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Literature Review:

We all know that the passage of time affects our memory, even in the short term. For example, most of us have had the experience of being introduced to someone only to realize moments later that we've already forgotten their name! However, our experience of time is subjective and influenced by the world around us: "Time flies when you're having fun" or a very busy day, but "a watched pot never boils" and time can feel like it is dragging on when we are bored. Which matters more for our short-term memory - the physical passage of time, or our perception of it? My study will continue a line of work that addresses this question as well as continuing to explore a relatively new discovery: Time does not only decrease our ability to recognize what we have learned, it can increase our ability to correctly identify (and reject) what is not a part of our memory.

The surprising discovery that a longer passage of time can paradoxically improve some aspects of our short-term memory was first reported by Jang et al. (2022). They tested participants using a standard probe-recognition (Sternberg) working memory task. These kinds of tasks have three phases: First, during the encoding phase, a set of letters are presented and the participant's task is to hold them in memory. The second phase is the delay period, also called the retention interval, with a fixation in the center of the screen. The third phase is the probe or test phase, during which a single letter (the memory probe) is presented and participants are asked to indicate whether or not the probe item was in the set of letters presented at the encoding phase. A relatively unique aspect of the Jang et al study is that it used 2 different retention intervals: A "short" delay of 4 seconds, and a "long" delay of 16 seconds.. As expected, it was harder to remember that a probe was a member of the memory set after the longer retention interval. The more surprising finding was the longer retention interval also made it easier to reject unstudied probes as not being members of the memory set. Importantly, modeling analyses suggested that this enhanced correction rejection rate was related to the quality of the memory representations, not simply an increased bias to call something "new".

Jang et al. (2022) speculated that this new finding might be explained by extending the Temporal Context Model (TCM; Healey & Kahana, 2016). The TCM states that when the probe is presented, the context of the encoding period is reactivated, and the degree of match between that representation and the context in which the probe is presented helps decide whether the probe was or was not part of the encoded set (i.e., whether it was also present in the encoding context). The more time passes between the encoding period and when the probe is presented (i.e., longer retention interval), the more difference there is between the context in which the probe is presented and the original encoding context. The TCM posits that for situations where the probe is one of the encoded letters, the greater context differences might make it more difficult to identify the 'match'.

Jang et al. reasoned that those greater differences might also make it easier to reject new, unstudied probes as they would have less of a contextual match with encoding. If the TCM is able to explain the discovery of Jang et al (2022), then manipulating the amount and speed of context changes within the retention-interval might induce the same effects. That is, manipulating the subjective experience of time might also result in enhanced ability to correctly reject. To test this possibility, Whitney (2022) conducted a follow-up study that held the duration of the retention interval constant, but manipulated other factors that might affect people's perception of the passage of time.

Specifically, Whitney (2022) kept the retention interval at a constant 12 seconds, but manipulated how quickly (and how much) a circle presented in the retention interval changed from nearly transparent to more opaque. In the slow-changing condition, the circle gradually increases its opacity every 3 seconds. Thus, the circle's opacity changes 4 times during the retention interval. This was expected to make participants feel as if time were passing relatively faster, mimicking the "short" delay in Jang et al. (2022). In the fast-changing condition, the circle gradually increases its opacity every second. Thus, the circle's opacity changes 12 times during the retention interval. This was expected to make participants feel as if time were passing relatively slower, mimicking the "long" delay in Jang et al. The fast-changing condition thus had greater changes in temporal context.

As predicted, Whitney (2022) found that correct rejection rates were higher after 12 color-changes than 4 color-changes, even though the actual retention interval was identical. The results of Whitney's (2022) study show that the increase in correct rejection rates is not dependent on the physical passage of time. However, the nature of the manipulation used in that study makes it difficult to precisely determine what the underlying mechanism might be. The 12 color-changes condition was both faster and had a greater difference (greater change from transparent to opaque between the start and the finish of the retention interval). While this manipulation mimics real-world conditions (usually things that change faster also change more), it leaves the door open to several possible interpretations as to the underlying mechanism.

For example, things that move faster often induce more arousal. (One rarely hears of a "slow-moving, heart-pounding adventure".) They also tend to hold our attention better. Are those effects of the speed of change enough to induce the increase in correct rejection rate, or is it really the amount of change between the encoding and probe period that matters?

My study will attempt to disentangle these factors by focusing specifically on the speed at which changes occur during the retention interval, while keeping the amount of change constant. Similar to the Whitney (2022) study, I will keep the retention interval constant at 12 seconds, and have either 4 or 12 color-intensity changes within that interval. However, the present study will use only two color intensities: light and dark, and alternate between them. Thus, the speed of color change will be different between the two conditions, but the amount of color-intensity difference between the start and end circles will be identical. If speed alone can increase the correct rejection rate, then 12 color-intensity changes should have the higher correct rejection rate. If the amount of change is the critical factor, then there should be no difference in correct rejection rate between 4 and 12 color-intensity changes. To further explore the possible impacts on arousal and attention, I will also add simulation of both 4 and 12 color-intensity changes followed by questionnaires.

Research Hypothesis:
The main question is whether the speed of context changes or the amount of context changes is the mechanism underlying for the improved higher rate of correct rejections. In order to do that, the retention interval will be constant, and there will be fast and slow context changes. Does the speed of changes during the retention interval impact working memory performance - specifically, the ability to correctly reject "new" probes?

Research Design:
Participants:

The pilot study will consist of participants from the Subject Pool of Psychology Introductory class. Then, the main participants will be recruited from Prolific. In Prolific, the eligible participants will be filtered through age, sex, education, nationality, etc. The final number of participants needed will be finalized after the pilot data is collected.

Task and design:

The primary task of interest will be a Sternberg working memory task with a very similar structure as that used by Jang et al. (2022) and Whitney (2022). In addition, participants will complete a short follow-up task to assess their subjective response to the slow vs fast color-intensity changes. Both tasks are programmed in PsychoPy (v2022.1.1) and converted to Java for implementation on Prolific.

Participants will first receive information about the overall structure of the whole experiment (how many trials, how long the experiment is expected to take, etc.) and complete informed consent procedures. They will also be asked to indicate their willingness to share their de-identified data (on OSF or a similar site). They can participate in the experiment even if they decline data-sharing. As noted above, the Sternberg working memory task used in the current study has the same basic structure as that used by Jang et al. (2022) and Whitney (2022), with the major difference being the content of the retention interval. On each trial, a memory set of 4, 6, or 8 letters is presented for 3 seconds. This is followed by a retention interval of 12 seconds. During the retention interval, a colored circle is presented that alternates between low (8% opacity) and high (98% opacity) at either a fast (every second) or slow (every 3 seconds) rate. After the retention interval, a letter will be presented for 3.5 seconds and the participants have to decide whether the letter belongs to the previously presented set size using the "z" and "/" keys. (Mapping of keys to "yes" or "no" will be counterbalanced across participants.) Participants will be given feedback after each trial: “Correct”, “Incorrect”, or (if they do not respond within the 3.5s time period) , “Please respond faster”. Participants will also be presented with their cumulative percent accuracy throughout the trials.

Participants will be given explicit instructions to follow for each stage of the task. They will start with an example trial, followed by the practice trials. In order to make sure the participants are able to perform the task as necessary, there will be 5 sets of 10 practice trials before the main trials. The participants must get 80% correct on one of the sets in order to move on to the main trials. In the main task, there will be a total of 150 trials, separated into 5 runs of 30 trials each.

After completing the Sternberg task, participants will complete a short follow-up task with 12 trials that present the fast and slow opacity changes (6 each, randomly intermixed) separate from the Sternberg task, and be asked to complete questionnaires to assess their subjective responses. The questionnaires will ask how fast participants felt time was passing while viewing the stimuli, how energetic they are, how bored they felt, how sleepy they were, how alert they were, and if the changing stimuli kept their attention. Each of the questions will have a rating scale from 0 to 100 with a slider. Three of the questions will be presented at a time with the rating scale. These questions will give us insights into participants' subjective responses to the fast- vs slow-changing stimuli, , and will be used to interpret the main results and guide the design of new studies.

After completing the rating scales, participants will be asked two open-ended questions. One will ask their thoughts on what the experiment was about, and the other there is anything they would like to tell us. The answers to those questions can help provide potentially converging evidence or suggest additional variables we need to consider in future studies, as well as help identify participants whose data may need to be excluded for unexpected reasons (e.g., disruption during the experiment, difficulty understanding instructions, health conditions that may have affected performance).

Analysis

My analyses will generally follow those used by Jang et al. (2022) and Whitney (2022). For a first step I will use a 2 x 3 within-subjects ANOVA (Speed (fast, slow) X Set size (4, 6, 8)) on both hit and correct rejection data. The main question is whether there is a main effect of speed on correct rejections. Later analyses may include diffusion-modeling parameters in a similar design. Secondary analyses on the questionnaire data will use a within-subjects t-test again comparing responses for the fast vs slow conditions.

Timeline:

June: Literature Review
July: Programming task
August: Sync to Pavlovia
September-October: Data collection and analysis
November: Writing Methods section
December: Writing Introduction section

January: Writing Discussion and Abstract section
February: Finish rough draft
March: Final draft

Support and feedback:
My mentor will be Dr. Lustig and plan to meet bi-weekly. Every day I work on something related to my thesis. I write about the work I did for her to evaluate and plan on what I should do next.

References:

Howard, M. W., & Kahana, M. J., (2002). A distributed representation of temporal context. *Journal of mathematical psychology*, 46(3), 269-299 https://doi.org/10.1006/jmps.2001.1388

Jang, H., Lewis, R., & Lustig, C. (2022). Opposite reactions to loss incentive by young and older adults: Insights from diffusion modeling. *Psychology & Aging* 34(7), 469-485. *https://doi.org/10.1037/pag0000689*

Whitney, E. (2022). Effects of retention interval context changes on working memory. Psychology Department, University of Michigan.