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Short-term effects on temporal judgement: Sequential drivers of interval bisection and reproduction

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ABSTRACT

Our prior experiences provide the background with which we judge subsequent events. In the time perception literature one common finding is that providing participants with a higher percentage of a particular interval can skew judgment; intervals will appear longer if the distribution of intervals contains more short experiences. However, changing the distribution of intervals that participants witness also changes the short-term, interval-to-interval, sequence that participants experience. In the experiment presented here, we kept the overall distribution of intervals constant while manipulating the immediately-prior experience of participants. In temporal bisection, this created a noted assimilation effect; participants judged intervals as shorter given an immediately preceding short interval. In interval reproduction, there was no effect of the immediately prior interval length unless the prior interval had a linked motor command. We thus proposed that the immediately prior interval provided a context by which a subsequent interval is judged. However, in the case of reproduction, where a subsequent interval is reproduced, rather than seen, the effects of contextualization are attenuated.

1. Introduction

A minute is *objectively* the same whether stuck in traffic or on a rollercoaster. *Subjectively*, one lasts much longer; personal time is malleable. One driver of temporal perception is past experience. Waiting three minutes versus nine minutes for one friend determines if five minutes spent waiting for a second friend seems like a long time. This is an example of *contrasting* temporal experience; five minutes seems short if preceded by longer prior experiences (Hampton, Estes, & Simmons, 2005; Wiener, Thompson, & Coslett, 2014). The opposite effect is also possible; temporal *assimilation* is when an interval appears shorter when preceded by a short prior experience. For example, a ≈ 250 ms interval can appear even shorter if preceded by a shorter interval (referred to as 'time-shrinking,' see Nakajima, Ten Hoopen, Hilkhuysen, & Sasaki, 1992; Nakajima et al., 2004).

Two common experiments used to investigate subjective temporal experience are the bisection (Church & Deluty, 1977; Wearden, 1991b) and reproduction tasks (Lejeune & Wearden, 2009; Vierordt, 1868). Though both these tasks have generated a great deal of research, the effect of immediately prior durations has received little attention. In other research traditions relating to time, the investigation of sequential effects is common. For example, in the variable foreperiod task (Woodrow, 1914) sequential effects are a main area of interest. In this type of task, participants are required to react as quickly as possible to a response imperative appearing at some time after a warning signal. If the imperative occurs earlier in the current trial than in the previous trial, reaction times (RTs) tend to be extended. When the current trial is longer than the previous trial, or when the current and prior trials are both the same duration, RTs tend to be shorter (Drazin, 1961; Karlin, 1959; Los, 2010, 2013; Nobre, Correa, & Coull, 2007; Steinborn, Rolke, Bratzke, & Ulrich, 2008; Vallesi & Shallice, 2007; Woodrow, 1914; Zahn, Rosenthal, & Shakow, 1963).

In the following experiments, we exposed participants to a single long/short 'reference' (standard) interval prior to each trial. We maintained the 'mean' experience of intervals presented throughout each experiment but adjusted the immediately prior interval that participants received. This dissociates short-term experience, which has had relatively little attention paid to it, from the effects of a skewed distribution of intervals (e.g. a higher percentage of shorter intervals) which has previously been shown to affect both bisection (e.g. Wearden & Ferrara, 1996, Experiment 2), and reproduction (e.g. Acerbi, Wolpert, & Vijayakumar, 2012).

In the broader 'comparison' literature (e.g. comparison of weight) both contrast and assimilation effects from short-term experience have been reported (e.g. Parducci & Marshall, 1962; Sherif, Taub, & Hovland, 1958). Similarly, it has been proposed that more recent temporal

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experiences more strongly modulate upcoming temporal decisions (see Los, Kruijne, & Meeter, 2014; Taatgen & van Rijn, 2011). Specifically, in models such as the internal reference model (Dyjas, Bausenhart, & Ulrich, 2012), our current representation of time is proposed to be skewed by our immediately prior experience (see also Bausenhart, Dyjas, & Ulrich, 2014; Brown, McCormack, Smith, & Stewart, 2005; Gu & Meck, 2011). The following experiment looks at the effects of providing a single reference interval prior to the presentation of a test (probe) interval, similar in design to tasks used in, for example, the weight comparison literature (e.g. Bravo & Mayzner, 1961; Sherif et al., 1958). We will discuss the bisection and reproduction tasks used in turn.

In the commonest version of temporal bisection, participants are exposed to two reference time intervals, identified as Short and Long standards. They are then shown intermediate probe durations and asked which of the reference intervals each one is closest to. The probe time at which participants choose either reference with equal probability is the *bisection point*, indicating the subjective midpoint of the standards (see Wearden, 2016, for discussion, see Kopec & Brody, 2010, for a broad review). The bisection point tends to be near the arithmetic mean of the presented interval durations for humans (e.g. Wearden & Ferrara, 1995, 1996).

Though the effects of presenting a standard duration prior to the probe duration has not been investigated in the temporal bisection paradigm, several ‘direct comparison’ experiments have investigated the effects of presenting a standard stimulus duration prior (or after) a probe duration (e.g. Droit-Volet & Rattat, 2007; Dyjas et al., 2012; Lapid, Ulrich, & Rammsayer, 2008; Ulrich, 2010). These tasks require participants to make comparisons between immediately presented standard and probe durations, judging which of the two is longer. The current experiment is somewhat similar to both bisection and direct comparison methods in that we are presenting a standard duration prior to a probe duration, however the probe duration is not compared to the prior “standard” but rather is judged in comparison to two previously established reference durations.

The temporal reproduction procedure has a long history in psychology, at least since Vierordt (1868). In this task, participants are presented with one or more reference intervals, and are subsequently required to repeat this interval in some way. This means that the durations of both the currently requested reproduction interval and the previously presented reproduction interval are the same, therefore the ‘standard’ reproduction task is incapable of examining the influence of prior interval length on current reproduction. Here, we decouple this pattern by requiring participants to reproduce one of two intervals, irrespective of the immediately-preceding example interval length.

Generally, the temporal reproduction procedure used here is similar to the temporal bisection task; participants are exposed to several short and long standard durations initially. After this exposure, participants are required to reproduce one of these standards, signaled by the letter “S” or “L” for a short or long reproduction, respectively. Prior to the presentation of one of these letters, one of the two standards is shown. However, this duration is not predictive of what duration the participants would be required to reproduce. For example, the long standard could be shown, then an “S” could require participants to reproduce the “short” standard duration.

Temporal reproduction was conducted in two ways here. The first method was as described above; participants passively observed a standard, then reproduced either a short or long duration depending on the signal presented. The second method required participants to respond to the termination of the standard interval presented prior to the letter indicating which interval to reproduce (a simple reaction time task). In other words, participants alternated between reacting to the offset of one of the two standard durations, and reproducing one of the two standard durations. We did this to test if perhaps response to the end of the standard duration strengthens a tendency to respond at one of the standard durations, as per theories such as the trace-conditioning model of implicit timing (Los et al., 2014; Los & van den Heuvel, 2001). This in turn could conceivably affect the subsequent reproduction.

In summary, the following experiments examine performance on two temporal tasks. The first is a temporal bisection task in which participants decide which of two referent intervals an intermediate probe interval is closer to. The second task requires participants to reproduce a short or long interval, irrespective of the prior interval length and whether the participant has responded to the termination of the preceding interval. Participants also performed a retrospective time judgement task regarding the durations they experienced in this experiment. We also present the results of another bisection task run on a separate group of participants which follows on from the findings of the first temporal bisection task. This final study replicates the finding of the initial bisection task, and extends the effect to longer durations, an important consideration given the possible differences in timing of subsecond and suprasecond intervals (e.g. Hayashi, Kantele, Walsh, Carlson, & Kanai, 2014).

In everyday life, our directly prior experience with duration can affect how we perceive a subsequent interval. We examine this effect using the above-mentioned paradigms. We hypothesize that the prior interval will provide a context with which participants will experience the subsequent interval. This may lead to a contrast or assimilation effect of the first interval on the second, as mentioned in the introductory paragraphs. Though some models, for example the internal reference model, appear to predict contrast effects, in other literature, for example weight comparison, assimilation effects are also found. Of further interest, we examine whether these effects are present in the judgement of a subsequent duration, as measured by the bisection tasks, the recreation of intervals, as measured by the reproduction task, or both. In the bisection task, the participant is exposed to both the standard duration and a comparison duration. However, in the reproduction task, the participant is only exposed to the standard, and reproduces the comparison duration without necessarily seeing the requested reproduction duration first. It is then possible that the effects of the standard duration on the subsequent measure of temporal experience may diverge, for example perhaps the standard duration has an effect on how we perceive a subsequent duration, but not on the active replication of said duration.

2. Method

2.1. Participants

Twenty participants took part in the first experiment (which included the bisection and reproduction task), and thirty in the second bisection study. All participants were paid $15AUD (each experiment took ≈ one hour) and recruited from the Macquarie University cognitive science register. Participants provided written consent, in accordance with the Declaration of Helsinki. The experiment was approved by the Macquarie University Ethics Committee. Half of the first set of participants answered retrospective temporal judgement questions after the first demonstration block (see below), and half after the second demonstration block. Mean age of participants in the first study was 23.9 years (range = 18–53). One participant was left handed, and five participants were male. In the second bisection study, the mean age of participants was 22.4 years (range = 18–34). Five participants were left handed and 11 participants were male.

2.2. Material

Experimental stimuli were presented on a Samsung SyncMaster SA950 (27 in.) monitor controlled by a Dell Optiplex 9010 PC (8GB RAM, 3.2Ghz Intel i5-3470 CPU) running 64-bit Windows 7. All experiments took place in dimly lit rooms with participants seated 0.8 m away from their monitor. Neurobehavioral System's Presentation (v18.3) was used to present the experiments. Responses were made