TECHNICAL NOTE

*AN AUTOMATED MULTIPLE CHOICE TEST OF SHORT-TERM
SPATIAL MEMORY FOR MONKEYS¹*

Since Hunter developed the delayed response test in 1913, it has been widely used in the study of memory, brain damage, and behavioral pharmacology. A major problem is that the usual dichotomous choice method allows the animal a 50% chance of being correct on any trial. Thus, it is necessary to average the results of many animals or many trials to obtain a reliable measure of accuracy. A few investigations (e.g., Riopelle, 1959) have utilized manual multiple choice delayed response procedures, but these have been tedious to conduct and have not provided a measure of the degree of error. The present multiple choice procedure was designed to provide a semi-quantitative measure of the degree of error on a single trial.

METHOD

Subjects

The test was designed for rhesus monkeys weighing 5 to 9 kg.

Apparatus and Procedure

The monkey is tested in its home cage, a 36-in. (91 cm) cube with a 14 in. (36 cm) square opening in the door. A Plexiglas panel is attached to the cage at the opening. Mounted on the panel are eight lights (G.E. #313) arranged in a circle with adjacent bolts for contact responses and a ninth central light with an adjacent water solenoid. The subject's responses are sensed by a transistorized circuit for contact responses (Jarvik and Carley, 1964).

The sequence of events for a trial is composed of four phases: (1) the subject is presented with one of the eight lights as a preparatory stimulus. The subject must respond to the bolt corresponding to the preparatory light within 10 sec in order to initiate the trial. (2) After the subject responds, the preparatory light is extinguished and a delay period of several seconds or minutes ensues (during which time responses produce no results). (3) After the delay period, all eight lights of the circle come on and the subject has 20 sec to respond to them; the subject is allowed three chances to make a correct response, i.e., to the light that served as the preparatory stimulus. If a correct response is made, the center light comes on signifying that the

subject will receive a water reinforcer upon touching the water solenoid. Responses made after three unsuccessful attempts are not reinforced. The eight lights extinguish when either the reinforcement light comes on, three incorrect responses are made, or the 20-sec period elapses. (4) An intertrial period (equal in duration to the delay period) follows during which all lights are out and after which the testing sequence resumes with the preparatory phase.

All parameters (except for the amount of water reinforcer) are programmed into a PDP-8/1, 4K core computer. The mainline program to run the test is basically a sequence of four timing subroutines that allow periodic jumps to servicing subroutines. The program monitors the subject's responses and deploys the proper subroutines, which are determined by test-phase indicators that are constantly up-dated with every response and phase change-over.

The test parameters may readily be changed. These include the number of monkeys working the test, the number of trials per test session, the number of responses allowed before error, and the four basic phase time intervals. The sequence of choices for preparatory lights is programmed by a list of random numbers typed in. The parameters, such as delay time, may even be changed automatically by a shaping program designed to advance a subject's delay as he reaches a chosen criterion of cumulative accuracies, e.g., 60%, 70%, and 80% for the first, second, and third attempt correct responses, respectively.

Output is to a high speed paper tape punch and also an ASR-33 teletype. Monitoring in the course of the test day is accomplished by periodic surveys of data initiated by manual break-for-inspection routines.

RESULTS AND DISCUSSION

One monkey (Basil) achieved excellent performance on delays up to 20 min in approximately a month of training. His cumulative third-attempt accuracy on 16 trials per day was maintained above 90% on the 20-min delay for several weeks. The most important feature of this test is that the circular arrangement of lights allows the magnitude of the errors on each individual trial to be estimated. An incorrect response may be from 45° ($\frac{1}{8} \times 360$) to 180° in error. On trials in which Basil's third post-delay response was correct, the first two incorrect responses were almost always observed to be 45° errors when performing at an asymptotic level on the 20-min delay; thus, the errors were not random.

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The error analysis greatly enhances the sensitivity of the test. An experimental treatment could induce a subtle defect in retention by increasing the magnitude of errors preceding correct responses without impairing overall accuracy. Figure 1 shows the magnitude of errors on trials in which Basil's second and third post-delay attempts were the correct responses. Note the spatial generalization gradient. These data are early shaping results. As accuracy improved, the gradient became steeper.

Fig. 1. Magnitude of errors preceding correct responses during shaping of Basil (based on total of 300 trials, of which 109 were correctly responded to on first attempt, 55 on second attempt, and 21 on third attempt).

The effect of a drug was tested with this technique. An intramuscular injection of 0.05 mg/kg of scopolamine hydrobromide was administered to Basil on four different days (after asymptotic performance had been achieved on the 20-min delay). At least three non-drug days intervened between each drug administration. Physiological saline injections were performed on these control days. Scopolamine was observed to impair performance markedly on this test. Overall accuracy was reduced from 69% to 48% on first attempt responses, from 86% to 60%, including second attempt responses, and from 90% to 68%, including third attempt responses. Moreover, scopolamine increased the magnitude of the errors preceding correct responses, i.e., 90°, 120°, and 180° errors were more frequent. These very clear results indicate that the test should be extremely useful for an analysis of the effects of many different treatments on short-term memory.

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