacDougall, 1904; Rammsayer, 1998; Rammsayer & Lustnauer, 1989; Roeckelein, 1972). Again, a meta-analysis of these experiments indicated that the overall effect of sex was small but statistically significant. However, revealed sex differences pertained largely to retrospective judgments of brief time intervals, with prospective judgments being less influenced by the sex of the participant (Block et al., 2000). Studies that have evaluated both age and sex effects in tandem are fewer in number (but see Bell, 1972). Some recent experimental results indicate systematic effects (e.g., Espinosa-Fernandez, Miro, Cano, & Buela-Casal, 2003). In general, the body of evidence concerning the interactive effects of age and sex are consistent with the studies that examine individual effects alone.

It is possible to compare the results of the present investigation with those of one of the most recent evaluations of brief intervals. When the present results are compared with those of Espinosa-Fernandez et al. (2003, Figure 1[d]), which shows the estimates by males and females of different ages of a 5-min interval, there is evidence of an immediate degree of concordance. First, there is an evident effect for sex; second, there is a clear effect for age; and third, within the constraints of the age limits chosen in the present investigation, there is no interaction between age and sex. Such a conclusion seems to indicate a strong degree of concordance between estimates as short as a few minutes and estimates as long as a prospective lifetime. However, the implied isomorphism between the respective patterns of results is not justified. For if we examine the estimates for the 5-min interval we find that the males are more accurate with respect to the target value and also provide estimate values that are higher than those of their age-matched female peers.

Initially, this might appear to provide a conundrum and perhaps implicate the absolute duration of the estimate as the pivotal difference between the two sets of outcomes. However, absolute duration of the estimated interval might not be the critical, mediating difference. In the case of the Espinosa-Fernandez et al. (2003) experiment, the method used to elicit duration estimates was the production technique (see Bindra & Waksberg, 1956). The question at issue here is how the present Lines Test and its subsequent derivative procedure relate to this established production technique. One fact is well established: The production technique and a comparably common technique called verbal estimation tend to provide completely inverted results (see Zakay, 1990). Thus, if the two techniques are inversely related and the Lines Test is considered methodologically equivalent to a form of verbal estimation, then the contradictory findings concerning the absolute level of male and female differences may well be explained by this methodological inversion. At present, this appears to be the most favored explanation of such a difference rather than some account based on the differing intervals involved. However, how the various mechanisms that underlie the estimations of these very different lengths of time are related is as yet only poorly articulated.

The most common explanatory construct invoked to account for any pattern of time perception changes with aging is that of the internal clock. Indeed, variation in the frequency of an internal clock is often used to explain sex differences in time perception. When named in this fashion, the internal clock is not really an explanation at all. Rather, it is a redescription of the outcome findings using a convenient and generally accepted semantic label. If the internal clock is to represent a more profound level of theorizing, it has to be articulated at a greater level of compositional detail. Fortunately, such a refined level of sophistication was provided decades ago in the careful and insightful work of Treisman (1963). Yet even this model is insufficient in itself. To produce a full explanation, we have to distinguish which element of Treisman's model of the internal clock is directly affected by personal characteristics such as sex and age. For the present findings, the source of variation appears to lie with the central pacemaker element of the model.

Our search leads us to the identification of a factor that influences the frequency of the central pacemaker and is consistent with both sex and age differences. The primary candidate for such a factor is metabolic rate and its covariate, body temperature. It is well established that metabolic rate decreases with age (see Frisard et al., 2007; van Pelt et al., 1997; van Pelt, Dinneno, Seals, & Jones, 2001). Furthermore, there is also evidence of significant sex differences in metabolic rate (see Arciero, Goran, & Poehlman, 1993; Poehlman, Toth, Ades, & Calles-Escandon, 2003). In fact, in the latter case there is evidence that such sex-related differences in metabolism can be differentiated within the brain itself (see Gur et al., 1995). We also know that a strong correlate of metabolism, body temperature, certainly does affect the perception of short intervals of duration (Hancock, 1993). Also, there is evidence of a sex difference in body temperature (Lu & Dai, 2009; Shoemaker, 1996; but also see Motohashi, Higuchi, & Maeda, 1998), as well as sex differences in intrinsic circadian fluctuations (see Hancock, Vercruyssen, & Rodenberg, 1992; Wever, 2005).

The picture relating body temperature and metabolic rate to aging is a little less clear (see Duffy & Czeisler, 2002), but current evidence suggests a relationship consistent with the sequence established earlier in this article. It may also be possible that the reduction in dopamine across the life span is related to the present outcome (Mangan, Bolinskey, & Rutherford, 1997). This general explanatory sequence is also consistent with Treisman's (1963) original observations concerning the influence of temperature and its effects on pacemaker frequency (see also Hoagland, 1933). From this information, we might well conclude that the present behavioral results are a direct outcome of the participant's age and sex and the resultant metabolic rate (and related body temperature effects). Interindividual variability then reflects individual differences in metabolic rate, at any particular age or for either sex. Thus, we appear to have a consistent and plausible explanation at the neurophysiologic level for the pattern of findings reported. However, what is as yet uncertain is whether such influences that seem to affect judgments on the order of a few seconds in duration actually pertain to intervals as long as a lifetime, which assuredly must also involve some greater level of cognitive appraisal and the strong involvement of autobiographical memory. Although this is a form of explanation at one level of analysis, it may also be a reasonable strategy to embrace a second, cognitive-based explanation of the present findings (see Schiffman, 2000).

Indeed, one can argue that the present response data derive directly from immediate cognitive judgments and must at least to some degree be the direct result of a form of scaling appraisal (see Glicksohn, 2001). That is, for participants to express their opinion, whether using either version of the Lines Test, they must begin with some general notion of their own potential longevity. Indeed, it is evident from the data collection process that some participants engage in an overt computational appraisal. They often make statements such as "I expect to live to 80; the future mark should be made here." Numerous participants made either explicitly expressed or obviously derived quantitative calculations. Thus, in addition to sufficient neurophysiologic accounts of the present pattern of data, we must also seek an equivalently satisfying explanation of these findings at the cognitive level of analysis.

One obvious source of cognitive-level explanation lies in this formerly mentioned scaling activity. This scaling conception can be understood by considering the proportion of a person's life as represented by the coming year. For example, for a 20-year-old person, the coming year represents 5% of their present existence (i.e., 1/20 = 5%). For a 50-year-old, the same interval represents only 2% of their existence to that time (i.e., 1/50 = 2%). Using this scaling algorithm, it is possible to derive a function for the scaled perception of aging across the life span (see also Schiffman, 2000). Because we know that males and females have different life expectancies, two separate functions can be generated in which the value of any forthcoming year can been scaled to the overall current life expectancy for males and females (i.e., males = 75.2, females = 80.4) (U.S. Department of Health and Human Services, 2007, Table 27, p. 175). Such functions match, in general, the overall pattern of the response data in the present investigations (also see Craik & Hay, 1999). Attractive as such a curve-fitting exercise is, the current inability to match the quantitative aspects of the relevant dependent variables renders this scaling notion an interesting possibility but far from an exclusive explanation of the current pattern of results. However, because the notion of life scaling is consistent with the reported outcomes, some general form of this cognitive appraisal must underlie the pattern of the data observed.

At present, the nominal scaling explanation does not account for the inversion in the difference scores. Looking at the absolute levels of the differences obtained, we must seek a further explanation as to why younger people overestimate their current age, whereas their older peers systematically underestimate their current life location. One potential reason could lie in the present sampling process. Participants in the present sample were drawn from the environs of a large university and may have had the reasonable expectation of greater than average life expectancy given their local standard of living (Keith, 1981–1982; Lehr, 1967). Furthermore, the intellectual stimulation that accompanies such circumstances has been implicated in a more beneficial aging process. However, this is largely a post hoc account, and direct comparisons across socioeconomic groups and differing spatial locations would be needed to substantiate it with any certainty. A second possibility might lie in the simple fact that older people are more afraid of death. Because placing any termination mark on the line indicates one's personal demise, placing that mark closer to the present time might simply be an aversive act that people shy away from, especially as they get older and closer to that event itself. Such an aversion factor is important to consider in any future investigations of life span estimation.

Of course, the two levels of explanation, the neurophysiologic and the cognitive, are not mutually exclusive. Both could be operating to produce the outcome data, and at present we have no independent data concerning, for example, body temperature or metabolism to distinguish whether the two forms of explanation can be separated. This awaits future investigation. What is evident is that there is a systematic change in the person's perception of his or her life expectancy across the life span and that expectancy is tempered by the sex of the person so tested. These data appear to be consistent with results from investigations of short temporal intervals, implying some form of memory accumulation for autobiographical status across the life span that is related to everyday attention. The way in which the apperception of very brief intervals of time and extended intervals up to the full life span can be integrated into a single model of human temporal processing remains a significant practical and theoretical challenge.

NOTES

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