

All computerized tasks are written in Microsoft Visual Basic or similar programming languages. These programs all involved a small round stimulus (or cursor) that monkeys control by manipulating a digital joystick with their hands. Monkeys are trained to use the cursor to make psychomotor and conceptual responses on the computer screen in a battery of four computerized tasks. The tasks are presented seamlessly, meaning that completion of one task within a training session initiates the presentation of the next task. Two of the tasks are psychomotor in nature, and two are conceptual. They are described below in the order in which they are trained.

For all tasks, the background color of the screen is white, and stimuli consist of either solid colored shapes or multi-colored clip-art images. Task colors can be changed as needed to accommodate any specific visual-color capacities/deficits of the participants. All tasks also include a variety of settings that can be easily adjusted by the experimenter (at program initiation) to make the tasks easier or harder, which aids in training the animals to success criteria. In addition, the experimenter can choose to present only some of the tasks rather than the full battery, so that monkeys do not have to repeat tasks that they have already mastered.

The two psychomotor tasks presented are called SIDE and CHASE. These tasks are used to ensure that monkeys know how to control the cursor on the screen. In the SIDE task, monkeys are trained to move the cursor to illuminated portions of the computer screen. At the onset of training, displacement of the joystick in any direction leads to auditory feedback (a melodic series of tones) and the presentation of food reward. After animals are shaped in this way to manipulate the joystick, the next stage involves sustained displacement of the joystick. The perimeter of the screen is illuminated green so that sustained movement of the cursor into contact with that perimeter counts as a completed trial. In subsequent phases, the task becomes successively more difficult as the illuminated portion of the screen is reduced to only 3 sides, 2 sides, 1 side, and finally only a small portion of 1 side. The experimenter can set criteria for successful completion of each phase on the basis of the number of trials completed or on the basis of the number of trials completed within a certain time period (e.g., 20 successive trials completed within 5 seconds each). Once animals successfully complete each SIDE phase, they are automatically progressed to the CHASE task.

In the CHASE task, individuals learn to bring the cursor into contact with a moving circular target. At the start of each trial, the cursor appears at a random position on the screen. A larger green circle (called the target) also appears at random on the screen. When the joystick is displaced in any direction, the target also moves. This movement is linear, and when the target reaches an edge of the screen, it reverses direction in such a way that the circle appears to bounce off the edge of the screen. If the animal stops moving the cursor, the target also stops moving. Thus, contact between the cursor and the target can only be made through sustained, continuous joystick manipulation. The experimenter can set the target to one of three sizes and to one of three speeds, and these parameters can be titrated within a session to make the task successively more difficult in terms of having to contact smaller and faster moving targets. Success criteria is set according to the number of trials completed, or the number of trials completed within a specific period of time (e.g., 20 trials with a 10 second limit to contact the target). When monkeys reach success criterion on each CHASE phase, they are automatically presented with the first conceptual task.

The two conceptual tasks in the training battery are Matching-to-Sample (MTS) and Two-Choice Discrimination (DISCRIMINATE). In MTS, monkeys are trained to move the cursor to a

sample clip-art stimulus presented in the center of the screen, at which time two comparison clip-art stimuli are presented in randomly chosen locations around the perimeter of the screen. One of the two comparison stimuli is identical to the sample and is the correct choice. If the correct stimulus is contacted, the monkey receives a food reward and melodic auditory feedback. The negative stimulus is visually distinct from the sample stimulus and selection of it results in a time-out penalty of 5 s and buzzing auditory feedback (these feedback parameters also could be varied as needed). Success criteria are set as a function of the percentage of correct matches made within a block of trials. Once these criteria are reached, a monkey is automatically presented with the DISCRIMINATE task.

In DISCRIMINATE, monkeys use the cursor to choose between two clip-art stimuli, one of which provides a food reward and melodic auditory feedback (S+), and one that provides a 5 s time-out penalty (in the form of a blank computer screen) and buzzing auditory feedback (S-). In this way, monkeys are trained to track the S+ across a block of 6 trials. After 6 trials, two new stimuli are presented, one as the new S+ and one as the new S-. Success criteria are set as a function of the percentage of S+ selections made within a block of trials and the number of problems in which the percentage criterion is met.

We consider an animal to be computer-trained when it can progress, within a session, through the SIDE, CHASE, MTS, and DISCRIMINATE tasks, meeting success criteria for all tasks. The software allows us to continually modify the task parameters to match the emerging skills of individual animals, so that we can provide additional training on tasks that are more difficult and provide less training on tasks already mastered by a monkey. However, to be considered fully computer-trained, monkeys have to meet these final criteria within a single session:

SIDE: 5 consecutive trials at each level with a response time of less than 5 s.

CHASE: 20 consecutive trials at each size with a response time of less than 10 s.

MTS: 80% correct performance over the most recent 50 trials.

DISCRIMINATE: 80% correct performance for Trial 2 through Trial 6 over 20 novel problems.