

INFLUENCE OF TEMPORAL CONTEXT IN TWO-CHOICE TIME DISCRIMINATION

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Abstract

Participants were asked to respond as quickly as possible in a two-choice time discrimination task. The short tone (ST) duration was constant across blocks of trials, whereas the long tone (LT) duration varied between blocks. In principle, response time to the ST could be independent of LT duration, as one could decide that the tone is long as soon as the subjective duration corresponding to the ST is over. The results showed instead that as the LT lengthened, reaction times to the ST decreased and reaction times to the LT increased. Performance was more accurate at longer LTs. Errors were found mostly with the ST when reaction times were shorter, whereas errors in late responses were as frequent with the long and short tones; this pattern of results was modulated by LT duration. Our findings show a strong influence of temporal context, even in a simple two-choice time discrimination task.

Deciding whether the duration of a stimulus is short or long is quite often required in everyday situations – think for example of deciding whether a handshake is long or unusually short. Accumulator models of timing (Gibbon, Church & Meck, 1984; Zakay & Block, 1996) provide detailed accounts of perceptual, memory and decisional processes involved in time estimation. The decisional processes are however not defined as well as other processes in timing tasks, and relatively few studies have specifically manipulated this component in human studies (Wearden & Grindrod, 2003). In two previous studies, responding in a two-choice time discrimination task seemed to depend on a relatively well defined decisional criterion when attention was shared between timing and expecting a break signal (Tremblay & Fortin, 2003; Fortin & Tremblay, 2006). It appeared that in this task, using a single criterion could be sufficient to make a decision in duration classification. Indeed, when only two durations are used, participants may in principle simply use an intermediate temporal value above which the short duration is elapsed to make a decision. This interpretation could not be tested directly in those studies because they used non speeded categorization responses. The present study addresses this question by using time reaction responses in two-choice temporal discrimination. The results show that responses in two-choice time discrimination are not based on a single criterion, but are instead strongly influenced by specific values of long durations used in the experiment.

Method

Twenty volunteers aged between 20 and 48 ($M = 21.9$, $SD = 3.7$) were recruited on campus and took part in a single experimental session. All participants reported normal hearing and were naïve to the purpose of the experiment. The experimental session took place in a soundproof test chamber. Stimulus presentation and response recording were controlled by E-prime 2.0. Three measures were collected: accuracy, reaction time and a judgment of certainty

relative to the response provided. Participants used keys on a standard computer keyboard to identify the short and long stimuli and to provide certainty judgments. Two tones, short and long (ST and LT) were used, both generated at a sinusoidal frequency of 550 Hz. Sounds were produced by stereo speakers placed on each side of the screen at an intensity of 50dB. The duration of the ST was fixed to 2 s in all blocks and the LT value, 2250, 2500, 2750, 3000 or 12000 ms, varied between blocks of trials. In a block of trials, STs and LTs were presented equally often.

In each trial, participants were required to decide whether the tone was short or long. Participants were asked to respond as fast and as accurately as possible, and could respond before the end of tone presentation. The participants were informed that only two durations were used in a block of trials. Instructions prohibiting counting and counting-like strategies were given. Trials were initiated by pressing the space bar; 100 ms after this input, the tone presentation began. Participants were asked to press the left and right arrow keys on the keyboard when the ST and LT were presented, respectively. After each response, participants rated their level of certainty relative to their decision on a scale ranging from 1 to 4, 1 being uncertain and 4 being certain. Each of the five 72-trial block was associated with a single LT duration and presentation order of blocks was randomized across participants.

Results and Discussion

RTs, accuracy and certainty judgements were analysed using repeated measures analysis of variance (ANOVA) with two factors: tone duration (ST or LT) and LT duration (which corresponds to the LT always used in the specific block of trials) (2250, 2500, 2750, 3000 and 12000 ms). For all analyses, an alpha level of .05 was used and a Greenhouse-Geisser correction was applied when required.

Figure 1 shows RTs as a function of presented tone duration in a given trial and the LT duration used in the block of trials. There was an effect of presented duration: RTs to STs were shorter than to LTs, $F(1,19) = 72.85$, $MSE = 185\,681$, $p < .001$, $\eta^2_p = .79$. No effect of LT duration was observed, $F(4,76) = 1.01$, $MSE = 154\,894$, $p = .37$, $\eta^2_p = .05$, but there was a clear interaction, $F(4,76) = 18.23$, $MSE = 86\,460$, $p < .001$, $\eta^2_p = .49$; tests of simple main effects confirmed that when responding to the ST, RTs decreased with increasing long tone duration, $F(4,76) = 10.85$, $MSE = 30\,851$, $p < .001$, $\eta^2_p = .36$, whereas when responding to a LT, RTs increased with increasing duration, $F(4,76) = 4.92$, $MSE = 74\,703$, $p = .008$, $\eta^2_p = .21$.

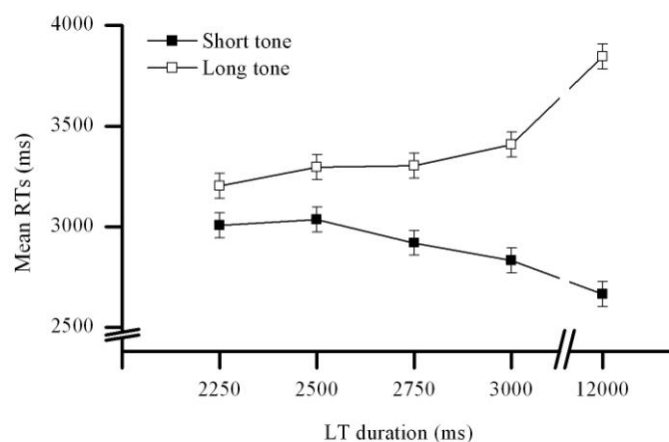


Figure 1. Mean RTs as a function of LT duration in a block of trials, in ST and LT trials. Error bars display pooled *MSE*.

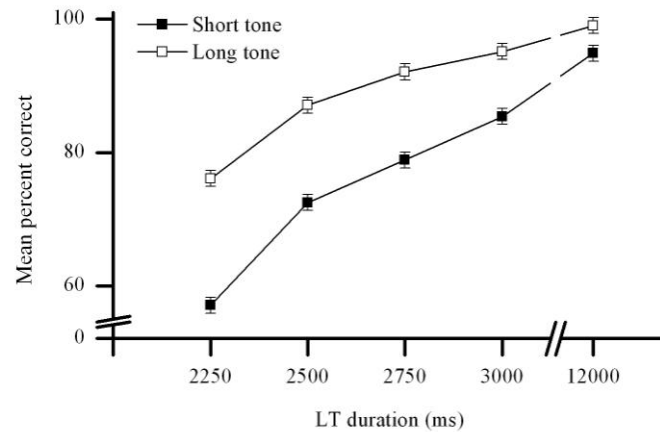


Figure 2. Percentages of correct responses as a function of LT duration in a block of trials, in ST and LT trials. Error bars display pooled *MSE*.

Figure 2 shows percentages of correct responses as a function of presented tone duration and LT duration. The participants were less accurate in responding to the ST than to the LT, $F(1,19) = 15.63$, $MSE = .047$, $p = .001$, $\eta^2_p = .45$. Accuracy increased with increasing LT durations, $F(4,76) = 81.6$, $MSE = .006$, $p < .001$, $\eta^2_p = .81$. There was also a significant interaction between presented and LT durations, $F(4,76) = 2.88$, $MSE = .011$, $p = .03$, $\eta^2_p = .13$: the increase in accuracy with LT duration was more pronounced in responding to the ST than in responding to the LT.

The results do not correspond to an interpretation based on a single criterion. Given that the value of the ST was the same in all blocks of trials (2 s), the time needed to respond to the long tone should not vary across blocks of trials if participants decided simply that “the short tone was over or not” on the basis of a single criterion. RTs to long tones increased with the lengthening of LT duration, showing that participants used the additional information provided by the long tone when it was available. This, indeed, increased their response accuracy in the LT condition, as shown in Figure 2. In contrast, RTs shortened with the lengthening of LT duration, with no cost on accuracy since as shown in Figure 2, accuracy also increased with LT duration in the ST condition. This result suggests that the larger difference between the short and the long tones, in a given block of trials, helped the participants to respond more quickly when the ST was presented, possibly by increasing their confidence in their decision.

In order to examine whether shorter RTs and increases in accuracy corresponded to higher degrees of confidence, we analyzed how the participants rated their certainty regarding their response choice. Figure 3 shows certainty judgements as a function of LT duration, in the ST and LT conditions. The participants were more confident in their judgement when LTs were presented than when STs were presented, $F(1,19) = 56.33$, $MSE = .057$, $p < .001$, $\eta^2_p = .75$. This corresponds to the generally longer RTs in the LT condition than in the ST condition shown in Figure 1. The participants took more time to decide that the long tone had been presented, and were more certain that their decision was correct. Certainty also increased with LT duration, $F(4,76) = 36.95$, $MSE = .27$, $p < .001$, $\eta^2_p = .66$, but in contrast with results with RTs and accuracy measures, there was no interaction between the presented duration (ST or LT) and LT duration, $F(4,76) = 1.61$, $MSE = .04$, $p = .18$, $\eta^2_p = .08$. Taken together, the results in Figures 1, 2 and 3 show that when the ST was presented, the participants responded generally more quickly than when the LT was presented, at the cost of accuracy and confidence, which were lower in those trials. In blocks in which LT duration was longer, RTs to the ST were shorter than in blocks with shorter LT duration (Figure 1), and both accuracy

and confidence increased correspondingly. In other terms, when the difference between the short and long tones was greater in a block of trials, the participants responded more quickly to the ST, were more accurate and more confident regarding the accuracy of their response. Overall, even though the ST value was the same throughout the experiment, responses to the ST varied significantly with the temporal context in which responses were provided.

When the ST was presented, longest RTs corresponded to lowest accuracy (see results in the 2250-ms LT block, in Fig. 1 and 2); when the LT was presented, longest RTs led to highest accuracy (see the 12000-ms LT block in Fig. 1 and 2). In order to examine more closely the relationship between errors and RTs, RTs of each participant were ranked and grouped in 6-trial bins. Percentages of correct responses and confidence ratings were computed in each bin (1st through 6th fastest trials, 7th through 12th, and so on) as a function of presented duration (LT or ST) and LT duration. ANOVAs were run with LT duration, presented tone duration and ranked RT bin (6 bins total) as factors. As shown in Table 1, the results confirm those obtained in the previous analyses. A three-way interaction was obtained with accuracy data however (see Fig. 4): when LT durations were short (i.e. in blocks in which discrimination was hardest, as the difference between ST and LT was smallest), fast answers to ST presentations were drastically inaccurate, below chance given that answers were dichotomous. Conversely, fast answers to the LT were near perfect. This pattern of results implies that, when responding faster, participants were biased towards a “long” response in both the ST and LT conditions (see Fig 4, both panels). As RTs lengthened however, accuracy decreased similarly for ST and LT presentations. Interestingly, no three-way interaction was found with certainty judgements (see Fig. 5). Participants were seemingly unaware of errors made when answering rapidly to the ST. Note however that slow responses were associated to lower certainty levels in responding to both the ST and the LT.

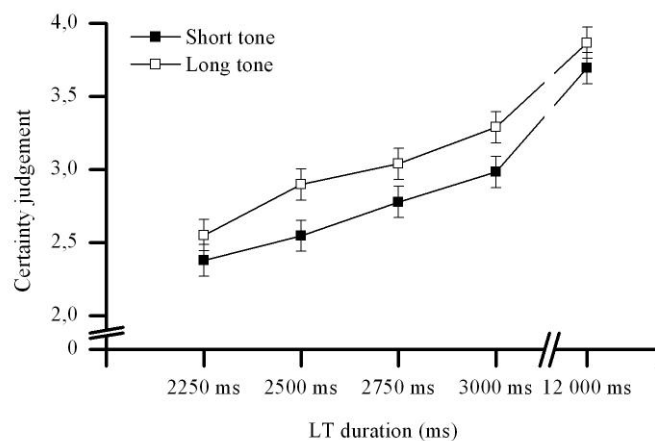


Figure 3. Certainty judgement data on a 1 to 4 scale as a function of LT duration in a block of trials, in ST and LT trials. Error bars display pooled *MSE*.

Table 1. Results of the 5 (LT duration) \times 2 (target tone duration) \times 6 (grouped ranked RTs) ANOVAs on accuracy and certainty judgement data.

<i>F</i> values, Mean Square Errors (<i>MSE</i>) and effect size (η^2_p)							
<i>Source</i>	<i>df</i>	<i>F</i>	Accuracy		Certainty		
			<i>MSE</i>	η^2_p	<i>F</i>	<i>MSE</i>	η^2_p
LT duration	4, 76	81.60 ⁺	.039	.81	36.95 ⁺	1.62	.66
Presented tone duration	1, 19	15.63 ⁺	.283	.45	56.33 ⁺	.342	.75
Grouped ranked RTs (GRRT)	5, 95	20.42 ⁺	.039	.52	60.53 ⁺	.219	.76
LT \times TTD	4, 76	2.88*	.065	.13	1.61	.240	.08
LT \times GRRT	20, 380	2.96 ⁺	.020	.14	5.80 ⁺	.122	.23
TTD \times GRRT	5, 95	13.35 ⁺	.051	.51	3.93 ⁺	.105	.17
LT \times TTD \times GRRT	20, 380	4.07 ⁺	.023	.18	1.40	.089	.07

* $p \leq .05$ ⁺ $p \leq .01$

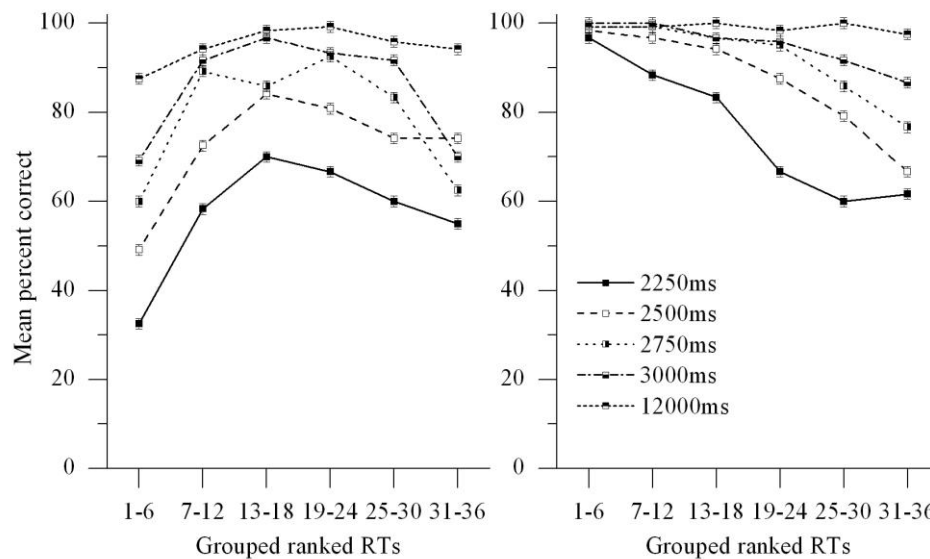


Figure 4. Percentages of correct responses as a function of grouped ranked RTs, at each LT duration. The left panel displays response accuracy to the ST presentation and the right panel displays response accuracy to the LT presentation. Error bars display pooled *MSE*.

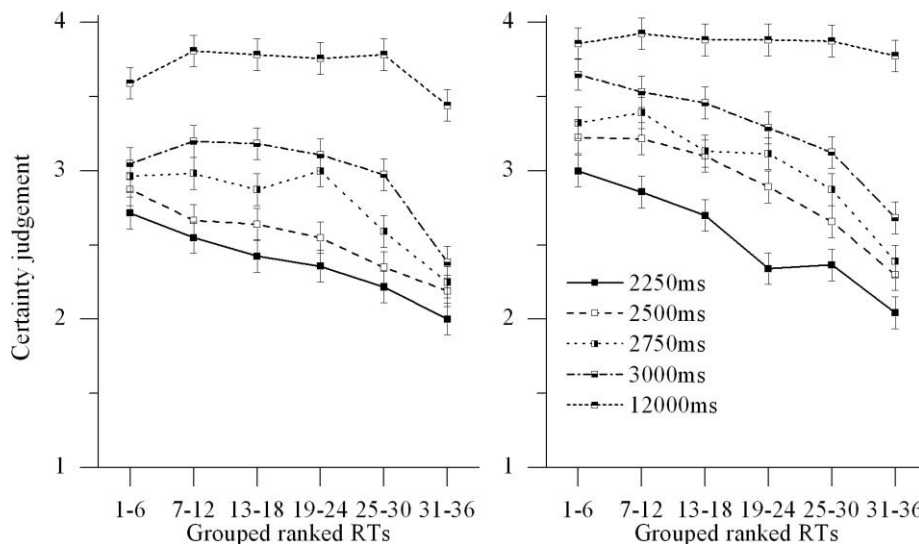


Figure 5. Certainty judgement data on a scale of 1 to 4 as a function of grouped ranked RTs, at each LT duration. The left panel displays response accuracy to the ST presentation, the right panel, response accuracy to the LT presentation. Error bars display pooled *MSE*.

Overall, the results of the present study show that the temporal context in which a simple two-choice time discrimination task takes place exerts a critical influence on performance. Although a single criterion based on the ST duration alone would theoretically be sufficient to discriminate between two durations, decisions are obviously not based on such a criterion. In blocks where the LT was longer, RTs to the LT were longer than in blocks with shorter LTs; this may be explained by a tendency, in participants, to increase their degree of certainty during the tone presentation when possible. Besides, the shortening of RTs to ST presentation as LT duration increases in a block of trials suggests that increasing certainty in less difficult temporal contexts may increase confidence at the expense of accuracy, of which the participants are unaware. We conclude that uncertainty related to task difficulty must be considered to explain performance in time discrimination.

Acknowledgments

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