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Memory Scanning: Improving Our Understanding of How We Remember

Adrienne Sands

Washington University in St. Louis

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Human beings have always been fascinated with understanding aspects of the self—whether that understanding is used to improve the self, one’s relation to others, or the very trait one seeks to understand. In particular, consider the persistent fascination with short and long term memory. Why does one remember certain things but not others? How can one hasten recall from one’s memory “files”? Is one’s ability to remember determined by factors beyond the passage of time? With the answers to these questions, human beings can work to improve--even perfect—the ability to remember holidays, important names, facts relevant to one’s trade, past experiences which don’t need to be repeated, etc. A complete understanding of memory would enhance productivity, social relations, and our general state of mind. After all, there is not one person who wouldn’t be better off without the occasional frustration of forgetting what one was doing at work; the blank stare as one’s partner mentions an important holiday that almost went by unnoticed; and the lost hours spent trying to find keys, wallets, cell phones, and glasses.

For illustration, consider the doors that would open if one could remember every piece of information stored inside our heads. This illustration distinguishes between the two major processes involved with memory: storage and recall. If one considers the mind as akin to a filing cabinet, storage is the process of categorizing information and storing it in the appropriate file. Recall is the process of retrieving that file as needed. Again, consider the possibilities with complete recall. Nordvik, Schanke, and Landro (2011) must have done so when designing their study on the impact of errors on recall performance. They questioned whether students learned best when motivated to try without guaranteed success (*errorful learning*) or to strive for 100% accuracy (*errorless learning*). They found that students had better recall when they only attempted methods that assured accuracy. With this finding, teachers now have a reason to choose an accuracy-based assignment over one that encourages trial and error; over time, perhaps this change will lead to more effective learning (vis-à-vis greater recall).

As the aforementioned study illustrates, a complete understanding of memory gives us the tools needed to improve it. But before one can consider likely methods of improving recall and storage, one must have a general idea of how memory works. To answer this fundamental question, Sternberg (Year) created what is now known as “Sternberg’s Memory Scanning Task”. He presented his participants with a varied-size set of numbers (the memory set) with another random digit displayed immediately after (the *probe).* For each trial, the participant’s goal wasto determine whether the probe was contained in the memory set. Sternberg believed that the key to understanding short term memory would be found by comparing participants’ rates of success in various conditions (described below).

One can imagine two methods that participants used to complete this task: either they compared the probe one by one to each member of the memory set or they compared the probe to all members of the set simultaneously. Sternberg (Year) coined the terms serial and parallel to describe each form of mental processing, respectively. More specifically, Sternberg also identified two types of serial processing. First, the participants could compare the probe to each member of the memory set only until they find a match*—*a method known as serial self-terminating processing. However, the participants could also compare the probe to each member of the memory set (whether they find a match or not) via serial *exhaustive* processing. By varying the length of each memory set and the presence/ absence of the probe, Sternberg believed that the pattern of the participants’ response times under each condition would reveal which type of process was at work. For example, if memory involves serial processing, reaction time (*RT*) would increase as the size of the memory set increased—reflecting the time needed to process each additional digit. If memory operated in a self-terminating fashion, the rate of increase in reaction time would be lower for probe-present trials as compared to probe-absent since the participant could respond as soon as he found a match. If memory is serial and exhaustive, we would expect a consistent rate of increase in reaction time for increased set sizes (in both probe-present and probe-absent trials) because the participant must traverse the whole list regardless of absence or presence. On the contrary, a relatively constant reaction time across set sizes would point toward parallel processing; the time needed to compare the probe to the entire set should not depend of the size of that set.

Our study is intended to replicate Sternberg’s (Year) findings and answer the same questions: Does short term memory involve serial or parallel processing? When it comes to short term recall, do human beings make comparisons in a self-terminating or exhaustive fashion? I hypothesize that memory processing occurs in a serial, exhaustive fashion because it is easier and more efficient than the other processes. While parallel processing requires that participants consider digits simultaneously, serial processing allows the brain to process one at a time. This particular task also requires that participants process the digit then judge probe presence. It is much more efficient to switch once at the end as (in an exhaustive process) than after every digit (self-terminating process). Evidence for (or against) this claim moves research one step closer to a complete understanding of memory. As aforementioned, understanding opens the door for improvement. The results of this experiment may have countless applications to education, self-improvement strategies, and work place training—arenas where the ability to remember (and remember well) is necessary.

**Method**

**Participants**

Thirteen undergraduate students participated in this experiment. They did not receive monetary compensation for this mandatory study. One participant was unable to complete the study since her computer crashed about half way through. The experiment took approximately 30 minutes and was scheduled to end with the class period.

**Apparatus and Procedure**

Participants were briefed on the experiment’s basic design and their task before the experiment began. Participants were seated in front of a standard PC computer monitor in a well-lit room. All stimuli were presented in white text of the same font on a black screen. On each trial, a random set of digits (the *memory set*) was presented in the middle of the screen for 1200 milliseconds. Each set contained between one and six digits (excluding “0”). The memory set was then replaced by a plus-sign for 500 milliseconds. After the plus-sign disappeared, the participant was presented with a *probe* *digit*. At this point, it was the participant’s task to respond as quickly as possible by pushing the “/” key with the right hand if the probe was a member of the set, or the “Z” key with the left hand if the probe was not a member of the memory set. If the participant responded correctly, the next trial would begin after 1500 milliseconds. If the participant responded incorrectly or failed to respond within 3000 milliseconds, an error message was presented for 500 milliseconds and the next trial would begin. For each trial where the participant responded correctly, the *reaction time* (time between the presentation of the probe digit and the participant’s response) was recorded by the computer program. Reaction times for incorrect responses (or those over 3000 milliseconds) were excluded from analysis.

**Design**

A 2 x 6 within-subjects factorial design was used. For this experiment, the independent variables were set size (levels 1, 2, 3, 4, 5, and 6) and probe presence (either present or absent), and each trial featured one level of each factor. Each participant performed under all possible conditions. A session consisted of 288 trials grouped into blocks of size 48—1 practice block followed by 5 test blocks. Between each block, participants were prompted to take a break of undetermined length. Set sizes and probe presence were randomized within each block, but trials were counterbalanced such that each of the twelve possible conditions occurred equally often (i.e. in 24 trials total). Reaction times were measured for each type of trial.

**Results**

Mean reaction times for each condition are shown in Figure 1. As can be seen, there was a main effect of set size on reaction time: participants were significantly slower as set size increased, *F*(5, 60) = 31.74, *p* < 0.001. The levels of probe presence are indicated by the separate lines in the figure. There was a main effect of probe presence on reaction times, *F*(1,12) = 50.89, *p* < 0.001. On average, participants were faster when the probe was present compared to trials where it was absent. We also conclude that set size interacted with probe presence, *F*(5,60) = 4.22, *p* < 0.005. While set size increased reaction time for both levels of probe presence, it did so at a faster rate for probe-present trials compared to probe-absent trials. Thus, the effect of set size on reaction time depended on the level of probe presence. This is shown by the steeper slope of the trend lines and by the position of the plotted means. We get the following line of best fit for the probe-absent data: 16.05 (set size) + 492.15, *R2*= 0.84; furthermore, the best linear regression for probe-present data was 24.96 (set size) + 420.79, *R2*= 0.84. For these regressions, the slope represents the time it takes to process each digit in the memory set while the y-intercept represents the time needed to respond (without a memory set). Since these lines fit the data pretty well, we can conclude that a one digit increase in memory set size takes 8.9 seconds longer for probe-present trials; furthermore, it takes participants about 71.4 seconds longer just to respond.

The mean reaction time for set size one appeared extreme; thus, an ANOVA was conducted without this data. Again, we find that reaction time increased with set size, *F*(1, 12) = 34.99, *p*< 0.001. Participants were also faster in trials where the probe was present, *F*(4, 48) = 15.02, p<0.001*.*  Without set size one, we find no interaction between set size and probe presence, *F*(4, 48) = 1.58*,* n.s. Thus, removing these reaction times maintained each main effect, but negated the interaction.

Accuracy rates for each condition are depicted in Table 1. First, note that there was a main effect of set size on accuracy, *F*(5, 60) = 6.48, *p <* 0.001. On average, participants were generally less accurate in their responses as set size increased. Next, we found that probe presence had no main effect on accuracy, *F*(1, 12) = 0.18, n.s. Participants had essentially the same accuracy in probe-present and probe-absent trials. However, there was also an interaction between probe presence and set size with regards to accuracy: while accuracy generally decreased with set size, participants were slightly more accurate on probe-absent trials for larger set sizes and equally as accurate for smaller set sizes, *F*(5, 60) = 2.40, *p* < 0.05. This is shown by the slightly non-parallel nature of the probe-present and probe-absent accuracy. We shall attempt to explain this result in terms of a possible speed-accuracy trade off in the next section.

**Discussion**

In the present study, reaction times increased with set size and were slower in probe-absent trials. As set size increased by one digit, reaction time increased by about 20.5 milleseconds in all trials (i.e. over both levels of probe presence). One must note that if memory comparisons occurred via parallel processing, set size would have no effect on reaction time; since there was a positive main effect, our data is inconsistent with the method of parallel processing.

We also found that participants were generally faster in probe-present trials across all set sizes. This result does not rule out--or directly support--any of the three methods of memory processing but suggests something else at work. For example, if participants were right handed, participants used their dominant (perhaps, quicker) hand to give a “present” response. It could also be the case that participants were more confident or eager (and therefore faster) to give a “present” response than an “absent” response. Nonetheless, this result does not rule out any of our hypotheses or potential methods of memory processing.

Next, consider the interaction between probe presence and set size: the effect of set size on reaction time was more pronounced if the string contained the probe. In fact, participants were more slowed by an increase in set size if the probe was present. First, note that the presence of an interaction between set size and probe presence is inconsistent with the method of serial, exhaustive processing. In this method of processing, participants process each and every member of the memory set—even if the probe is found before reaching the end. Since it would take just as long to traverse the set if the probe is present versus when it is absent under this method of processing, we would expect that probe presence would not affect the rate at which set size slows reaction time. Our results are inconsistent with this hypothesis; thus, we can rule out serial, exhaustive processing from our consideration. Finally, consider the method of serial, self-terminating processing: participants process each member of the memory set and may give a response before reaching the end of the memory set. For large set sizes, the probe could be an early member of the set and would yield a much quicker response than in trials where the probe is absent. Thus, we expect that participants would be more slowed by an increase in set size if the probe was absent. In other words, we expect an interaction in the opposite direction as the one we found, and so our data is inconsistent with the method of serial, self terminating processing.

The direction of the interaction between set size and probe presence presents a problem for our hypothesis (serial, exhaustive processing) and all three suggested methods of memory scanning. However, Figure 1 suggests that this inconsistency might be explained by the extreme result for set size one. Removing this outlier, we found that while the main effects stay the same, there is no longer an interaction. Ignoring set size one, the data are consistent with serial, exhaustive processing.

Finally, consider the possibility of a speed-accuracy tradeoff. As expected, the error rates were approximately equal for probe-present and probe-absent trials; participants became less accurate at a faster rate for probe-present trials than probe-absent trials. However, the most important result for this discussion was the presence of a main effect of set size on accuracy: as set size increased, accuracy decreased (especially for trials in which the probe was present). If participants had maintained the same level of accuracy across all set sizes, we expect that reaction times would increase with set size at a greater rate for probe present trials than probe absent trials. This would strengthen (but not reverse) the conclusions of this experiment; thus, it is unlikely that a speed-accuracy trade off influenced the results.

**Footnotes**

1 As discussed, this result does not hold for set size four. We believe that this result is an outlier with no important theoretical explanation. One must consider, however, that this may have contributed to our finding that probe presence had no effect on accuracy rate. It is likely that future replications of this experiment will not reach the same result. Regardless of this fluke, there was an interaction between set size and probe presence on accuracy rate.

Figure Captions

Figure 1*.* Mean reaction time for each level of set size and probe presence. The trend lines are also included and reflect the best linear fit for each level of probe presence.

Figure 1

Mean reaction time for each level of set size and probe presence. The trend lines are also included and reflect the best linear fit for each level of probe presence.

Table 1

Accuracy rates by probe presence and set size

|  |  |  |
| --- | --- | --- |
| Probe Presence  Set Size | Present | Absent |
| 1 | 96.16% | 95.77% |
| 2 | 95.39% | 96.93% |
| 3 | 93.08% | 93.46% |
| 4 | 95.77% | 91.54% |
| 5 | 89.62% | 93.46% |
| 6 | 85.39% | 87.69% |

General Comments

Intro: You did a nice job on this version and dealt well with the comments from the first draft. For specific comments, see those in the Intro section.

Results: Again, nice job addressing the comments from the first draft. No major issues, just see the comments in the Results section.

Intro: 9/10

Results: 9/10

Format: 4/5

Method: 8.5/10

Discussion 9/10

Total: 39.5/45