DOES REQUIRING PARTICIPANTS TO PRODUCE THE FOREPERIOD DURATION ELIMINATE THE EFFECT OF FOREPERIOD LENGTH ON A SUBSEQUENT RT TASK?

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Abstract

It is commonly found that shorter foreperiod durations yield faster RTs than longer foreperiod durations. This finding has been attributed to decreased time uncertainty for shorter foreperiods. In the present study, time uncertainty effects were eliminated by having the participants produce the foreperiod durations. Twenty psychology students participated in an experiment involving an even-odd digit RT task. Two foreperiod durations of either 2- or 8-sec in length were used, which the participants were asked to estimate themselves. Immediately following the production of these durations, the digit task was presented. The results of this experiment showed that RT to the digit task was still significantly faster in the 2-sec temporal production blocks than in the 8-sec temporal production blocks. As this RT difference between the 2- and 8-sec 'foreperiod' durations cannot be attributed to time uncertainty, these results call into question the validity of time uncertainty as an explanation for the presence of fixed foreperiod effects more generally.

The nature of the factors that affect people's ability to prepare themselves for action has always been a subject of great interest. One extremely robust effect is that increasing the length of time between the occurrence of a neutral warning signal and the occurrence of a reaction stimulus, known as the foreperiod duration, tends to slow down the time taken to respond to the reaction stimulus, but only when such durations are held constant within blocks of trials (Neimi & Naatanen, 1981). The most commonly accepted explanation for this effect is that longer foreperiod durations are associated with more time uncertainty regarding when the reaction stimulus is likely to appear. If this view is valid, then eliminating time uncertainty should eliminate the effect of foreperiod length on the time taken to respond to the subsequent reaction stimulus. This notion is tested here.

One key factor affecting a participant's response time (RT) is the degree to which they are mentally prepared at the exact moment the reaction stimulus is presented. Shorter RTs are associated with a higher degree of mental preparedness while longer RTs are associated with a lower degree of mental preparedness. In any RT experiment, there are five main elements involved (Niemi & Naatanen, 1981), specifically, the warning signal, foreperiod, reaction stimulus, response, and the inter-trial interval.

The warning signal is a stimulus preceding the reaction stimulus that signifies to the participant that the reaction stimulus is likely to occur within an allocated amount of time. This signal is typically a visual or an auditory stimulus that can vary according to certain characteristics (e.g., brightness or loudness). The foreperiod represents the time interval between the warning signal and the reaction stimulus. It is a common variable to study as this is the phase where preparatory processes take place in anticipation to react. When studying foreperiod effects, a major assumption is that if the participants can estimate the length of the foreperiod, then they can also strategically optimize their readiness to respond at the exact moment the reaction stimulus occurs. As such, better accuracy in estimating the length of the duration of the foreperiod by the participants should result in shorter RT (Niemi & Naatanen, 1981).

When studying RT and foreperiod effects, it is important to note that RT results depend first and foremost on the manner in which the foreperiod length is manipulated. That is, the foreperiod length can either be held constant in a block of trials, known as fixed foreperiods, or it can vary within a block of trials, known as variable foreperiods. It has been found that when pure blocks of fixed foreperiods are used, RT increases as the length of the foreperiod duration increases (Niemi & Naatanen, 1981). This finding has been widely accepted when dealing with fixed foreperiods (Leth-Steensen, 2009).

It is often assumed that the primary reason why shorter fixed foreperiods yield faster RTs than longer fixed foreperiods is because shorter foreperiods allow for a more accurate prediction of the timing of the impending reaction stimulus (Correa et al., 2006). In other words, under fixed foreperiod conditions when the foreperiod duration is known, longer foreperiods are associated with increased time uncertainty regarding the moment of occurrence of the reaction stimulus, which then limits the participant’s level of preparedness at the exact moment the reaction stimulus is presented. This assumption is consistent with the scalar timing view of the temporal estimation process (Gibbon, Church, & Meck, 1994) and the notion that as the length of time being estimated increases, estimates of it will tend to be more variable (Klemmer, 1957).

One finding that has been found to be inconsistent with the strategic time estimation view of the fixed foreperiod effect has been RT distributional results obtained by Leth-Steensen (2009) using a digit magnitude classification task. The main finding reported in that study was that lengthening the foreperiod duration from 2- to 8-sec between blocks of trials resulted in a shift of the front ends of the RT distributions upwards. As argued by Leth-Steensen (2009) such a finding is inconsistent with the strategic time estimation account of fixed foreperiod duration effects which would predict an increase in RT variability in both the tails and the front end of the RT distribution but not a consistent RT shift.

The Current Study

In the current study, two foreperiod durations of either 2- or 8-sec in length were used across blocks of trials. However, time uncertainty for the end of the foreperiod duration length was eliminated by having the participants estimate the length of the foreperiod duration themselves. That is, at the start of each trial, the participants had to first produce a time interval either 2- or 8-sec in length. As soon as they indicated that the duration has finished, a digit stimulus appeared to which a speeded response was made. Because the digit was timed to appear exactly at the moment that the participants believed the (2- or 8-sec) duration to be up, they could never be uncertain about the moment of its occurrence. Hence, they should have been equally prepared to respond to it regardless of the length of time that had just been estimated.

Method

Participants. Twenty students from Carleton University participated for course credit. Eight participants were male and 12 female with a mean age of 25.45 years (*SD* = 10.92). Each participant performed the task individually for a 90 min. session.

Materials and Apparatus. The tasks were programmed and ran on a 486 PC using Micro Experimental Laboratory (MEL: Micro Experimental Lab System 2.0 Psychology Software Tools, Pittsburgh, PA) which regulated event sequencing, generated the stimuli, and collected the responses. Vocal responses into a microphone that was connected to a PST serial MEL response box were used to end the production of the time intervals. The stimuli for the RT task were the digits 1, 2, 3, 4, 6, 7, 8 and 9 which were presented in the centre of the computer screen in white against a black background (4 mm in width and 6 mm in height). Responses to this task were made manually by pressing one of the first two keys on the MEL response box keys using the index and middle fingers of the right hand. Participants sat about 40 cm from the screen with the vocal microphone in front of them (but not obstructing their view of the screen in any way).

Procedure. Participants first performed two blocks of 80 time production trials. The time intervals to be produced in each of these blocks were 2- or 8-sec in length (with the order counterbalanced across participants). Each trial began with a "Ready?" prompt on the screen. When participants were ready to begin producing the time interval, they were instructed to press the space bar (with their left index finger). When they felt that the length of the duration had passed, they were to say the word "Time" into the microphone. Feedback was provided if the produced duration had either underestimated or overestimated the actual duration by a certain amount. This feedback involved presenting either the phrase "Incorrect – your estimation was too short!" or "Incorrect – your estimation was too long!" for 1 sec. For the 2-sec intervals, any productions within ± 300 ms were regarded as correct and no feedback was provided (i.e., the "Ready?" signal for the next trial appeared right away). Similarly, for the 8-sec intervals, any productions within ± 800 ms were regarded as correct. These two windows were chosen because productions of the longer 8-sec interval were naturally assumed to be more variable (i.e., less sensitive) and also because a bit of pilot work indicated that these two windows provided approximately equal production "accuracy" (about 70-75%).

In the remaining four blocks, the RT task was also performed. Participants were instructed that as soon as they had finished producing each time interval (i.e., right after saying "Time"), a digit would immediately appear on the screen. They were then to classify this digit as being either even or odd by pressing the left or right response keys, respectively. Participants were asked to respond to the digits as quickly as they could without unduly sacrificing accuracy, and it was also requested of them that they keep their fingers rested on these two response keys at all times. After the digit response, feedback regarding any under- or overestimation of the time interval (only) was provided (in exactly the same manner as described above). For participants who had started the experiment by producing 2-sec time intervals, the time intervals produced in these last four blocks were 2, 8, 8, and 2 sec, respectively, For participants who had started the experiment by producing 8-sec time intervals, the time intervals produced in these last four blocks were 8, 2, 2, and 8 sec, respectively. Each of these four blocks contained 64 trials (8 per digit) although the first two were each preceded by 16 practice trials.

Results

In this experiment, only the data from the last four blocks, excluding the practice trials, were used in the following analyses. The raw data of interest were the sets of 2- and 8-sec production times and the corresponding RTs to respond to the digit stimuli in each of the 2- and 8-sec temporal production blocks.

Production Times. Before any analyses were performed on the production time data, they were adjusted for any outliers by removing any produced durations greater than 3 standard deviations above the mean of each participant's production times in each of the 2- and 8-sec temporal production conditions. As well, all production times below 400 ms were regarded as erroneous productions and were also removed. These criteria resulted in the removal of 2.8% of the production responses. Means and standard deviations of the remaining production times in each of the 2- and 8-sec temporal production conditions were then obtained for each individual.

In accordance with the mean accuracy property of scalar timing theory, the overall mean of the 2-sec temporal productions was 1988 ms whereas the overall mean of the 8-sec temporal productions was 7868 ms, both of which are very close to the actual durations (i.e., relative accuracies were -0.6% and -1.65%, respectively). In accordance with the variance property of scalar timing theory, the mean of the standard deviations for the 2-sec temporal productions was 336 ms whereas the mean of the standard deviations for the 8-sec temporal productions increased to 980 ms (although the coefficients of variation were 5.92 and 8.03, respectively, indicating that the increase in the standard deviation of the production times was not strictly proportional to the increase in the mean).

Reaction Times. Before any analyses were performed on the RT data, they were adjusted for both outliers and incorrect responses. Removing any RTs associated with incorrect answers in the digit task resulted in the deletion of 5.27% of these data. A further adjustment of the correct RT data by eliminating RT outliers greater than 3 standard deviations beyond the mean of each participant's correct RTs within each of the 2- and 8-sec temporal production conditions, resulted in the further removal of 1.84% of the correct RTs. Median correct RTs in each cell of the following design were then obtained for each individual (where one outlying cell median was replaced by the cell mean + participant mean – grand mean; i.e., which is equivalent to the grand mean + cell effect + participant effect).

A within-subjects ANOVA was performed on the digit task RT medians that involved two factors: temporal production condition (i.e., 2- or 8-sec) and digit stimulus (1, 2, 3, 4, 6, 7, 8 or 9). A significant main effect of the length of the produced duration on the digit task RTs was indeed present, $F(1, 19) = 5.308$, $p < .033$, partial $\eta^2 = .218$, where $M = 607$ ms for the 2-sec production condition but $M = 671$ ms for the 8-sec condition. There was also a significant main effect of the specific digit stimuli on RT, $F(7, 133) = 6.808$, $p < .001$, partial $\eta^2 = .264$, where the exact nature of these effects is evident in Figure 1. The interaction between the production condition and the digit stimulus factors was not significant, $F(7, 133) = 0.709$, $p > .50$, partial $\eta^2 = .036$.

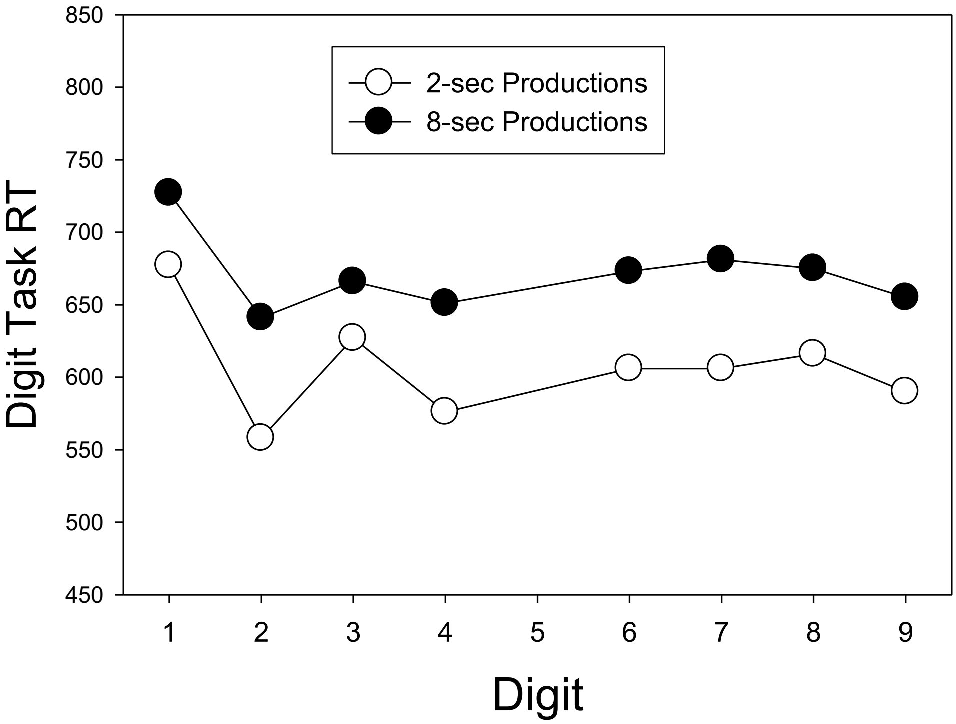

Figure 1. Digit task RT as a function of the digit and the foreperiod production condition.

Accuracies. A within-subjects ANOVA was performed on the (arc-sine transformed) accuracy of responding to the digit task that involved two factors: temporal production condition (i.e., 2- or 8-sec) and digit stimulus (1, 2, 3, 4, 6, 7, 8 or 9). A marginally significant main effect of the length of the produced duration on the digit task accuracy was present, $F(1, 19) = 3.287$, $p < .086$, partial $\eta^2 = .147$, where $M = .940$ (untransformed) for the 2-sec production condition but $M = .955$ (untransformed) for the 8-sec condition. There was a significant main effect of the specific digit stimuli on accuracy, $F(7, 133) = 9.902$, $p < .001$, partial $\eta^2 = .343$, that was analogous to that found in RT. The interaction between the production condition and the digit stimulus factors was not significant, $F(7, 133) = 0.811$, $p > .50$, partial $\eta^2 = .041$.

Discussion

The current study examined foreperiod RT effects in a completely novel fashion, namely, by having the participants estimate and produce the designated foreperiod lengths (after which time the reaction stimulus immediately appeared). This manipulation, in effect, served to eliminate the temporal uncertainty associated with the onset of the reaction stimulus (given that the foreperiod duration was always terminated by the participants themselves). Nonetheless, the RT results indicated that participants were still faster at the digit task when it followed a 2-sec temporal production “foreperiod” as opposed to an 8-sec one (i.e.. the standard foreperiod effect occurred). Importantly, this effect cannot be attributed to time uncertainty here. In turn, such a result then also calls into question the validity of this view as an explanation for the presence of fixed foreperiod effects in more standard RT studies.

In the temporal production part of this experiment, participants were asked to produce durations that were to last either 2- or 8-sec (after which they were to respond to the reaction stimulus). The results for this temporal production task indicated that participants were indeed trying to be accurate in these time productions for both the 2- and 8-sec durations given that the means of their production times were quite close to the requested time durations and the standard deviations of their production times were larger for the 8-sec productions than for the 2-sec productions (in accordance with scalar timing theory).

One final caveat regarding the RT results, though, is the fact that producing 2- and 8-sec time intervals could be assumed to consume more cognitive resources than simply waiting out such time intervals given that temporal estimation tasks have been assumed to be somewhat attentionally demanding (Block et al., 2010). However, it would also have to be assumed that attentional demands are less for the 2-sec productions in comparison to the 8-sec ones in order to account for the observed differences in digit task RTs.

To conclude, digit task RTs were faster after participant-mediated fixed foreperiod durations of 2 sec than 8 sec, which replicates the standard fixed foreperiod effect. Because time uncertainty could not possibly be the prevailing factor determining the effect obtained here, its role with respect to the more commonly observed fixed foreperiod effects might indeed be questioned.

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