*NOTE ON DELAY-INTERVAL ILLUMINATION
EFFECTS ON RETENTION IN MONKEYS (Cebus apella)*

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Two monkeys experienced with delayed matching to sample were given a 30-day baseline training period during which the delay interval was illuminated. Both subjects showed an increase in matching accuracy when shifted to dark delay intervals, and accuracy declined when the illuminated delay interval was reinstituted. These results, as well as earlier reports of facilitation of delayed matching behavior by dark delay intervals, support the view that the absolute level of delay-interval illumination can importantly affect visual retention in monkeys and may be indicative of significant differences in the retention mechanisms employed by monkeys and birds.

Key words: delayed matching, retention, retroactive interference, monkeys

An important variable that affects performance on a visual delayed matching-to-sample (DMTS) task is the level of illumination prevailing during the delay (retention) interval. Etkin (1972) and D'Amato and O'Neill (1971) reported that the DMTS performance of cebus monkeys was facilitated when the retention interval was spent in darkness rather than in moderate ambient illumination. These investigators also demonstrated that the effect was due neither to differences in the amount of activity during dark and illuminated delays (Etkin, 1972) nor to within-trial changes in illumination (D'Amato & O'Neill, 1971). Similar results have been obtained with birds. Grant and Roberts (1976) and Roberts and Grant (1978), using pigeons as subjects, reported that ambient chamber illumination during the retention interval of a DMTS task led to poorer performance than a dark retention interval, and that the difference in performance increased as the level of delay-interval illumination or length of exposure to the illumination during the delay was increased.

The illumination-induced decrement in visual DMTS performance has been interpreted as due to retroactive interference (RI) arising from the visual processing of environmental stimuli during the retention interval (e.g., D'Amato, 1973; Worsham & D'Amato,

1973). Darkness during the delay presumably reduces or eliminates such processing and thus attenuates this source of RI. Recently, however, Tranberg and Rilling (1980) have presented evidence which they claim does not support this interpretation (cf. Cook, 1980). These investigators found that pigeons given baseline training with illuminated delay intervals showed a performance decrement during transfer tests in which the delay interval was dark. They concluded that change in delay-interval illumination, rather than absolute level of illumination, caused the illumination-induced decrements reported by earlier investigators. According to Tranberg and Rilling, in previous relevant studies, including those of Etkin (1972) and D'Amato and O'Neill (1971), "it was always the case that during acquisition of DMTS and/or during DMTS training, prior to any manipulation, the delay interval was spent in darkness. The independent variable always involved an increase in delay-interval illumination" (p. 39-40).

Although this criticism might be justified for some of the papers cited by these authors, it does not apply to the Etkin (1972) or to the D'Amato and O'Neill (1971) study. Three of the four subjects employed by Etkin (Basil, Pete, and Roscoe) had had extensive previous DMTS experience, all with illuminated delay intervals. A recent check of our records indicates that, excluding 0-sec delay trials, prior to the Etkin (1972) study these three animals had approximately 10,000 such DMTS trials distributed over about 15 months of testing.

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The fourth subject, Coco, had experienced about 1,300 DMTS trials prior to the Etkin study, again all with illuminated delay intervals. Etkin (1972) did not specifically indicate that his subjects' previous DMTS experience occurred in the houselight-on condition; however, nothing in the report suggested that the delay intervals were dark.

The D'Amato and O'Neill (1971) study was conducted after the Etkin (1972) study, and employed as subjects Basil, Pete, and Roscoe. The delay-interval illumination manipulation took place immediately, with no baseline training. Therefore, the animals' most immediate experience with DMTS was with both illuminated and dark delay intervals. Clearly, then, the facilitation of DMTS performance reported by these investigators cannot be attributed to a change in delay-interval illumination from baseline to testing. Such a variable, if it operated in the Etkin (1972) study, should have produced poorer performance in the dark delay-interval condition.

Additional evidence that the absolute level of delay-interval illumination is an important factor in primate visual memory comes from the following experiment, which employed a subject (Roscoe) that participated in the Etkin (1972) and D'Amato and O'Neill (1971) studies.

METHOD

Subjects

Roscoe and Peewee served as subjects in the experiment. Both animals had extensive previous DMTS experience, for the most part with dark delay intervals. However, both had recently participated in a DMTS experiment with illuminated (houselight on) delay intervals; of their 32 most recent DMTS sessions, 24 were with illuminated delay intervals. Throughout the experiment, the animals were maintained at 85% to 95% of their full-ration body weight.

Apparatus

One wall of two Lehigh Valley monkey chambers (Model 1317) contained four inline stimulus projectors (Industrial Electronic Engineers, Inc., Series 10,000) located at the four corners of a 12-cm square, with a fifth projector at the center. Each projector was fitted with a transparent key that served as the re-

sponse mechanism. Depression of a microswitch centered below the projector array initiated each trial. Noyes banana pellets (190 mg) were used as reinforcers and were delivered to a cup located on the right wall 11 cm from the stimulus panel. A four-item stimulus set consisting of a red disk, vertical line, square, and triangle was employed. As projected, the form stimuli were composed of 17-mm white lines approximately 1 mm thick on black backgrounds. The red disk illuminated a circular area approximately 2.5 cm in diameter. The overhead houselight, a 25-W soft-white bulb located behind a translucent shield, provided illumination which measured 3 ft-ca on the floor of the experimental chamber. The houselight could be dimmed by adding a 500-ohm resistor in series with the bulb, reducing the illumination level to .1 ft-ca. With the houselight extinguished, the experimental chamber was in near-total darkness. Stimulus presentation, programming of trial events, and data collection were controlled by a PDP 8/e computer.

Procedure

Baseline training. This phase consisted of 30, 24-trial sessions of DMTS, with the houselight on during sample presentation, the delay interval, and presentation of the comparison stimuli. The duration of the delay interval was gradually increased, with the intention of reaching a terminal level of performance that would permit either facilitative or inhibitory effects to be observed in the test period. The terminal delay was 90 sec for Roscoe and 120 sec for Peewee. To maintain the animals' motivation in the face of these long delays, 8 of each 24 trials were 2-sec delay trials. These short-delay trials were also useful as a means of monitoring the animals' attending to the sample stimuli.

A typical trial proceeded as follows. Completion of a fixed-ratio (FR) 10 schedule on the microswitch immediately produced the sample stimulus on the center key. The sample stimulus remained present for at least 1 sec and until at least one response was made on the key (conjunctive FR 1 FT 1-sec). The delay interval followed, at the end of which a tone sounded for .6 sec, signaling the appearance of the two comparison stimuli (the sample and one of the other three stimuli) on two of the four outer projectors, which remained

present until a response was made. A correct response was followed by delivery of a single banana pellet and advancement to the 20-sec intertrial interval, signaled by the dimming of the overhead houselight and the illumination of a small circular well beneath the micro-switch. An incorrect response initiated a 1-min timeout, signaled by the dimming of the overhead houselight. At the end of the timeout period the 20-sec intertrial interval began.

Testing. Test sessions also consisted of 24 trials, of which 16 were long delay and eight were 2-sec delay. During Sessions 31 to 34, as soon as the sample was terminated and the delay interval initiated, the houselight was extinguished, placing the experimental chamber in near-total darkness. The houselight remained off throughout the delay and was reilluminated simultaneously with the presentation of the comparison stimuli and the tone signal. The houselight-off condition remained in effect for four sessions, followed by a return to the houselight-on condition for four additional sessions (Sessions 35 to 38).

Each stimulus served as sample and as comparison stimulus an equal number of times, and the stimuli were paired with each other with equal frequency within both 2-sec and long-delay trials. Each of the four projectors presented the correct and incorrect comparison stimuli equally often. To eliminate any possible bias due to the sequential arrangement of trials, the same four 24-trial sequences were employed during Sessions 27 to 30, 31 to 34, and 35 to 38, the blocks of sessions over which matching performance was to be compared.

RESULTS

Baseline. With the houselight-on condition, Roscoe could tolerate only a 90-sec delay whereas Peewee performed at a high level at 120 sec. Figure 1 shows that Roscoe's poorer performance was not due to inadequate attending to the sample stimulus, as he rarely made an incorrect response on the 2-sec delay trials. Because we wished to maintain the amount of baseline training constant for both animals, we did not attempt to increase Peewee's delay beyond 120 sec.

Testing. Figure 1 reveals a dramatic increase in Roscoe's DMTS performance on the long-delay trials during the four sessions of houselight-off testing (Sessions 31 to 34). The pro-

Fig. 1. Proportion of correct responses on 2-sec (dashed lines) and long-delay (solid lines) trials during the terminal delay of baseline training (Sessions 17 to 30) and the 8 test sessions (31 to 38). The long-delay trials were 90 sec for Roscoe and 120 sec for Peewee. During baseline (Sessions 1 to 30) and Sessions 35 to 38, the houselight was on during the delay interval (unfilled circles); dark delay intervals (houselight off) prevailed during Sessions 31 to 34 (filled circles). Each 2-sec and long-delay data point is based on 16 and 32 trials, respectively.

portion of correct responses on the 64 90-sec delay trials of Sessions 31 to 34 was .95, whereas it was only .63 for Sessions 27 to 30. It is particularly interesting that on the very first houselight-off session Roscoe performed perfectly on both the 2-sec and the 90-sec delay trials. When the houselight-on condition was reinstituted (Sessions 35 to 38), Roscoe's performance immediately suffered a substantial decline (proportion correct = .73). A Z-test (Edwards, 1968) comparing the proportions of correct responses on 90-sec delay trials achieved during Sessions 27 to 30 and Sessions 31 to 34 indicated that the increase in performance produced by the houselight-off condition was statistically significant ($Z = 4.55$, $p < .001$). A similar test based on Sessions 31 to 34 and 35 to 38 showed that the decrease in performance

which attended the reinstitution of the house-light-on condition was also statistically significant ($Z = 3.41$, $p < .001$).

The same pattern of results was obtained with Peewee, although because of his high baseline performance level the differences were not as dramatic as with Roscoe. The proportions of correct responses on the 120-sec delay trials over Sessions 27 to 30, 31 to 34, and 35 to 38 were .89, .95, and .81, respectively. Only the difference between Sessions 31 to 34 and 35 to 38 was statistically significant ($Z = 2.47$, $p < .02$).

DISCUSSION

The present results provide further evidence that in monkeys a dark delay interval can facilitate visual DMTS performance even when it represents a change from the baseline illumination condition. In view of the fact that both subjects had considerable earlier training with dark delay intervals, it might be objected that the 30-day houselight-on baseline period was not sufficient. Our response is that, as already indicated, both animals experienced illuminated delay intervals in 24 of the 32 (24-trial) DMTS sessions (one session per day) that immediately preceded the present study. Thus the effective houselight-on baseline period was considerably longer than 30 days. And as already discussed, the four subjects of the Etkin (1972) study entered that experiment with extensive experience with only the houselight-on condition. This is not to deny that a shift in delay-interval illumination can lead to a performance decrement, even in monkeys. But the present results and those of Etkin (1972) and D'Amato and O'Neill (1971) show that such a decrement is, in monkeys at least, more than compensated by the facilitative effect of delay-interval darkness.

If, as indicated by the presently available relevant data, delay-interval illumination plays a different role in monkeys' and pigeons' visual DMTS behavior, different control mechanisms might be involved in the two species (a possibility also suggested by the vastly different retention intervals tolerated by the two species). Perhaps monkeys are more adept at forming and maintaining an internal representation of the sample stimulus than are pigeons, which may require peripheral behavioral maintenance mechanisms to manage delayed stimu-

lus control (Zentall, Hogan, Howard, & Moore, 1978). An internal representation of a sample stimulus may be more susceptible to interference from interpolated visual processing than more peripheral maintenance mechanisms. On the other hand, the latter may be more vulnerable to disruption from changes in the contextual conditions under which they were developed.

It is also possible that delay-interval darkness interferes with visual DMTS in pigeons as it does in monkeys, but the effect is less robust than that produced by baseline-testing changes in delay-interval illumination. In the Cook (1980) study all the birds were trained in the houselight-on condition, and although all showed a decrement when shifted to houselight off, the possibility remains that if subjects had been trained in the houselight-off condition and shifted to houselight on, they would have shown a larger performance decrement. Tranberg and Rilling (1980) gave baseline training in both the houselight-on and houselight-off conditions, but because this variable was manipulated between- and within-subjects and the design included an additional variable (intertrial interval illumination), it is not possible to evaluate adequately from their data the relative deficit produced by the direction of change in delay-interval illumination. Manipulating delay illumination during baseline may not, however, be the most efficient design to assess the role of absolute level of delay-interval illumination. A more efficient procedure might be to change delay-interval illumination every one or two sessions from the beginning of DMTS training, thereby eliminating baseline considerations altogether.

Whatever the outcome of a more thorough analysis of the role of delay-interval illumination in birds' DMTS performance might be, it seems clear that in primates the absolute level of delay-interval illumination can significantly affect visual DMTS performance.

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