Monkey and Human Pictorial Memory Scanning

Abstract. *A rhesus monkey accurately recognized pictures in a Sternberg memory scanning experiment. When the monkey was tested with pictures that were reused during the same session, the monkey's performance was nearly identical to that of a human subject; this result demonstrates that monkeys are capable of some of the short-term retrieval mechanisms of humans.*

We recently trained a rhesus monkey to perform a serial probe recognition (SPR) task with lists of 10 or 20 items (*1*). We presented a sequential list of color slide pictures followed by a single, spatially distinct probe item on each trial. The monkey then indicated (by moving a lever) whether the probe item was the same as one of the list items or different from all of them. It performed correctly 86 percent of the time with 10-item lists and 81 percent of the time with 20-item lists. Recognition accuracy of "same" items as a function of their serial position within the list showed best memory for the initial (primacy effect) and terminal (recency effect) list items. This demonstration of accurate multiple-item memory performance in the monkey and its comparability to human performance in the identical task encourages a comparative approach to the study of memory processes. Sternberg measured reaction times (RT's) of humans performing an SPR task with lists of various lengths and derived a model to reveal the strategies the subjects used to scan memory (*2*). We now present results of a Sternberg memory scanning experiment with a monkey and a human, the purpose of which was to determine whether or not the monkey could and would use retrieval and decision strategies similar to those of the human (*3*).

The 5-year-old male rhesus monkey (*Macaca mulatta*) had extensive previous experience in the SPR task (*1*). It sat in a primate chair and viewed rear-projected color slides (12 cm by 19 cm) on two separate screens (16 cm center to center) from a distance of 50 cm. The slides were pictures of 211 distinctly different fruits, flowers, people, animals, laboratory hardware, and household objects. A 21-year-old female college graduate viewed the same pictures from 100 cm, but received no primary reward in an otherwise identical procedure.

The monkey and human initiated each trial by pressing down on a three-position lever. One second later the first list item was presented on the top screen for 1 second. Additional list items (if any) appeared sequentially for the same amount of time with 0.8-second intervals separating them. One second after the last list item, a probe item appeared in the bottom screen and remained in view until a choice response was made or until 2 seconds had elapsed. A lever movement to the right was a "same" response, and one to the left was a "different" response. Correct choices were followed by a 0.25-second 4000-Hz tone, and the monkey was rewarded by a small (0.5 cm^3) squirt of orange juice, a banana pellet, or a small squirt of applesauce. Errors turned on the chamber light for a 10-second time-out. A 2-second intertrial interval separated successive trials. For the monkey, four sessions of 140 lists each were conducted daily. "Same" and "different" probe trials occurred with equal frequency in a pseudorandom sequence (*4*). In experiment 1, "different" probe items were not seen in any previous list in order to maximize accuracy. A total of 5460 trials were conducted with the monkey and 1400 with the human.

Results from the monkey subject experiments are shown in Fig. 1. On "same" trials, mean RT for both subjects increased monotonically as a function of list length (*5*); each additional list item added about 13 msec. Similar values have been shown for humans with picture stimuli (*6*), but most experiments (even those employing picture stimuli) have found increases of 20 to 50 msec per item (*2, 7*). The monkey's "same" RT was roughly constant for the different serial positions occupied by the matching list item, with a hint of an inverted U shape for the two longer list lengths (inset, Fig. 1). For the human, serial position effects are evident with the "same" responses being quicker for items at the end of the list (inset, Fig. 1). Serial position effects are not uncommon in human memory scanning experiments (*7*), and they tend to complicate the interpretation of the results with respect to the underlying cognitive processes.

Unlike performance on "same" trials, mean RT's on "different" trials as a function of list length differed for the monkey and human. The human RT generally increased with increasing list length, whereas that of the monkey did not (*5, 6*). A lack of any RT increase with list length may reflect our procedure of making each probe item on "different" trials distinct from any other session item. Under these conditions, memory scanning may be unnecessary. The monkey would only need to answer the question "Have I seen this item sometime before during this session? If not, respond 'different.' " Such judgments, based on probe item novelty, could be as rapid after a six-item list as after a one-item list and thereby generate a flat "different" function. A similar interpretation has been applied to human performance

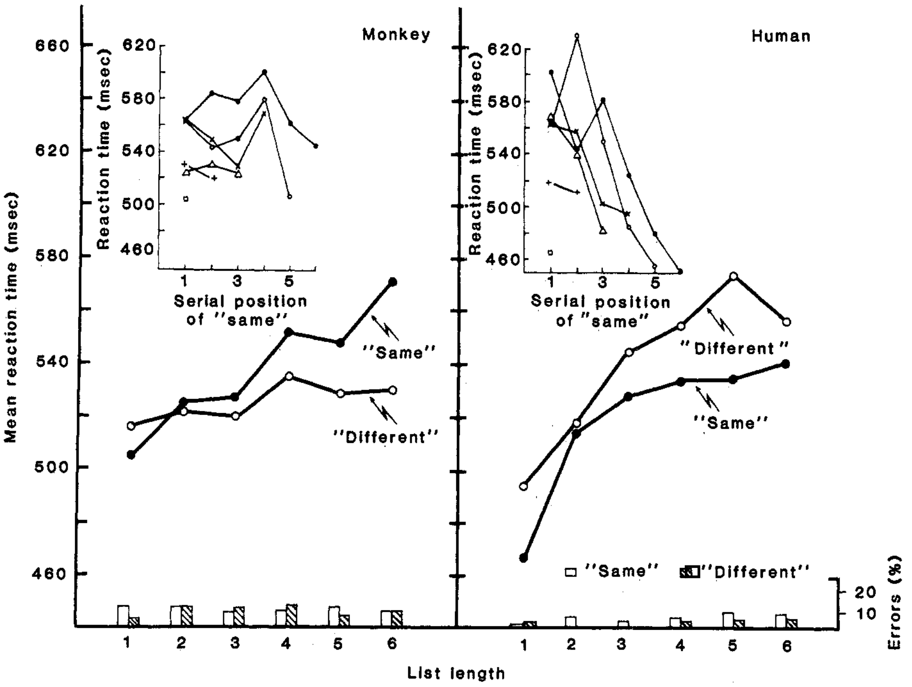

Fig. 1. Mean reaction time on correct "same" and "different" trials as a function of list length. Errors are shown on the abscissa. Insets show mean reaction time as a function of serial position on correct "same" trials for each list length: □, 1; +, 2; △, 3; x, 4; ○, 5; ●, 6. Serial position 1 corresponds to the first list item.

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in other experiments (*8*). One might expect a flat RT function for "same" trials because of a complementary strategy to respond "same" on the basis of item familiarity. But the slope is instead positively sloped, suggesting a bias toward novelty judgments.

We reasoned that we should be able to modify the monkey's "different" RT function by eliminating or diminishing its tendency to make a rapid novelty judgment on "different" trials. Changing the monkey's strategy to resemble that of the human would establish that, at least under some conditions, the monkey can use memory scanning processes similar to those of the human.

In experiment 2 we made it more difficult for the subjects to be correct on "different" trials by occasionally displaying a to-be-used "different" probe item in a previous list. Novelty judgments on such trials would produce errors, and possibly an abandonment of the novelty judgment strategy. The procedure was identical to that used in the first experiment except that there were two types of "different" trials: trials with familiar probe items that had been previously seen (between 11 and 45 items previous) and trials with novel probe items. The monkey participated in 11,280 trials, and the human in 2820 trials.

The monkey changed its performance dramatically on "different" trials and performed very similarly to the human (Fig. 2). For monkey as well as human, an increase in list length resulted in an increase in RT, indicating that each additional item requires an additional amount of processing time presumably associated with serial scanning. The RT's on "different" trials were slower than on "same" trials, reflecting greater difficulty or some feature of the decision process of this judgment independent of whether the probe item had been previously seen (familiar) or not (novel). For both subjects, the familiar probe items on "different" trials required more time than novel ones. This greater difficulty with familiar probes, which may be due to indecision at the response output stage, is reflected in an increase in the intercept of the RT function. On "same" trials the human's and monkey's RT's are of similar value and show regular increases with list length; each additional list item adds about 11 msec to the RT. Another indication of the strategy change brought about by our manipulation is shown by the monkey's serial position functions (inset, Fig. 2), which slope downward like the human's functions; RT's are faster for "same" trials when the probe item matches items at the end of the list, a result shown in SPR studies for humans recognizing picture stimuli (*6*).

Whatever the cognitive mechanisms or strategies involved, the monkey, which has no identifiable language with which to code, rehearse, or scan items, and human performed similarly in experiment 2 and the results are similar to other human memory scanning results, which have been interpreted as representing serial memory scan processes (*6*, *7*).

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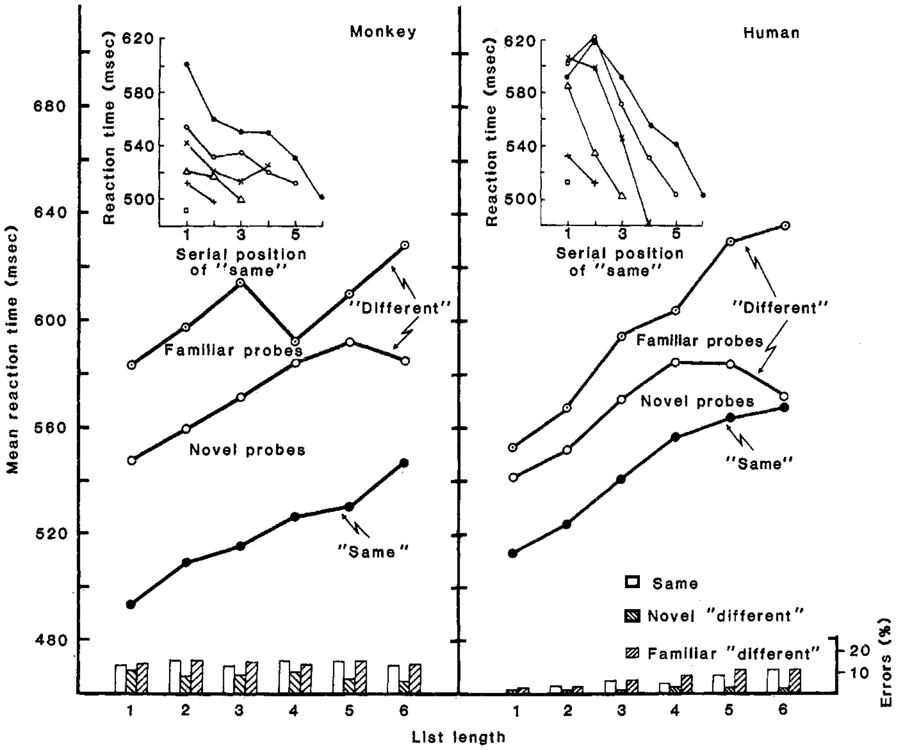

Fig. 2. Results from an experiment where the "different" probe items had been seen in a previous list (familiar) or had not been seen in a previous list (novel). Insets show mean reaction time as a function of serial position on correct "same" trials for each list length: □, 1; +, 2; △, 3; x, 4; ○, 5; ●, 6.

References and Notes

1. S. F. Sands and A. A. Wright, *Science* **209**, 938 (1980); *J. Exp. Psychol. Anim. Behav. Processes* **6**, 386 (1980).
2. S. Sternberg, *Science* **153**, 652 (1966).
3. Ours is not the first attempt to obtain memory scanning functions from a nonhuman subject. D. R. Eddy [thesis, Carnegie-Mellon University (1973)] trained monkeys in a task related to the Sternberg procedure but found only modest performance (70 percent correct) with short (one- to three-item) lists.
4. Our bottom projector slide tray (Kodak Carousel) held 70 "same" and 70 "different" probe items. The top projector contained the list items, which were presented sequentially. The 141-item sequence was presented 3.5 times per session, and the mean list length was 3.5 items. Under this scheme, "same" probe items could become familiar, whereas "different" probe items were always unique in experiment 1. There were no general performance trends across the individual sessions. Lists were programmed so that each new list resulted in a novel combination of items. To avoid the possibility that the monkey and the human might gain familiarity with the list sequences, no two sequences were tested consecutively. Lists of variable length (one to six items) were intermixed pseudorandomly, with equal probability within a session.
5. To determine the effects of list length on RT, the data were first fitted by linear regression and then tested for a slope significantly ($P < .05$) different from zero.
6. D. Gaffan [*Q. J. Exp. Psychol.* **29**, 451 (1977)] found much steeper RT functions for "same" than for "different" trials. Gaffan used conditions almost identical to ours, pictorial stimuli and novel probe items on "different" trials. Thus, like our monkey, Gaffan's humans may have adopted a quick novelty response strategy on "different" trials.
7. D. W. J. Corcoran, *Pattern Recognition* (Penguin, London, 1971); V. P. Raeburn, *Mem. Cognit.* **2**, 66 (1974); J. F. Juola, I. Fischler, C. T. Wood, R. C. Atkinson, *Percept. Psychophys.* **10**, 8 (1971); D. Burrows and R. Okada, *ibid.* **10**, 305 (1971); M. Aube and B. Murdock, *Mem. Cognit.* **2**, 27 (1974); R. E. Morin, D. V. De Rosa, R. Ulm. *Psychon. Sci.* **9**, 617 (1967); J. Theois, P. G. Smith, S. E. Haviland, J. Traupmann, M. C. Moy, *J. Exp. Psychol.* **97**, 323 (1973).
8. R. C. Atkinson and J. F. Juola, in *Attention and Performance*, S. Kornblum, Ed. (Academic Press, New York, 1973), vol. 4, p. 583; in *Contemporary Developments in Mathematical Psychology*, D. H. Krantz, R. C. Atkinson, R. D. Luce, P. Suppes, Eds. (Freeman, San Francisco, 1974), p. 242.
9. This research is based on experiments 6 and 7 of a thesis by S. F. Sands, University of Texas, Houston (1979). We are grateful for the suggestions of S. Sternberg, P. Urcuioli, and H. Santiago on an earlier draft of this manuscript, and we thank J. Cornish for her technical assistance. Partially supported by NIH grant EY-01256, NSF grant BNS 78-07253, and NIMH grant MH35202 to A.A.W.

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