FOREPERIOD'S LENGTH AND VARIABILITY INFLUENCE THE PERCEPTION OF BRIEF TIME INTERVALS

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Abstract

The period of time preceding an interval to be timed is called the foreperiod (FP). When multiple FPs are randomly varied within a testing session, longer FPs result in longer perceived duration. The aim of the present study is to test an attentional account of the impact of the FP on perceived duration (a) by comparing directly with a within-subjects design the relative effects of variable and constant FPs, and (b) by using different ranges of FP's durations in order to reach a potential limit to this effect. Results show that the impact of the variable FP is smaller when FPs belong to a longer range and that the influence of FPs on perceived duration might differ from that reported in the reaction times literature when they are constant.

The role of attention in timing and time perception is central (Zakay, 2000). Many investigations for understanding this critical role were based on resource allocation manipulations and, more specifically, on the use of a dual-task paradigm (see Brown, 2008). In the present study, the role of attention in time perception is approached from a different perspective.

Using a different framework to address the question of attention allocation in timing, Grondin and Rammsayer (2003) manipulated the duration of the foreperiod (FP) – that is, the period of time preceding an interval to be timed – in a duration discrimination task. Typically, FPs are used to study participants' preparation for responding to a signal in a reaction time experiment (Los & Van den Heuvel, 2001; Niemi & Näätänen, 1981). Grondin and Rammsayer obtained two main results. Firstly, longer FPs lead to longer perceived duration and, secondly, FP length only has an impact when it is varied randomly from trial to trial. When the same FPs are held constant within a session, there is no effect on perceived duration. Grondin and Rammsayer suggested a potential explanation for the FP effect, based on the so-called attentional-gate model (Zakay & Block, 1997). According to this model, a pacemaker emits pulses at a given rate, determined by the level of arousal, and these pulses are filtered through a gate that leads to an accumulator. The more attention allocated to time, the wider the opening of the gate and thus the more pulses amassed in the accumulator. Using this theoretical framework, Grondin and Rammsayer (2003) hypothesized that the probability of occurrence of the first signal marking time increases with the passage of time, with the result that more attention is allocated to temporal information. Consequently, the gate opens more widely when longer FPs are used, leading to greater temporal accumulation, i.e., longer perceived duration.

In addition to the effects reported by Grondin and Rammsayer (2003), another typical pattern of results is observed in RT tasks when FPs are held constant: Longer FPs result in longer RTs (Karlin,1959; Niemi & Naatanen, 1981). This would be due to the fact that temporal uncertainty increases with longer FPs, reducing the efficiency of the preparation. The study of Grondin and Rammsayer (2003) did not highlight such a pattern. Indeed, two limitations of this study might explain why, for the constant condition, there is some inconsistency between the results obtained in RT studies and those reported for perceived duration. On the one hand, Grondin and Rammsayer (2003) used a restricted range of FPs (all inferior to 1.5 s) and, on the other hand, their single experiment involving a constant FP condition was based on a between-subject design. Indeed, Grondin and Rammsayer (2003) did not provide a direct comparison of the perceived duration in the variable vs. constant FP conditions. Such a test would allow a better comparison of the literatures on the effect of FPs on RTs and on time estimation. In RT studies, RTs are typically found to be shorter in the constant than in the variable condition.

Method

Participants

The participants were 5 female and 4 male adult volunteers ranging in age from 19 to 27 years. Note that twelve participants were originally tested, but three were excluded from the statistical analysis due to very low goodness-of-fit of their results (average R^2 of .41, .47 and .42). All participants were undergraduate or graduate Laval University students and received $20 (Canadian) for taking part in this experiment. All participants had normal hearing.

Apparatus and stimuli

The presentation of the auditory intervals and the recording of the participant's responses were computer controlled, using E-prime 3.0 software. The auditory stimuli were 1000-Hz square wave tones. The intervals to be discriminated were silent durations (empty intervals). The empty intervals were marked by onset and offset tones 10-ms in duration, presented binaurally through headphones (Sony MDR-V600) with an intensity of approximately 70 dB SPL.

Procedure

Each trial consisted of the presentation of a single empty interval. An experimental session was initiated by 10 presentations of a 100-ms standard interval followed by eight blocks of 96 trials each. On each trial, an empty interval shorter or longer than the 100-ms standard interval was presented. There were four durations shorter (79, 85, 91, 97 ms) and four durations longer (103, 109, 115, 121 ms). Within each block, each of these eight intervals was presented 10 times in random order. Also, what is called the FP is the period of time from completion of the participant's response to the preceding trial to the onset of the following stimulus presentation.

Participants were tested according to three within-subjects variables: the FP type (Variable vs. Constant), the FP range (Short vs. Long), and the FP duration (300, 400, 500, 600 ms in the short range condition; 1200, 1800, 2400, and 3600 ms in the long range condition). In the variable condition, FPs were grouped in two different types of sessions, according to their range. Within a session, the four FPs from the respective range were varied randomly from trial to trial (for example, in the "long range" session, 1200, 1800, 2400, 3600-ms were used). There were four blocks of 96 trials per range, for a total of eight blocks. In the constant FP condition, there were also eight blocks, one with each FP being kept constant. Each participant was tested in the variable and in the constant conditions on separate days.

Participants were seated at a table in a dimly lit, sound attenuated room. Participants' task was to decide whether the presented empty interval was shorter or longer than the 100-ms standard interval by pressing "1" (short) or "3" (long) on the computer's keyboard. The instructions for the participants emphasized accuracy: there were no requirement to respond quickly. Each participant was run individually. Each experimental session lasted approximately 40 min.

Data analysis

All trials were kept for analysis. For each participant and for each foreperiod, an 8-point psychometric function was traced, plotting the eight comparator intervals on the x-axis and the probability of responding "long" on the y-axis.

The cumulative normal distribution was fitted to the resulting curves using Origin 7.0 software's fitter (least-squares method). Two indices of performance were estimated for each psychometric function, one for sensitivity and one for the perceived duration. One dependent variable was the temporal bisection point (BP). The BP can be defined as the x value corresponding to the .50 probability of "long" responses on the x-axis. The observed shift of the BP for different FP conditions can be interpreted as an indication of differences in perceived duration. Thus, longer perceived durations are reflected by smaller BP values. This implies the assumption that with the uncertainty conditions of the present experiment, participants employed the same response criterion for all FP conditions and that the differences in the distributions of "long" and "short" responses depend on the perceived duration in each FP condition (Grondin, 1998).

As an indicator of temporal sensitivity (or level of duration discrimination), the other dependent variable, estimates of the standard deviation (SD) on the psychometric function were determined. For this purpose, the difference between the x values corresponding to .84 and .16 probabilities of "long" responses, on the y-axis, was divided by 2. Using one SD (or variance) is a common procedure to express temporal sensitivity (Grondin, 2008).

Results

Mean BP are illustrated in Figure 1 as a function of the three independent variables. A descriptive analysis of the resulting functions suggests that the BP decreases as a function of the FP in the variable condition in both the short and long range conditions. In the constant condition, the BP remains relatively stable as a function of the FP duration, but seems to interact with the FP range.

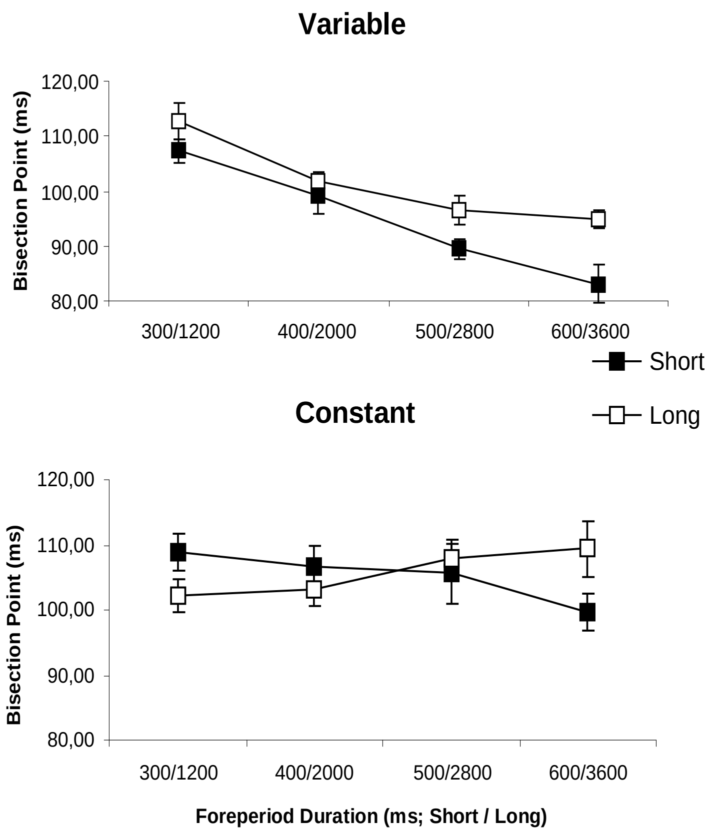

Figure 1. Bisection point (ms) in the variable (upper panel) and constant (lower panel) FP conditions as a function of the FP duration and the FP range (± within-subjects standard error of the mean).

To test the presence of statistically significant differences, a 2 (Type) x 2 (Range) x 4 (Duration) factorial ANOVA according to a within-subject design was conducted on the mean BPs, setting alpha at .05. The FP Duration main effect was significant, F (3, 24) = 10.052, p = .0002, η^2_p = .56, but not the two other main effects (FP Range: F (1, 8) = 1.70, p = .23, η^2_p = .18; and FP Type: F (1, 8) = 3.55, p = .10, η^2_p = .31). Two interaction effects were significant: FP Duration × FP Type, F (3, 24) = 10.58, p = .0001, η^2_p = .57, and FP Duration × FP Range, F (3, 24) = 3.57, p = .029, η^2_p = .31.

Regarding the significant FP duration, post-hoc pairwise comparisons using the Bonferroni correction (α = .0125) revealed that the only significant contrast was that between the 300/1200 FP and 600/3600 FP (p = .008).

Simple effects were performed to break down the interactions and tested with alpha set at .0375 according to Holm's procedure. Results showed that the FP Duration effect was significant in the variable condition (p = .01) but not in the constant condition; and that the effect of duration was significant in the short range condition (p = .001) but not in the long range condition.

As regards the other dependent variable, SD, the mean results are illustrated in Figure 2. A 2 (Type) x 2 (Range) x 4 (Duration) factorial ANOVA according to a within-subject design was conducted and revealed a significant FP Type main effect, F (1, 8) = 5.72, p = .04, η^2_p = .42. Sensitivity was higher in the constant condition. The analysis revealed that neither of the other two main effects were significant, the FP Range, F (1, 8) = 4.34, p = .07, η^2_p = .35; and the FP Duration, F (3, 24) = 2.23, p = .11, η^2_p = .27. Note that the sensitivity tended to be higher with the set of long (SD = 17.2) than with set of short (SD = 20.0) FPs. None of the interactions were significant.

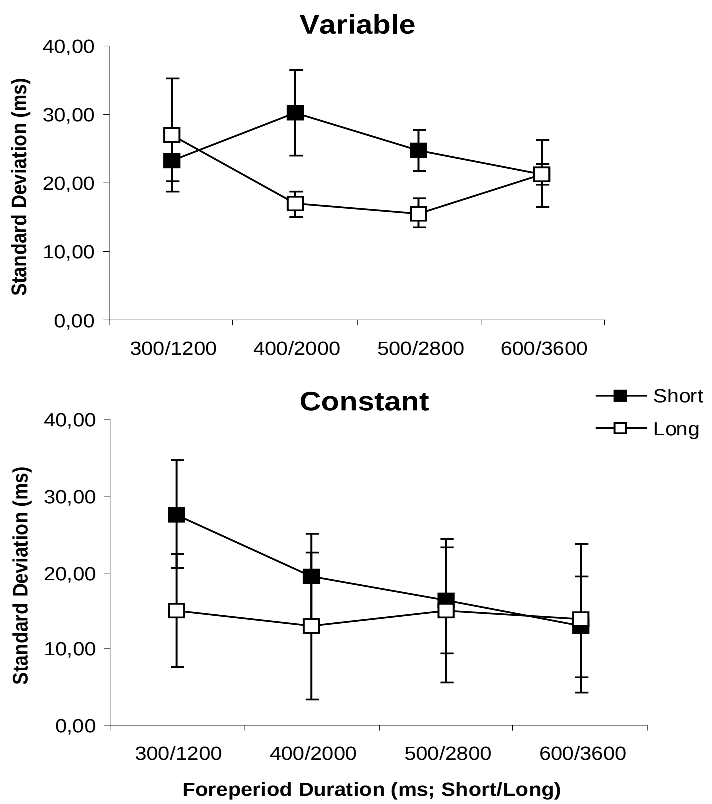

Figure 2. Mean standard deviation (ms) in the variable (upper panel) and constant (lower panel) FP conditions as a function of the FP duration and the FP range (± within-subjects standard error of the mean).

Discussion

The aim of this study was to extend our understanding of the impact of foreperiods on time perception. The variable FP effect on perceived duration reported here is consistent with the results reported by Grondin and Rammsayer (2003) and Bendixen et al. (2005). In the variable FP paradigm, longer FPs resulted in longer perceived duration. Most importantly, there was no such effect when FPs were held constant within a block, and the overall results are not the exactly the same with the short and long FPs ranges.

The analysis of perceived duration revealed an interesting Duration × Range interaction, indicating that the BP decrement as a function of the FP duration is restricted to the short range condition (300 to 600 ms). The lack of interaction of this effect with the FP type (no triple interaction) indicates that this pattern of results is also present in the constant FP condition. Figure 1 illustrates that this interaction is present in both the variable and constant conditions, but seems to have different causes. In the variable condition, using the set of long FPs only seems to decrease the effect of the FP duration, while in the constant condition the patterns seem to have moved: longer BP with longer FPs with the set of long FPs, and relatively equal BPs with the set of shorter FPs. Based on the RT literature, one would expect longer perceived duration with shorter foreperiods in the constant condition because, even if the FPs are held constant, the longer they are, the more uncertainty is induced as regards the occurrence of the signal. This could easily be accounted for by the scalar property of timing (Gibbon & Church, 1984) which predicts that shorter durations are timed with more precision than longer ones, on an absolute scale. In this experiment, this expected pattern in the constant condition was observed only with the set of long FPs, suggesting that decreasing the FP does not necessarily allow a better preparation. A better preparation might be reached only through a compromise between having a FP duration short enough to generate an accurate estimation of its duration (reducing temporal uncertainty), but long enough to allow the recruitment of enough resources in order to process the target duration. The fact that this type of interaction is not observed within this range of FP durations in RT studies (e.g., Karlin, 1959; Niemi & Naatanen, 1981) might reveal that the preparation prior to react to a given signal is different than the preparation needed to time the duration of the signal. In a duration discrimination context, knowing accurately when the signal will occur might not be enough to ensure that the temporal system is ready for its processing.

Moreover, there is no FP type main effect on BP. If more attention was allocated to the target intervals in the constant condition, we would expect longer perceived duration as compared to the variable condition. The fact that perceived duration in the constant condition is always equal or shorter than that in the variable condition is opposed to the pattern of results that would be expected have perceived duration results been like RTs data. However, an important distinction should be made between RTs and perceived duration. The first measure is absolute, whilst the perceived duration is inferred from a relative measure. Indeed, durations judgments depend on a comparison of the actual interval to a standard representation in memory. This representation is updated within an experimental block, depending on previously processed intervals (Gamache & Grondin, 2008; Jones & McAuley, 2005; Jones & Wearden, 2003). That is, suppose that the reference duration is generated from trials completed in the context of a variable FP paradigm. According to the attentional explanation, this reference should contain less pulses than a reference generated in the constant FP paradigm. That is, even if the subsequent target durations lead to a smaller accumulation of pulses because they are also part of a variable FP paradigm, their duration relative to the reference should not be affected. As a consequence, the absolute effect of variable vs. constant FPs on RT cannot be paralleled out using perceived duration as the dependent variable.

However, the other dependent variable, SD, might better reflect the absolute differential effect of constant and variable FPs. Indeed, if less attention is available at the encoding of the standard and/or while processing target intervals, more variable judgements are expected (Zakay & Block, 1997). The significant increase of the SD with variable FPs observed here supports this prediction.

As in Grondin and Rammsayer (2003), the effect of the FP duration on SD was not comparable to the one observed for perceived duration. Although perceived duration was strongly affected by the FP in the short range condition, there was no difference for temporal sensitivity between the 300-, 400-, 500- and 600-ms FPs. However, more variability is expected with longer perceived duration according to the scalar property of timing (Gibbon & Church, 1984). The fact that the SD does not increase as a function of the FP, while perceived duration does, suggests that in the variable paradigm, there might be a reduction in relative variability with longer FP.

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