Study on Effect of Temporal Context in a Timing Task

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Abstract

We study the effect of temporal context in a Timing task utilizing inputs from both human participants and an ACT-R simulation. We aim to understand how a distribution of temporal stimulus is perceived and reconstructed, and to test the effect of inter-test durations on the memorization of time. We present a hypothesis that given long inter-test durations, the effects of priors from a set of tests does not get carried over to another set of temporal tests. We also present the case that humans have an inherent bias in the perception of time and hence are unable to reconstruct skewed distributions of time quite as accurately as they could reconstruct uniform distributions. We compare the results observed with the results from a previous experiment run on human participants.

Keywords: Temporal Perception, Reconstruction, Stimulus, ACT-R

Introduction

Quantifying and estimating time is important to humans. A variety of human activities depend on being able to accurately estimate time intervals and the effect of said time intervals on an activity or action (trading in stock markets, understanding when the right time to buy or sell stocks would occur based on market history, setting up meetings or conferences). Biologically, time plays a very important role in the functioning of the human system, on both macro and micro levels, with the intrinsic sense of time controlling activities ranging from sleep cycles to hormone secretions and physical growth.

In cognitive science, the understanding of how time is perceived and estimated is largely based on two frameworks. The intrinsic framework of temporal encoding models argue that the representation of time is an intrinsic process, rising from non-dedicated neural mechanisms, while the dedicated framework argues that temporal perception can be attributed to dedicated specialized neural processes (Ivry & Schlerf,2008) (Spencer, Karmarkar, & Ivry,2009). The dedicated framework models temporal processes as activity in certain specific sensory regions of the brain, with the region depending on the stimulus causing the temporal activity (Spencer et al.,2009). Dedicated models of temporal encoding focus on explaining experimental findings through the design of theoretical models (Spencer et al.,2009), a very popular model designing a temporal process develops temporal encoding using a timing module, a memory module and a comparison module to encode the difference (Van Rijn, Gu, & Meck,2014).

Humans have shown that they adapt to temporal tasks in a Bayesian manner, that is, their accuracy at such tasks depend on their prior experiences (Acerbi, Wolpert, & Vijayakumar,2012). Humans have been seen to function well when tasked with temporal events that follow uniform distributions such as the timing experiment carried out in (Jazayeri & Shadlen,2010). The experiment hypothesized that in real world scenarios, humans are able to reproduce time intervals (based on a stimulus) with higher variation between the stimulus and the production time when tasked with longer intervals between the stimulus and the response. In fact, when the experiment was carried out with human participants, such a variance in reproduced intervals was noticed when the participants tried to reproduce longer duration as opposed to shorter duration (Jazayeri & Shadlen,2010). Jazayeri and Shadlen noticed in their experiment, that even though there was a tendency for large variance in long interval experiments, the reproduced times exhibited a regression trend toward the mean stimulus time. Humans have shown that they

We hypothesise that during the process of the test, the prior experience of a participant may not be equally distributed over the time of the experiment and could depict a skew in favor of the shorter or longer durations. In this paper, we attept to test this hypothesis, utilizing a temporal experiment based on the design in (Jazayeri & Shadlen,2010).

We also hypothesise that the effect of priors could be reduced if participants were to take a long duration break between the blocks of the experiment, which could mean that temporal perception is task specific and short-term (Matthews & Meck,2016).

Methods

The experiment was set up to determine the effect of Temporal Priors on a timing task using the OpenSesame toolkit. Slides with an initial stimulus and a response recording mechanism were set up in the toolkit to determine a participant's sense of time. The pulse duration for the stimulus was given by the formula $(n * 100) - 5ms$. The task was a single input task, and the participants were notified of the aim of the experiment. Participants were also given some information regarding the action they were expected to take and warned against using techniques to track time. The experiment was divided into two blocks, with a short break between the blocks. In the first block a visual stimulus is introduced in the form of a green dot with an exclamation mark. The stimulus was presented for a set of predetermined times *[*$1165ms, 1265ms, 1395ms, 1535ms$ *and* $1675ms$*]*. At the end of the preset time, a target stimulus appeared on the screen in the form of a red dot with a question mark. The participant was tasked with pressing the space bar key when they felt the target stimulus was on the screen for the same duration as the original visual stimulus.

In the first block of the experiment, all preset times for the visual stimulus were equally distributed, in a random order. In the second block of the experiment, the longest (1675*ms*) and shortest (1165*ms*) times were repeated more than the other preset times.

Participants and data aggregation

The participants were students of the Cognitive Modelling course at the University of Groningen. Participants were randomly assigned systems, splitting them into two groups. One group had more long duration pulses in the second block while the other had more short duration pulses in the second block of the experiment.

Initially, there were 77 participants in the experiment. Some participants took the experiment on a different day and some participants had issues with unresponsive hardware. Excluding these participants, the final data set consists of a total of 61 participants, split as 30 participants in the group with higher frequency of long duration and 31 participants in the group with higher frequency of short duration.

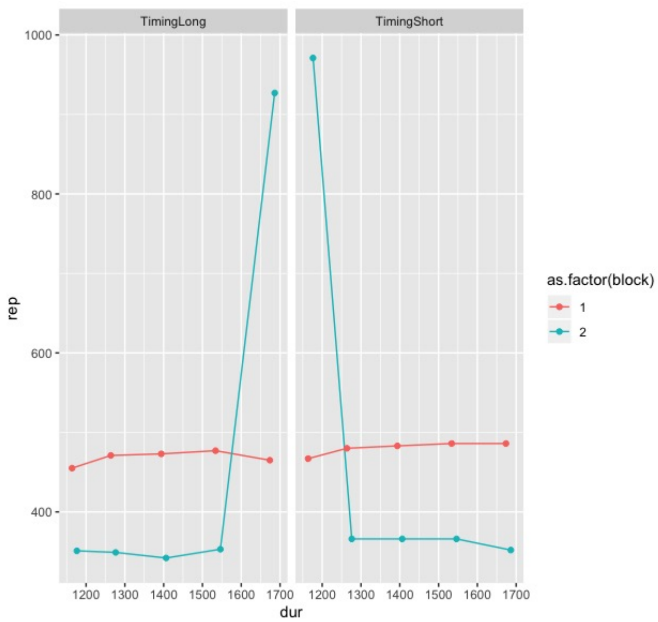

Figure 1: Summary of a single trial

Model

A model was built to simulate a participant pool, comprising of 80 ACT-R agents. Each agent was identified with a subject number in order to divide the agents equally among long and short conditions. Each agent participated in two blocks of temporal tasks, similar to the human participants. At the end of a block, comprising of 80 stimulus-response pairs (the agent receives 80 inputs in one block of the test), the agent is given a 30000*ms* break, as the participants in the real-life experiment were given a 5 minute break at the end of a block. In the second block, odd numbered agents were subjected to higher number of shorter pulses and even numbered agents were subjected to higher number of longer pulses.

Data was generated and randomized for the two blocks and the two conditions (long duration or short duration skew) based on the experimental setup data given in Table 1.

Time Duration in *ms*	1165	1265	1395	1535	1675
Block 1 Frequency	16	16	16	16	16
Block 2 Frequency Condition Long	12	12	12	12	32
Block 2 Frequency Condition Short	32	12	12	12	12
Inter Trial Interval	$3000 \pm 250ms$				
Inter Stimulus Interval	$800 \pm 100ms$				

Table 1: Experimental Design

The model was simulated in the Python programming language (Rossum & Boer,1991) with a Python implementation of ACT-R. We expect the model to assist in proving our hypothesis of the effect of priors reducing over time and proving that there are inherent biases in the perception of time.

Results

All analysis of the real-life experiment was carried out using the R language (R Core Team,2013).

Based on the analysis of the data obtained from the final list of 61 participants, we find that the effect of experimental delays on the participant performance is quite different from the observations made by Jazayeri and Shadlen, who stated prior representation of various time intervals interfere with each other(Jazayeri & Shadlen,2010). There may be several factors that contribute to this behavioral anomaly, such as similarity between samples. The results from a single trial are as in Figure 1.

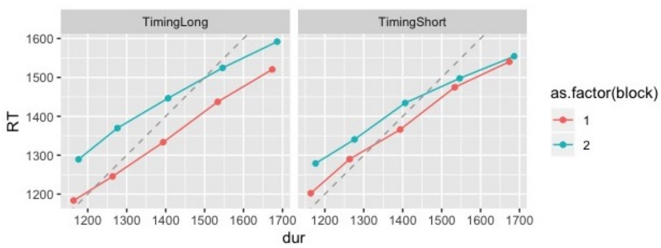

Figure 2: Reaction times based on experiment

We fit Linear Mixed Effects Models (Bates, Mächler, Bolker, & Walker,2015) to the cleaned data in order to test the effect of various other predictors on the reaction time. We noticed that including more predictors to the mixed effects model only resulted in lower fitness scores. The final model of choice utilized the formula $(ReactionTime = Intercept + StimulusDuration + ParticipantIntercept)$, based on the comparison of the Akaike Information Criterion *(lower is better)* (Akaike,1998).

Based on the models, we conclude that the subjects showed no effect of priors on the timing task. The performance of the participants can be explained by simple linear models.

It could be possible that the data from the real-life experiment is skewed due to the participants tiring from the temporal task and thus increasing the errors in perceiving differences in the stimulus.

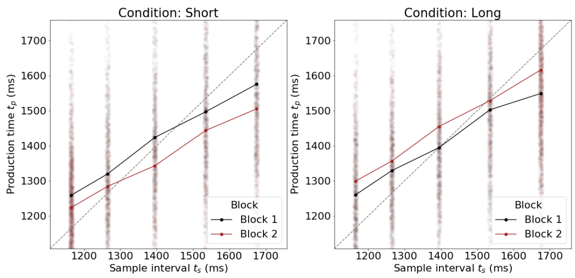

Figure 3: ACT-R Agent simulations: 5 minute inter block interval

The simulations of ACT-R Agents performing the temporal task are as in Figure 3. We notice that the results of the simulation are significantly different from the expected result of (Jazayeri & Shadlen,2010).

Discussion

From Figure 3, we notice that the model does not behave as expected from (Jazayeri & Shadlen,2010), with the effect of temporal priors skewing the response times in the second block for both long and short durations of the experiment. Based on the figure, we see that the model's responses for the longer bias follow a steeper curve than that for the shorter bias. Thus the model is able to approximate the intervals it sees most frequently with lower error. The general relationships between sample intervals and the production times vary slightly for both short and long biases. The curves are now not expressed by a linear model as discussed in (Jazayeri & Shadlen,2010). We notice that the model does not depict the pattern that the human participants depicted on the same experiment. This could be due to the lack of a "tiredness" factor in the model, allowing the model to focus better at the task than the human participant.

As discussed in (Acerbi et al.,2012), we see that humans are not very adept at perceiving time unless it is a uniform distribution. A similarity is seen in the ACT-R agents, although the effect is not as significant as seen in the human subjects.

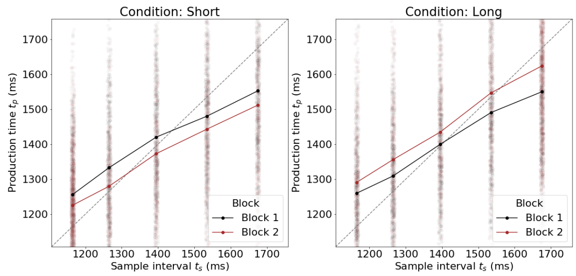

Figure 4: ACT-R Agent simulations: 15 minute inter block interval

Furthermore, when the model is allowed to have a longer break between the two blocks of the task, we notice the effect of priors from the first block are almost completely lost. As in Figure 4, the plots for the blocks for both biases are almost parallel, depicting that the effect of times memorized has been forgotten over the break between the blocks. Similar behaviours may be expected in humans, when subjected to time-based tasks with large breaks in between (consider a drummer on hiatus, the drummer would find it difficult to play to a rhythm perfectly after a long vacation).

Hence we see that the effect of priors is immediate in the perception and recollection of temporal signals. The priors can decay over time, causing errors in perception of time later in the task. This also supports the argument that the perception of time is task specific (Mangels & Ivry,2001). The interference effect supports is visible in the decay of memorized time signals when the participants are made to take a long break in between blocks of the experiment (Brown,1997).

Humans have an inherent bias to shorter or longer time signals when faced with a temporal task. Humans are also imperfect at recollecting odd distributions of time (Acerbi et al.,2012).

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