SELF-TIMING IN MEMORY AND VISUAL SEARCH TASKS

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Abstract

We investigated the ability of people to time themselves as they perform cognitive tasks. One group did a memory search task, another did a visual search task. After each response, participants estimated the duration of their own reaction time. In both tasks, correlations between reaction times and temporal judgments were significant, showing that people can provide precise quantitative estimates of mental processes when they perform memory and visual search tasks. Increasing load lengthened reaction times and temporal estimates in both tasks. Accuracy of temporal judgments increased across blocks of experimental trials, showing considerable improvement in self-timing with practice although in visual search, improvement was more pronounced under low load conditions. Results demonstrate excellent ability for self-timing of memory and visual search, but suggest that in visual search, self-timing is influenced by stimulus conditions.

Corallo, Sackur, Dehaene & Sigman (2008) showed that reaction times in number comparison and in tone discrimination are accessible to deliberate report: people were quite accurate at providing introspective temporal estimates in those tasks, with significant correlations between reaction times and temporal estimates of those reactions times. The present study examines whether processing time of item sets in memory search and visual search tasks is accessible also to introspective duration estimation. The interference effect, one of the most common findings in human timing research (Brown, 1997), suggests that temporal processing should be perturbed when tasks requiring attention or working memory executive resources are carried out concurrently with timing. This leads to general temporal underestimation. However, a previous study showed that although time interval production revealed general temporal underestimation concurrent to both memory search and visual search, higher load increased underestimation in memory search, but not in visual search (Fortin, Rousseau, Bourque, & Kirouac, 1993). In another study, longer visual processing in color comparison led to greater underestimation (Gaudreault, Fortin & Macar, 2010). A recent study showed that visual discrimination led to temporal underestimation in concurrent timing, but only when the markers of the interval to be timed were spatially distant (Cicchini & Morrone, 2009). Overall, nontemporal processing requiring attention affects performance in concurrent timing tasks, but the effect seems to vary in the case of visual processing.

In the present study, people estimated their reaction times (RTs) in memory (Exp. 1) and visual (Exp. 2) search. General underestimation was expected, but effects of search load might affect differently temporal estimates (TEs) in the two tasks. To see whether temporal accuracy improved with practice, TEs were examined across blocks of trials in both experiments.

Experiment 1: Self-Timing in Memory Search

Method

Twenty young adults (11 men, 9 women, mean age = 21.6 years, *SD* = 3.6) recruited through advertisement at Université Laval received a small honorarium ($5.00 Can) to participate in one experimental session. They were tested individually in a quiet room, the task and data collection being controlled by a computer running E-Prime 1.2. As in the classical Sternberg paradigm, the instructions were to memorize letters presented successively (1 s/letter with no delay between letters) on the monitor screen at the beginning of each trial. The word "Ready" then appeared and remained present until the participant pressed a key to make a probe appear. The task was then to indicate as quickly as possible, by clicking the left or right key of the mouse, whether the probe was present or absent in the memory set. The number of items in the memory set could be four or six letters selected randomly from a list of 20 consonants, "y" being excluded. Set size and target presence/absence varied from trial to trial. The number of trials in each combination of factor levels was balanced. After each RT response, the participant provided an estimate of the RT by clicking on a line continuously scaled between 0 and 1,500 ms presented on the screen. The line was labeled every 500 ms. Immediately after the click on the line, a row of asterisks appeared, indicating the beginning of a new trial. When the participant pressed a key, a new memory set was presented. No feedback was provided on memory or self-timing performance. There were 20 trials in a demonstration block of trials, which was followed by six 40-trial blocks.

Results and Discussion

Trials in which RTs were longer than 1500 ms were removed (3.7% of the data). Trials with errors in memory search were then eliminated (8.9% of remaining trials). The data used for the analyses are mean RTs and mean temporal estimates (TEs), computed for each participant, at each combination of factor levels. An analysis of accuracy in self-timing performance across blocks of trials was also carried out, using percent relative error. This index of performance was computed in each trial as (TE-RT)/RT x 100. A negative value means that TE is shorter than the actual RT, an underestimation of RT, whereas as a positive value indicates an overestimation; zero represents an exact temporal estimate of RT. Means of percent relative error were computed for each participant, at each combination of set size, target presence/absence condition, and experimental block of trials. A repeated measures ANOVA was then performed on these means, with a Greenhouse-Geisser correction applied to degrees of freedom when appropriate.

Figure 1 presents RTs (left) and TEs (right) as a function of set size, when the target was present and absent in the memory set. RTs and TEs were clearly related, the correlation between the two measures being significant, $r = .39$, p < .001. The effect of set size on RTs was significant, $F(1,19) = 84.53$, MSE = 1131.8, $p < .001$, $\eta^2_p = .82$, but there was no effect of target presence/absence, $F(1,19) = 1.542$, MSE = 4201, $p = .229$, $\eta^2_p = .08$ and the interaction between the two factors was not significant. An ANOVA on TEs showed an effect of set size, $F(1,19) = 12.11$, MSE = 2008.3, $p = .003$, $\eta^2_p = .39$, but no effect of target presence/absence. The interaction was significant, $F(1,19) = 5.86$, MSE = 545.3, $p = .026$, $\eta^2_p = .24$: the effect of set size was weaker in the target present than in the target absent condition, but it was significant in both conditions, $p=.03$, $p=.002$, respectively.
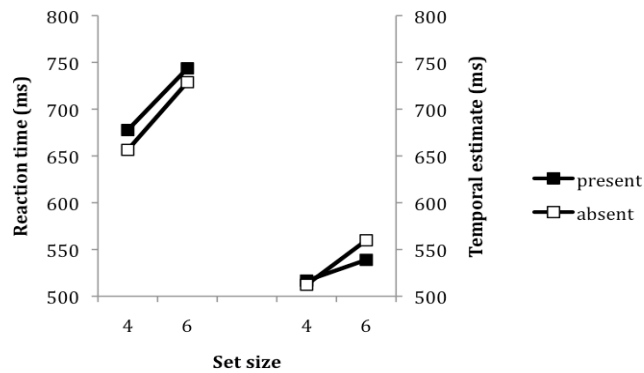
Figure 1. Reactions times (left) and temporal estimates (right) as a function of set size in the memory search task, in the target present and target absent conditions. Pooled SEM = 23.98 (RTs) and 56.10 (TEs).
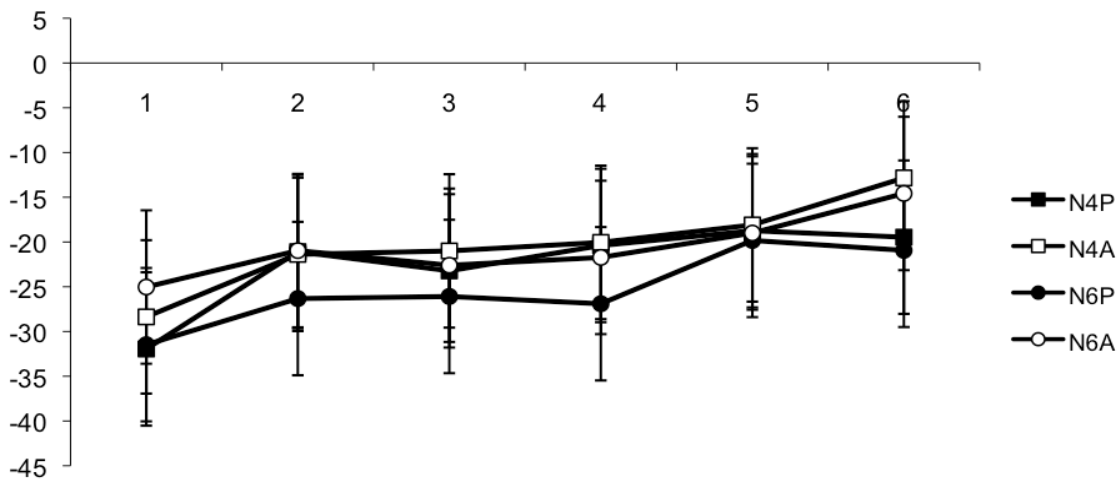

Figure 2. Mean percent relative error across experimental blocks of trials, at each set size, in present/absent target conditions in memory search. N = Set size, P / A = Present / Absent target. Error bars: pooled SEM.

Figure 2 shows mean percent relative error across blocks of trials, in each condition of set size and target presence. RTs were generally underestimated, as was found in a previous study where people estimated their response times in cognitive tasks (Corallo et al., 2008). There was some improvement in performance across experimental blocks of trials however, $F(5,95) = 3.61$, MSE = 392.5, $p = .026$, $\eta^2_p = .16$, percent relative errors getting closer to 0 across blocks of trials. There was no effect of set size, $F(1,19) = 1.85$, MSE = 160.7, $p = .190$, $\eta^2_p = .09$ nor of target presence/absence, $F(1,19) = 2.66$, MSE = 521.8, $p = .120$, $\eta^2_p = .12$ on relative errors. All interactions were nonsignificant. RTs in the memory task were considerably underestimated: a t test showed that overall, percent relative errors were significantly lower than 0, $t(19) = -2.59$, $p < .05$.

Results in Experiment 1 show that the correlation between RTs and TEs was significant. TEs as well as RTs increased with set size in memory search, but RTs were significantly underestimated. There was some improvement in estimation accuracy with practice however, TEs getting closer to actual RTs in successive blocks of trials.

Experiment 2: Self-Timing in Visual Search

Method

Twenty young adults (15 women, 5 men, mean age = 22.3 years, SD = 4.6) were tested in this experiment. The general procedure was similar to that in Experiment 1, except for the task, which was a visual task similar to one designed in a previous study on visual attention (Treisman & Souther, 1984, Exp. 1). The objective was to detect a target (circle) among distractors (circles with vertical intersecting lines) in a visual display, which contained 6 or 12 stimuli. The method was identical to that in Experiment 1 in all other respects.

Results and discussion

Trials with RTs longer than 1500 ms (4.0%), and then trials with errors in visual search were eliminated (5.2% of remaining trials). Figure 3 shows RTs and TEs in the visual task. RTs and TEs correlated significantly, r = .47, p < .001. Effects of set size and of target presence on RTs were significant, $F(1,19)$ = 84.91, MSE = 3294.9, p < .001, η^2_p=.82 and $F(1,19)$ = 53.65, MSE = 9756.7, p < .001, η^2_p=.74, respectively; the interaction was also significant, $F(1,19)$ = 7.32, MSE = 2110.3, p = .014, η^2_p=.28 . An ANOVA on TEs revealed significant effects of set size, $F(1,19)$ = 57.18, MSE = 1570.2, p < .001, η^2_p=.75, of target presence, $F(1,19)$ = 51.64, MSE = 5469.6, p < .001, η^2_p=.73, and of the interaction, $F(1,19)$ = 9.67, MSE = 760.8, p = .006, η^2_p =.34.
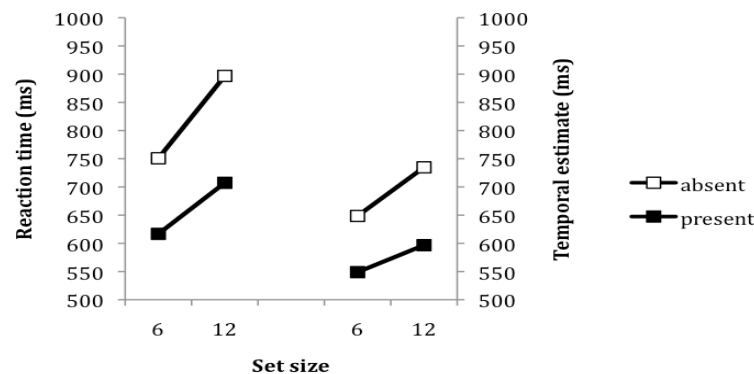

Figure 3. Reactions times (left) and temporal estimates (right) as a function of set size in the visual search task, in the target present and target absent conditions. Pooled SEM = 26.24 (RTs) and 38.28 (TEs).

Figure 4 shows that as in Experiment 1, RTs were generally underestimated and that accuracy of TEs improved across blocks of trials. There was a significant block effect, $F(5,95)$ = 3.21, MSE = 638.3, p = .05, η^2_p=.145, which interacted with set size, $F(5,95)$ = 3.18, MSE = 55.7, p = .011, η^2_p=.14. Underestimation was greater when visual load (i.e., set size value) was

higher, $F(1,19) = 13.72$, MSE = 205.1, $p = .002$, $\eta^2_p=.42$, but there was no effect of target presence. Tests of simple main effects showed that the effect of block was significant in the low load condition, $F(5,95) = 4.09$, MSE = 202.4, $p =.022$, $\eta^2_p = .18$, but that it did not reach statistical significance in the high load condition $F(5,95) = 1.83$, MSE = 145.2, $p = .167$, $\eta^2_p = .09$. These results show that in visual search, accuracy in temporal performance improved with practice, but improvement was more limited under high load conditions. All other interactions were nonsignificant. Note that despite general underestimation of RTs in the visual task, a t test showed that in contrast with what was found with the memory task, mean percent relative errors did not differ significantly from 0, $t(19)= -1.86$, $p > .05$ in the visual task. Temporal underestimation was thus less pronounced in visual search than in memory search.
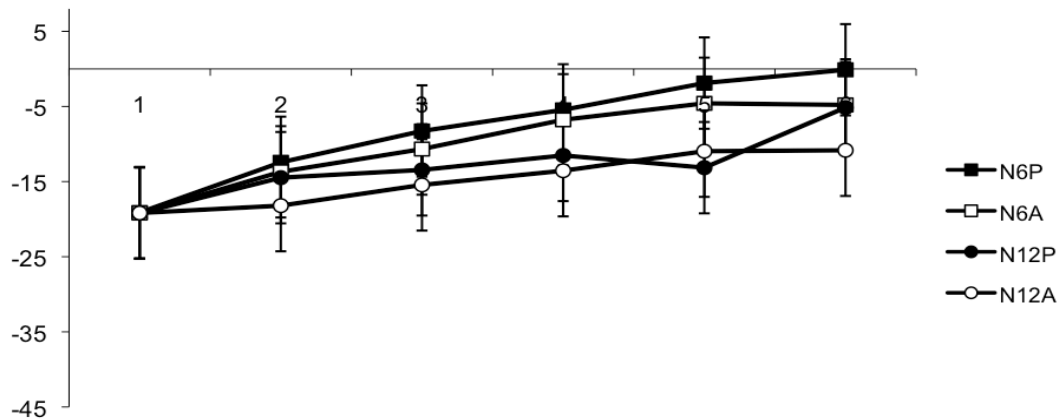

Figure 4. Mean percent relative error across experimental blocks of trials, at each set size, in present/absent target conditions in visual search. N = Set size, P / A = Present / Absent target.

General discussion

The present study shows that as with number comparison and tone discrimination (Corallo et al., 2008), people are competent at self-timing in memory and visual search tasks, correlations between RTs and temporal estimates being significant. RTs were generally underestimated, which was also observed with number comparison and tone discrimination (Corallo et al., 2008). This result may be explained by interruptions in timing while the memory and visual tasks are carried out. According to attentional models of time estimation (e.g., Zakay & Block, 1996), timing requires attention so that performing simultaneously attention-demanding tasks interrupts timing momentarily, leading to general underestimation of the completed task.

General underestimation was greater in the memory than in the visual task, temporal estimates being significantly lower than the perfect estimate in the memory task, but not in the visual task. This is in agreement with previous results showing greater interference from memory search than from visual search on concurrent time interval production (Fortin et al., 1993).

Temporal estimates lengthened with increasing load in both search tasks, showing that timing can take place concurrently with search related processes. The lengthening of temporal estimates was weaker than the corresponding increases in RTs however, suggesting that interruptions in timing during the search occurred with both tasks. This does not support previous findings, which suggested that timing could be performed in parallel with processing items in

visual search (Fortin et al., 1993); this would have led to parallel functions of RTs and of temporal estimates in Exp. 2. Differences in procedures could explain this difference in results (e.g., in the present study: shorter durations to be timed, complete integration of search and timing tasks, no independent practice in timing task, fewer experimental trials). In particular, given that underestimation was greatly reduced with practice with visual search, it could be expected that a larger number of experimental trials might lead to time estimates very close to RTs in visual search.

After a few blocks of practice, temporal estimates were very close to actual RTs in visual search, but the improvement in performance was weaker under higher load conditions. Although performance usually improves with practice in concurrent processing situations (T. L. Brown & Carr, 1989), practice failed to reduce interference when timing was performed concurrently with tracking a moving target light (Brown, 1998). It is therefore possible that in visual tasks, improving concurrent timing performance is more difficult when the load is higher.

To conclude, people demonstrate impressive ability to time their own cognitive processes. However, together with results from previous studies (e.g., Cicchini & Morrone, 2009), results from the present study suggest that timing during visual processing could be sensitive to specific stimulus conditions.

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