Serial List Recognition in Rhesus Macaques (*Macaca mulatta*) and Humans

Patricia A. Wilson, Janet Metcalfe, Ph.D. & Herbert S. Terrace , Ph.D.

Columbia University Psychology Dept. & NYSPI

INTRODUCTION

Here we describe a new method for studying serial memory in rhesus, the Serial List Recognition (SLR) paradigm. To obtain comparative data, we also trained and tested human subjects using the same paradigm. The SLR paradigm has a trial structure similar to that used in the SPR (Serial Probe Recognition) paradigm. In both paradigms, the subject observes a multi-item sample (see Figure 1A) and following a retention interval, the subject's memory of the samples are tested. On the SPR paradigm, the subject is shown a *single* probe. The task is to indicate whether that probe appeared during the sample. On the SLR paradigm, all of the sample items appear simultaneously, along with a number of distractors. In this series of experiments, the subject is rewarded only after it responds to *all* of the sample items shown on each trial (in any order). A response to any of the distractors ends the trial with a time out.

METHOD

Monkeys were first trained on a simple matching-to-sample (MTS) task where the samples and choices were presented on a touch-sensitive video monitor. They were then trained on 3 and 4-item SLR tasks. Human subjects were given the SLR task without prior training. They responded by moving a mouse to each item they selected.

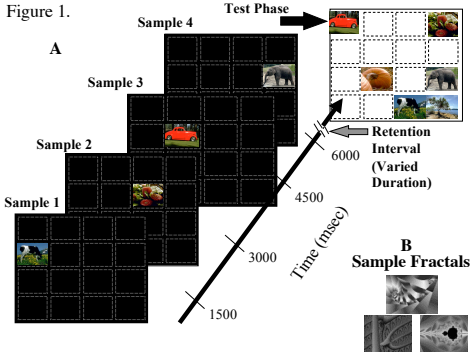
Monkeys were required to touch each sample item 3 times. This extended the programmed duration of each sample item (1.5 s) by a small amount (μ= 1.995 s; SD = 0.236 s). Sample items, which were trial unique, were presented successively with a 0-s interstimulus interval.

Human subjects were only required to click on the sample once and were assigned to one of four conditions. The Picture condition utilized the same stimuli the monkeys received. Black and white fractal images (Figure 1B) were used in the Fractal Condition. During the first two conditions (Picture and Fractal) the human subjects viewed the sample until they clicked on it; no time limit was determined. For the third condition (Time), subjects were only given 1.5 s to select the sample and were shown black and white fractals. For the final condition (Babble), the samples were composed of color fractals. Subjects were given 5s. to respond to each sample. During the entire session subjects were required to repeat the word "the" to prevent rehearsal.

Following a retention interval, (1-8 s) the 4 sample items were presented simultaneously, along with 6-8 distractors. The position of the sample items and the distractors varied randomly from trial to trial on the subject's video monitor. The distractors were selected at random from a pool of approximately 800 items, with the restriction that each distractor was only shown once during the same session.

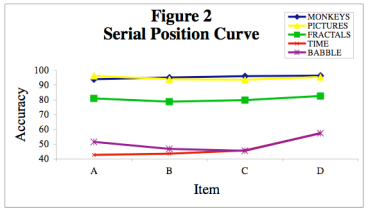
The subject's task was to select all of the items displayed on the sample list, in any order. Correct responses produced brief auditory and visual feedback. Errors terminated the trial with a 5-s blackout. Subjects were given a reward (a 190 mg BioServ banana pellet, or "Good Job" message) only if they responded to all of the sample items without selecting any of the distractors

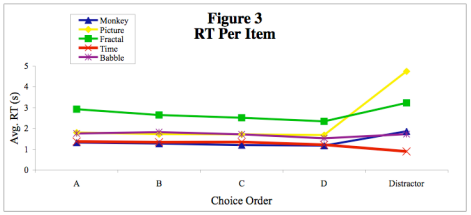
Figure 1.



RESULTS

As can be seen in Figure 2, subjects recognized most of the sample items on each trial. For human subjects, accuracy decreased with each condition (Pictures, Fractals, Time, and Babble). Reaction times (RTs) followed the a different pattern. While the RTs were explicitly constrained in the Time Condition to match the RTs of the monkey subjects, RTs increased under the Pictures, Fractals, and Babble. The RT increase mirrored the subjects' reported difficulty with the task. Interestingly, RTs to distracters were longer than to target items with the exception of RTs during the Time and Babble Conditions.





The order in which monkeys reported the sample items was heavily biased toward recency. Mean out position (MOP) is a measure of the relationship between the order in which sample items are presented and the order in which subjects respond to those items during test. If, for example, D (the last item presented) is selected first it would be assigned an output position of 1 for that trial. While a D on the next trial that was selected third receives an output position of 3 for that trial. The relevant data are shown in Figure 4. The MOP was lowest for D, followed by C, B, and A respectively. Under the Picture and Babble Condition, human subjects showed both primacy and recency effects (A has the lowest MOP, followed by D). However, under the Fractal, Time, and Babble conditions, human subjects showed a large recency effect for item D.

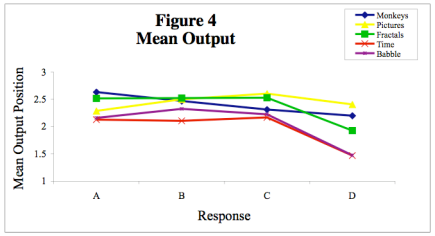
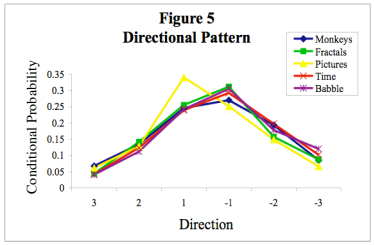


Figure 5 illustrates the directional pattern of subjects' responses. Previous research with human subjects showed that they were twice as likely to go forward as they were to go backward through word lists trained with a free recall paradigm. Under the Picture condition, human subjects showed this pattern of responses. However, monkeys and human subjects in the Fractal, Time, and Babble condition showed a symmetrical directional pattern (i.e., they were just as likely to move forward as they are to move backward).

One limitation to our current analysis, is our discovery that half of the subjects in the Babble condition still reported using a verbal strategy during the task. Data collection is ongoing, in order to divide the condition into reported verbal and nonverbal subjects. It is anticipated that differences between these groups within a condition may affect results.



CONCLUSIONS

Monkeys' performance on all of the measures that we used showed a strong recency effect [reaction time (Figure 5), choice order (Figure 3), and choice frequency (Figure 4)]. Our data also suggest that monkeys don't implement any strategy to enhance their memory of the order sample items were displayed. By contrast, the performance of our human subjects showed both primacy and recency effects. As the task was made increasingly difficult for the human subjects, primacy effects decreased and their patterns of responding approached that of monkeys in directional pattern (Figure 5) and mean output position (Figure 3). The absence of a primacy effect in monkeys and the difficult human conditions, is consistent with the frailty of primacy that has been found in other animals, infant and adult human studies.

The SLR paradigm provides an effective assay of working memory of serial presented items. By requiring multiple responses, this method provides insights into the strategies that naïve subjects use. In future studies we plan to train monkeys to respond to the stimuli in the order in which they were presented.

ACKNOWLEDMENTS

pwilson@psych.columbia.edu

- Terrace Lab:
  - Herbert Terrace
  - Tammy Moscrip, Ph. D.
  - Dustin Merritt
  - Tamar Kornblum
  - Gin Morgan
- Eric Anderson
- Metcalfe Lab:
  - Janet Metcalfe, Ph.D
  - Nate Kornell
  - Bridgid Fin
- Monkeys: Prospero
  - Horatio
  - Guildenstern