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The effects of sex, target duration, and illumination on the production of time intervals

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Abstract

An experiment is reported which examined the effects of illumination, sex, and the duration of target intervals on the perception of time. Six male and six female participants made repeated estimates of one, three, seven, and twenty seconds each, using the production technique. There were sixty trials per duration, half of which were performed with the lights on and half with the lights off. Order of administration of lighting condition and duration of target time was randomized. For estimates expressed as ratios of target times, results indicated significant main effects for participant sex and duration of target time on mean time estimates. However, manipulation of lighting condition did not produce a significant main effect. For the variability of response, there was a significant interaction between sex and light condition such that women were less variable in lighted conditions. These findings are discussed in terms of previous equivocal evidence for the influence of participant sex on time perception and the modification of such an influence through change in experimental conditions.

1. Introduction

There is a continuing debate over the presence and degree of difference in cognitive capabilities that exist between the sexes [1]. A number of reviews have examined the spectrum of potential differences and while some general statements about sex effects may be supported, it is often the case that individual differences are a major stumbling block to strong assertions (Baker, 1987; Halpern, 1992; Maccoby and Jacklin, 1974). Of all capabilities that do exhibit sex differences,

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spatial perception appears to be the most robust (cf. Watson and Kimura, 1991). It is strange therefore, that few statements have been made concerning its companion faculty, namely temporal perception. There is scattered information on sex differences in time perception which has emerged since before the turn of the century (e.g., Gilbert, 1894), however, no definitive statements have been made about the potential for such differences in either the literature on cognitive sex differences (Halpern, 1992) or time perception (Doob, 1971; Fraisse, 1963; Ornstein, 1969). Some studies have reported significant sex differences (Axel, 1924; Bell, 1972; Carlson and Feinberg, 1970; Delay and Richardson, 1981; Goldstone, 1968; Greenburg and Kurz, 1968; Gulliksen, 1927; Hancock et al., 1992; Hornstein and Rotter, 1969; MacDougall, 1904; Martin et al., 1981; Rammsayer and Lustnauer, 1989; Yerkes and Urban, 1906). Others have reported no influence of sex on time estimation (Baldwin et al., 1966; Geer et al., 1964; Getsinger, 1974; Gilliland and Humphreys, 1943; Roeckelein, 1972; Smythe and Goldstone, 1957; Swift and McGeoch, 1925). For those studies reporting differences, the collective finding is that females overestimate time intervals relative to males when using the method of verbal estimation.

There are a number of potential reasons for this contradictory pattern of results. Previous work has demonstrated a number of interactive influences which apparently magnify or diminish a potential sex effect. Such sources of interaction include time-of-day of testing (Hancock et al., 1992; Kirkcaldy, 1984), ego strength (Getsinger, 1974) and sensory modality (Roeckelein, 1972). However, considerable resolution of the confusion over sex differences in time perception can be derived from an understanding of the different methodological approaches used to assess time perception (see Hornstein and Rotter, 1969). There have been two major time estimation methods used in the present research realm. One of these, as noted before, is verbal estimation, the other is interval production. A full account of these methods has been given by a number of authorities (see for example Bindra and Waksberg, 1956). The point is simple. It has been established that verbal estimation and interval production are inversely related. That is, underestimates of an interval through verbal report represent overestimates of that same duration by (interval) production. The source of confusion is now manifest. Some studies report a sex difference in time estimation where females *overestimate* intervals compared to males using verbal estimates. Other studies report similarly significant

[1] The terms sex and gender are here used interchangeably. However, in recent work, there is a tendency to use sex as the physiological differentiate while gender refers more to a social role. As then becomes evident, those expecting that time perception differences are primarily due to social factors would refer to gender differences and expect that as such differences may be distributed along a continuum, so time perception differences would follow in terms of degree of difference. Reference to sex implies an expectation of an innate difference and one dominated by physiological characteristics. As sex is dominantly a bifurcated state, so sex differences in time estimation might be expected to reflect these two discrete categorizations. We have used the term sex differences in this work. This nomenclature follows on our findings here and the collected findings in the literature (see Hancock and Vercruyssen, 1994). The contribution of innate versus learned capabilities in this important behavioral attribute have yet to be fully understood. The present work is directed toward this goal.

findings but show that females *underestimate* intervals compared with males using production. Commentators unaware of the importance of methodological differences present these studies as evidence of contradiction. However, when the relationship between measures is accounted for, such apparent disparity is dispelled and a much clearer, less confusing, picture of collective findings emerges.

However, there are a number of further factors which affect sex differences in time perception. One of particular concern is the range of intervals over which assessment is made. In early work, Elkine (1928) showed that for children, the presence or absence of a sex effect depended upon the length of estimate. More recently, Hornstein and Rotter (1969) and Adkins (1972) have shown that estimation accuracy varies across estimation lengths depending on the sex of the participant. Each of the above effects is potentially contingent on whether subjects are tested in darkened or lighted conditions (see DeLong, 1981). While Geer et al. (1964) found no influence for light condition, Delay and Richardson (1981) subsequently reported that light level differentially modified the estimates of duration by males and females. Such contradictions serve to promote uncertainty over the presence of a sex difference in time estimation. The present work, therefore, is directed to a clarification of the respective influences of illumination and differential target time on duration estimations of men and women. In so doing, the current investigation addresses the central and unresolved question of the existence of an overall sex difference in time perception.

2. Method

2.1. Experimental participants

Twelve subjects, six males and six females, volunteered to participate in the time estimation experiment. The subjects were drawn from the faculty, staff, and student body of the University of Minnesota. The men ranged in age from 20 to 37 and the women from 20 to 34. All were in good health at the time of testing. All subjects were tested in the early afternoon at approximately the same time of day (but see Hancock et al., 1992).

2.2. Experimental task

The task in the present experiment was time estimation using the method of filled production (Bindra and Waksberg, 1956; Clausen, 1950). Subjects estimated four different times namely; 1, 3, 7, and 20 seconds. We chose these values because when expressed in natural logarithmic units the sequence is represented as 0, 1, 2, and 3 respectively. The values were also chosen as they bracket the intervals selected as 'short' durations by Allan (1979) and differences between memory and non-memory laden intervals by Poppel (1988). Each subject was asked to estimate each period 60 times, half with the lights on and half with the lights off. The order of administration of light and dark conditions was randomized across subjects, as was the order in which the four intervals were estimated. In all, each subject made a total of 240 time estimations. The times that subjects estimated were recorded on a millisecond timer and entered directly into a Macintosh IIci computer. There was a single light in the light proof room which was used for the lights on condition. This was a 15 watt fluorescent bulb which gave an ambient light condition of 50 foot lamberts. In order to prevent extraneous auditory cues from affecting estimated durations, subjects wore earphones in all conditions, which attenuated noise by 15 dB. In addition, the subject was seated alone in an isolated room so that no auditory cues as to time were available.

2.3. Experimental procedure

Subjects were seated before a response board consisting of a response button which allowed them to make time estimations. The experimenter instructed the subjects to make different time estimations by depressing the button until they believed the time period was ended and then releasing the button to end their estimate. The subjects paused briefly between each trial during which the experimenter entered the data into the host computer. Subjects were not given explicit instructions concerning an estimation strategy, although in post hoc interviews each subject indicated that they used a counting strategy (see Doob, 1971 for discussion of counting strategy use). After 30 trials on any one interval, the subject was told the new target interval and asked to begin estimation. Subjects were given a ten-minute break half way through the experimental sequence. On average, each subject took approximately 55 minutes to finish the whole experiment. This varied depending on the actual estimations of each individual.

2.4. Experimental design

A $2 \times 2 \times 4$ mixed design was used with sex (SEX) as the between-subject factor, while light condition (LIGHT) and target time duration (TIME) were both within-subject factors. Each subject performed 30 trials within each of the eight light-by-time conditions. As initial analyses indicated that trial had no singular or interactive influence on response, the mean response over thirty trials was calculated for each subject in each of the light by time combinations and these eight summary scores were used for analysis. Therefore, analysis was performed on the mean of the raw estimates themselves, these same mean time estimates converted to a ratio of the imposed target interval, and the standard deviation of the ratio responses.

3. Results

A summary of the raw score data is presented in Table 1. Tables 2 and 3 present the analysis of variance results for the mean of raw estimates and such estimates transformed as a ratio of the imposed target interval. Of central

Table 1
Summary of raw score data. Means for each condition are shown with respective standard deviation values given in parentheses

	Men		Women	
	Dark	Light	Dark	Light
1 second	1.40 (0.327)	1.23 (0.208)	1.18 (0.375)	1.15 (0.265)
3 seconds	4.15 (0.955)	3.32 (0.461)	2.97 (0.581)	2.65 (0.650)
7 seconds	8.37 (1.779)	8.67 (0.755)	6.35 (1.664)	6.06 (1.427)
20 seconds	24.57 (3.424)	22.64 (2.347)	19.44 (4.173)	18.62 (5.177)

importance to the present work is the significant difference between the estimates of men and women, where the men responded with significantly longer overall mean productions (Ratio Mean = 1.239, Raw Score Mean = 9.294 s) than their female counterparts (Ratio Mean = 0.985, Raw Score Mean = 7.301 s). Such a difference remains significant when considering either raw or ratio mean estimates. This difference is more dramatically illustrated by the fact that the overall mean of only two of the male subjects fell within the range of mean estimates produced by the female participants. The overall pattern of findings is illustrated in Fig. 1 as mean ratio scores where a score of 1 is equivalent to achieving the target estimation. There was a significant sex by target interval interaction for raw scores only, whereby men provided longer estimates than women and the sex difference increased with longer target intervals. The sex by time interaction failed to reach significance when examining ratio scores and the standard deviations of ratio scores.

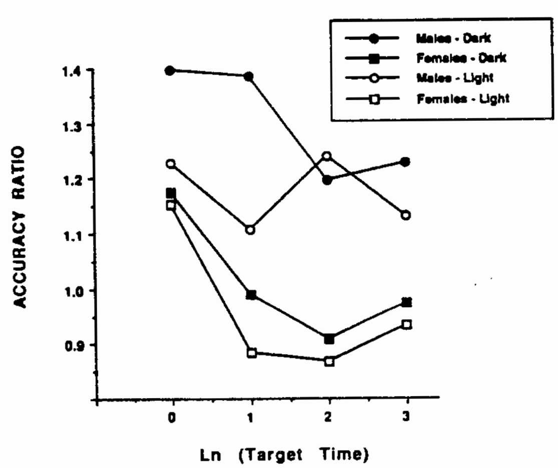

Fig. 1. Produced estimates described as a ratio of the actual target interval against the target interval itself described in log units. The illustration shows the differential effect for subject sex and for the two levels of illumination, lights on versus lights off. Note the consistency in the female data is not repeated in the male data, although overall trends are similar.

Table 2
Repeated measures analysis of variance results for time estimates (TE)

Source	*df*	*MS*	*F*	*p*
Sex	1	95.248	6.950	0.025
Error	10	13.705		
Light	1	6.237	1.938	0.194
Light × Sex	1	0.520	0.162	0.696
Error	10	3.217		
Time	3	1963.366	367.382	0.000
Time × Sex	3	22.654	4.239	0.013
Error	30	5.344		
Light × Time	3	2.372	2.251	0.103
Light × Time × Sex	3	0.760	0.721	0.547
Error	30	1.054		

The main effect for target interval was significant for the raw estimates, ($F(3,30) = 224.537$, $p < 0.001$, see Table 2), and also for ratio scores ($F(3,30) = 4.421$, $p = 0.011$, see Table 3). Illumination had no significant main effect on either raw estimates or those estimates expressed as ratio scores. The light-by-target interval interaction was significant for ratio scores only ($F(3,30) = 2.993$, $p = 0.046$) and appears to arise from two atypical points, being the three-second estimate with the lights on compared with the seven-second estimate with the lights off. Of doubtful theoretical significance, the present interaction did not accrue from any systematic variation across light or time.

A second facet of the present findings is represented in the variability of estimates expressed as ratio scores. This analysis is presented in Table 4. As can be seen, only two effects achieved a significant level, being the main effect for target

Table 3
Repeated measures analysis of variance results for time estimates (TE) expressed as a ratio of requested target interval (TI), (TE/TI)

Source	*df*	*MS*	*F*	*p*
Sex	1	1.553	7.195	0.023
Error	10	0.216		
Light	1	0.190	2.565	0.140
Light × Sex	1	0.032	0.433	0.525
Error	10	0.074		
Time	3	0.178	4.421	0.011
Time × Sex	3	0.041	1.016	0.399
Error	30	0.040		
Light × Time	3	0.038	2.993	0.046
Light × Time × Sex	3	0.021	1.613	0.207
Error	30	0.013		

Table 4
Repeated measures analysis of variance results for the standard deviation of time estimates (TE) expressed as a ratio of requested target interval (TI), (*sd*, TE/TI)

Source	*df*	*MS*	*F*	*p*
Sex	1	0.012	1.604	0.234
Error	10	0.008		
Light	1	0.008	4.108	0.070
Light × Sex	1	0.010	5.121	0.047
Error	10	0.002		
Time	3	0.073	18.914	0.000
Time × Sex	3	0.001	0.140	0.936
Error	30	0.004		
Light × Time	3	0.003	2.536	0.076
Light × Time × Sex	3	0.000	0.069	0.976
Error	30	0.001		

interval, and the interaction between participant sex and lighting condition. For target interval, it is clear that the standard deviation of the ratio scores decreases as a function of increasing interval length (i.e., 1 second = 0.203, 3 seconds = 0.11, 7 seconds = 0.087, 20 seconds = 0.087), meaning that individuals get relatively less variable as target time increases. The case of the interaction between subject sex and light condition is more interesting. This pattern, illustrated in Fig. 2, indicates that male subjects remain unaffected by light condition in terms of variability of their response. However, female participants produced significantly less variable responses in light compared with dark conditions. This pattern was not due to one atypical response but was true of five of six female subjects, while the remaining female subject did not change her level of variability with light condition.

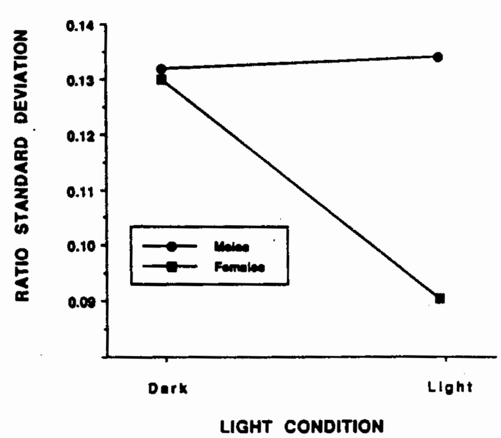

Fig. 2. The variability of women's estimates changes with light condition, while the variability of men's estimates remains constant. Note that women reduce variability in lighted conditions.

4. Discussion

The present findings confirm a significant difference in the mean production responses of men and women in a time estimation task. In terms of previous investigations, the sex difference in mean estimation accord with the majority of empirical studies (see Hancock and Vercruyssen, 1994). It is important to note that a sex difference did not appear in the analysis of standard deviations. So, while men and women differ in their mean estimates of time, they do not differ in the variability of these estimates. Initially, it might appear from perusal of Table 2, that the presence of a sex effect is modified by the length of estimate selected. With respect to the reporting of raw scores, this statement is true. That is, the difference between the estimates of men and women grows proportionally with the lengthening of target duration. However, it is this proportionality that is critical here. When such scores are transformed to ratio scores of the target interval, this effect falls away, (cf. Table 3). Such an observation is instructive in that it implies that the identification of this modifying effect is directly influenced by the way in which the dependent variable is expressed. Thus identification of sex differences and their modification by interactive influences depends directly upon the selection of initial conditions to be tested and the manner in which dependent variables are treated. While this observation appears to be a recommendation for experimental thoroughness and a case of facilitating the sensitivity of performance measures (Poulton, 1965) this objection is more than methodology alone, as the initial selection of conditions and analytical model are directly dependent upon the theoretical nature of the question under investigation. Indeed, it is still reasonable to assert that much of the previous confusion over sex differences in time perception are a direct result of such investigative failings.

The present findings are clear with respect to the influence of lighting condition on mean estimates. As is obvious from both Tables 2 and 3, there is no influence for light condition on either raw estimates or estimates transformed to ratio values. In an interesting paper on the influence of spatial scale on temporal perception, DeLong (1981) speculated that light and dark conditions would influence duration estimates as they would have a direct effect on perceived scale. The present findings contradict such an assertion since light condition per se, had no main effect on either mean estimates or variability of those estimates (see also Meredith and Wilsoncroft, 1989). As such, this finding confirms the observations of Geer et al. (1964) and apparently opposes the pattern found by Delay and Richardson (1981). However, this is an oversimplification. First, the pattern found by Delay and Richardson (1981) was that females reduced their estimates slightly between the dark condition and the low illumination condition, where the latter light level was similar to that used in the present experiment. Males showed a comparable reduction in estimates between these two conditions. Males subsequently went on to increase their estimates in the high illumination, while females continued to reduce their estimates as illumination level rose. Thus it appears that the interaction reported by Delay and Richardson (1981) occurs between levels of ambient illumination and not between darkened and lighted conditions. We can therefore find some support for the present findings in the apparently contradictory assertions of Delay and Richardson (1981). We can also find some evidence of a positive effect for illumination in the work of Geer et al. (1964). Although these latter authors found no significant interaction between sex and light condition, they did report a significant three-way interaction between sex, illumination, and trial. Although they declined to interpret this multi-way effect, it is the case that their data do contain support for a significant effect in the higher order interaction.

In the present experiment, we did find a differential influence of light condition in the variability of scores for men and women. As is represented in Table 4 and illustrated in Fig. 2, women reduced their variability in lighted conditions, while men did not change variability as a function of lighting. Therefore, with respect to sex effects and the influence of illumination, it does appear that lighting conditions can act to modify the presence and degree of a sex effect in this facet of time estimation. How much this latter effect has been responsible for previous contradictory results in the overall literature on sex differences is difficult to assess, as such basic change in experimental conditions are rarely described. Although the effect is far from clear as yet, it is prudent to observe that future studies in this area should account for lighting condition as one potential source of influence. We do not focus here on the light by target interval interaction. Suffice it to say that the pattern responsible appears to be a reversal in estimate lengths at the seven-second intervals. As can be seen in Fig. 1, this effect is primarily due to the male subjects' estimates at that interval.

While it might be thought such findings are of somewhat esoteric concern, it is the case that temporal perception can have a fundamental influence on behavior. Time perception has been shown to be diagnostic of a number of clinical pathologies and has also been related to learning deficits in children (Doob, 1971). In a particularly graphic example of the practical influence of temporal distortion, Loftus and her associates have demonstrated sex differences in recall of duration by eye witnesses viewing recordings of criminal events such as bank robbery (Loftus et al., 1987). Hancock (1986) has indicated that temporal distortion is a direct influence on the decision to eject from disabled jet aircraft. Further, Caird and Hancock (1992) have demonstrated sex differences in the perception of time to collision of on-coming vehicles in driving simulation. A robust sex difference in these respective situations has numerous practical ramifications for human performance assessment.

It remains to make explicit what the present results say concerning the current contradictions about sex differences in time estimation. The most important thing to note is that we here confirm the presence of a sex effect in time estimation, but one that is influenced by a number of methodological factors. The simple statement of support for this effect is one which adds weight to the consensus of findings of a significant difference in this important behavioral attribute. It has not escaped our attention that such differences in temporal perception and the more established differences in spatial perception may reflect two facets of a single capability, namely, spatio-temporal orientation (cf., Hancock and Newell, 1985).

With respect to the influence of the length of estimate chosen, our findings suggest that interactions derived are those that accrue from analysis of raw scores. Further the interaction we have observed here is due to the influence of estimates around the one-second interval. We suggest that such an effect is related to an intrinsic limitation in producing quite low temporal durations, where reaction time capabilities assume a relatively increased importance. With respect to conditions of illumination, our results indicate that the variability of male estimates are unaffected by lighting condition. However, the variability of estimates by female participants are substantively affected by light condition. As such, light conditions are important in this realm and therefore, we favor support for the contention of Delay and Richardson (1981) over Geer et al. (1964), while noting the multiple interaction reported by the latter authors. In sum, we have illustrated that understanding problems of methodology and analysis suggest why a number of null findings have been reported in this area. Researchers, therefore, must make informed decisions concerning their initial experimental design and their treatment and analysis of time estimation data because these decisions will influence whether sex differences are or are not observed.

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