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BRIEF COMMUNICATION

Discrimination Learning Without Reward[1]

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GAZZANIGA, M. S. *Discrimination learning without reward.* PHYSIOL. BEHAV. 11(1) 121–123, 1973.–Three split-brain monkeys successfully learned a visual pattern discrimination in one hemisphere in a training sequence that did not make use of a reward. The results suggest that reward information is not a necessary condition for learning.

Learning Reward Split-brain

THE long standing question surrounding the necessary and sufficient conditions for learning are as real today as when originally posed in the first half of the century [4, 6, 9]. The past years of formalizing data from animal learning experiments has yielded more adaptation to the problem than understanding. Curiously, the simple theoretical notions derived from this work (SR theory, contiguity, drive reduction, etc.) has left a greater residual influence on associative fields in psychology than on learning theory per se. Many leading neurologically based theories of learning, for example, take seriously the notion that reward is a critical neurological event for discrimination learning [5]. As a result explicit neurological circuits are offered as the physical basis of learning [3].

Recently, we have been involved in examining some of the enduring issues surrounding learning theory using the split-brain monkey [7,8]. Such surgical interventions allow for the careful testing of a variety of hypotheses generally considered important in learning theory. In brief, by using a split- brain monkey we can explicitly control the kind and type of behavioral experience one hemisphere has while observing the knowledgeable performance of the other. In the past we have observed that when a naive hemisphere observes the errorless performance of the knowledgeable hemisphere on a visual pattern discrimination, it too learns the problem [7]. In a subsequent attempt to determine the necessity of reward in learning of this kind we failed to answer the question because of the disruptions that occurred by witholding reward [8]. In the present experiment the problem has been overcome and we show that reinforcement is not a necessary condition for the learning of a visual discrimination.

METHOD AND PROCEDURES

Three split-brain monkeys (maccaca mulatta) were used in the experiment. All had undergone midline section of the anterior commissure, the optic chiasm and the corpus callosum. The surgical procedures used have been described elsewhere [2]. All three animals were experienced laboratory animals who had been trained on a variety of visual discriminations in prior tests. Animals FRL and LVR were killed and their brains inspected. The optic chiasm was completely sectioned as was the anterior commissure. In both animals, the corpus callosum had approximately 2 mm of fibers intact in the anterior tip of the genu. The other animal is still being used in other experiments.

The training apparatus and general experimental design had been described elsewhere [7,8]. In brief, the monkeys were maintained in specially designed restraining chairs throughout the training and testing procedures. During an experimental session, the chair was placed in a soundproof box facing a response panel. Vision was restricted on three sides, allowing the panel to be viewed only through two small eyeholes. Arm movements were not restricted, but head movement was limited so that each opening could only be used by one eye.

Centered on the panel were two 5 x 6.3 cm transparent plastic panels, one immediately above the other. Two IEE one-plane readout projectors were placed behind the panels and a trial was initiated by the monkey depressing a lever positioned directly below the response panels. Red and green filters (Kodak Wratten No. 29 and 64 respectively) were placed within each readout projector. Filters were also placed in front of the eyeholes. In this way different stimuli could be simultaneously and separately presented to each

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eye from the same readout projector. In this case the pattern projected in red light went to the left eye and the one in green to the right eye. At the intensity of lights used, the bandpass of the filters is such that no leakage of light is evident.

The discriminative stimuli used in this study were geometric patterns such as square vs circle, triangle vs star and vertical vs diagonal lines presented on a black background. The discrimination used on the nonrewarded task was a swastika vs a plus sign. The stimuli were matched for brightness with the pattern of the stimuli being the only reliable dimension by which discrimination could occur. To double check the possibility of an aberrant stimulus cue, possibly resulting from variations in the light source and the like, naive human observers proved unable to detect any salient cues other than the discrimination itself. During some trails, only one eye viewed the discriminative cues, while the other eye simultaneously viewed at the same point in space, a blank field. The stimuli were within the center of the monkey's field of vision and could be reached by either hand. A response was recorded by pressing one of the panels. Responding to either panel caused all stimuli to be turned off and initiated an intertrial interval. A response to the panel displaying the positive stimulus yielded several drops of water presented through a tube near the monkey's mouth. All animals were deprived of water 22 hr before testing. After each testing session, water was available for 10 min..

Each disconnected hemisphere learned a different visual discrimination. After reaching a stable performance (90% correct over 80 trials) a reward was presented only every other trial and performance was stabilized. Introduction of this reward schedule proved to have little or no obvious disruptive influence on the animals' behavior. Subsequently, a strict training procedure was presented as follows: On a reinforced trial each hemisphere viewed the visual discrimination it had been trained. On the nonreinforced trial one hemisphere viewed the same problem it had been trained upon, while the other naive hemisphere simultaneously viewed a completely new discrimination which appears at the same point in space but in the complementary color. As a result, when good performance is initially evident on these trials, it can be assumed the hemisphere viewing the well-trained problem is in control, with the other naive hemisphere only observing that the responding hand continually pushes the panel with a particular stimulus on it.

Each training session usually consists of eight trials which resulted in forty nonreinforced trials. Thus, it was only on these nonreinforced trials that the naive hemisphere had an opportunity to learn. At the end of this 80 trial set, the nonreinforced probe trials were exclusively given to the naive hemisphere. The experimental sessions were continued daily until evidence of learning obtained in the hemisphere observing the new discrimination.

RESULTS

The results are seen in Fig. 1. All animals with varying amounts of observation trials were able to learn the discrimination in the absence of a reward to at least a criterion of 8 out of 10. As can be seen from the probe trials, no animal was able to perform the discrimination viewed under the nonreward condition until approximately 120 nonreward trials had been run. HRY took 120 trials,

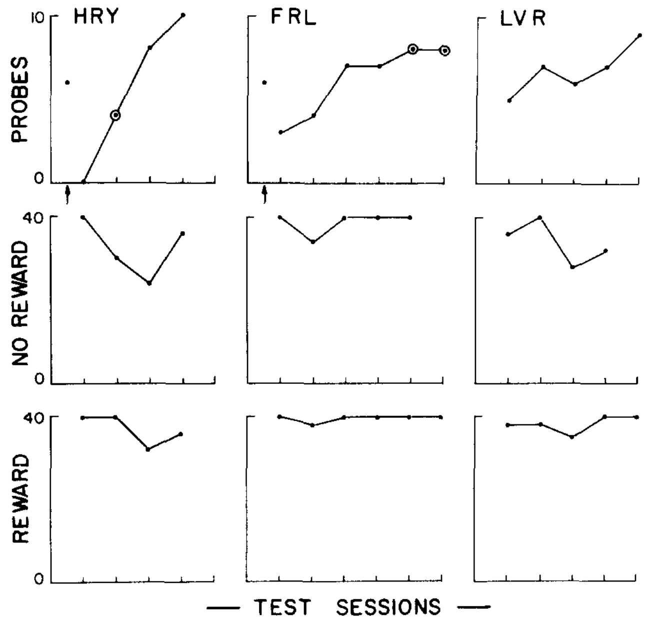

FIG. 1. Shows performance level and errors made during both the rewarded and nonrewarded observation trials and the score obtained on the subsequent probe trials. In HRY, and FRL, a pretest probe to the naive hemisphere was run as indicated by the arrow. Probe trials with a circle indicate sets of trials where the animal only worked for 5 trials. Here, the correct/incorrect score was doubled for the illustration.

for example, while FRL took 200 trials. It should be pointed out, of course, that the probe trials were in effect extinction trials and would work against any weak learning that might be present in the early probe sessions.

DISCUSSION

In the foregoing it was shown that one hemisphere of a split-brain animal successfully learned a visual discrimination in a testing arrangement that only allowed this hemisphere to observe the performance of the other in the absence of primary reward. The possibility that secondary reinforcement factors were made use of in learning of this kind is diminished by previous studies which show it is unlikely that such effects, if they exist at all, cross over in the split-brain animal [8]. Other cross cueing strategies, however, such as the frustrating effects of nonreward, can not be entirely ruled out as playing a role in the discrimination learning seen in the naive hemisphere [1].

These findings are consistent with a variety of earlier classic studies in the field of learning theory [10]. From a neurological point of view, results of this kind seem to illustrate how information pertaining to reward need not be considered as a necessary aspect of a neural model of learning and memory. In particular, the idea that the limbic-reward system must be connected to cortical processing centers for visual learning to occur does not seem to apply here [3].

The results suggest the search for a neurological model of memory or information storage should not overly concern itself with consideration of the role of reward or of brain systems involved in general motivation. To store or not to store information would seem more dependent on other aspects of behavioral life such as contiguity, frequency and the like.

This is not to say, of course, that rewards do not normally play a major role in controlling behavior and in the learning process. It may well be, however, that the major contribution of reward contingencies is to alert the organism that meaningful events are occuring or about to occur and that decisions must be made whether or not to store the relevant information.

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