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Delayed matching to sample in pigeons: Effects of delay of reinforcement and illuminated delays

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ABSTRACT

Pigeons show relatively poor memory when trained on 0-s delayed matching and tested with longer delays. We hypothesized that one reason for the effect of delay may be a loss of association between sample responding and reinforcement. To test this hypothesis, we compared the effect of standard delays inserted between the offset of the sample and the onset of the comparison stimuli with similar delays inserted between the comparison response and reinforcement. We also manipulated whether the delay was dark or lit because there is some evidence that lit delays are disruptive but filled intervals may also help bridge delays. In Experiment 1, pigeons were trained with a 0-s delay and were tested with longer delays. When both delays and delay illumination were novel, we found no effect of delay of reinforcement and only a small effect of delay illumination. In Experiment 2, to eliminate the effect of the novelty of the delay and delay illumination, pigeons were trained with delays from the start. Results indicated once again that delay of reinforcement had little effect on matching accuracy. However, in Experiment 2, delay illumination produced a general decline in matching accuracy and when it preceded comparison choice its effect increased with increasing delay. The results indicate that the rate of forgetting seen in the typical delayed matching experiment is not due to delay of reinforcement for attention to the sample. The results also confirm that lighting the delay after the sample is detrimental to delayed matching. Surprisingly perhaps, lighting the delay after the comparison response is also detrimental to delayed matching. Finally, it was concluded that a more accurate assessment of the rate of forgetting in delayed matching can be obtained by training with variable delays from the outset.

Delayed matching-to-sample is a versatile task that can be described as a conditional discrimination in which the correct response in the presence of two simultaneously presented stimuli (the comparison stimuli) depends on the nature of a third stimulus (the sample). For example, on some trials a pigeon may be presented with a red stimulus on the center response key and a response to that stimulus may illuminate a stimulus on each side key, one red the other green. Choice of the red side-key stimulus would be reinforced but not the green side-key stimulus. Conversely, when on other trials a green stimulus is presented on the center response key, choice of the green side-key stimulus would be reinforced. This task became popular after Skinner (1950) described the task as involving simple stimulus–response chains, for example as "the discriminative response of striking-red-after-being-stimulated-by-red" and suggested that it "is apparently no easier to establish than

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striking-red-after-being-stimulated-by-green." This implies that it is the relation between the sample response and the comparison response that determines matching accuracy and as the duration between the stimulus and response increases the relation between those two responses may be weakened.

Perhaps the most extensive use of matching-to-sample has been as a measure of working memory when a delay interval is inserted between the offset of the conditional stimulus or sample stimulus and the onset of the choice or comparison stimuli. The most common procedure used to assess working memory has been to train pigeons using a 0-s delay between sample offset and comparison onset to establish the appropriate sample-correct-comparison associations and then test them with delays that vary in duration from trial to trial (see e.g., Roberts, 1972). The decrease in matching accuracy with increasing delay has been interpreted as evidence of memory loss over time.

Although sample forgetting varies considerably with such variables as the duration of the sample stimulus (Roberts, 1972), the dimension that defines the difference between samples (e.g., color or line tilt; Farthing, Wagner, Gilmour, & Waxman, 1977), and whether the delay is illuminated or dark, (Calder & White, 2014), in general, there is relatively rapid forgetting of the sample. For example, Roberts (1972) found that when pigeons were trained with matching to sample (with a single presentation of the sample on each trial), matching accuracy dropped to about 56% correct after a delay of only 6 s.

The rapid drop in matching accuracy with increasing delay between the offset of the sample and the onset of the comparison stimuli has been attributed to the fact that there are many trials per session and thus, there is likely to be substantial proactive interference from earlier trials (Grant, 1975). The fact that increasing the intertrial interval improves matching accuracy suggests that proactive interference does contribute to the decline in matching accuracy with increasing delay (Roberts, 1980).

However, another source of poor matching accuracy is the effect that the sample-comparison delay might have on orienting and responding to the sample (Sacks, Kamil, & Mack, 1972). That is, in matching to sample, responding to the sample should be reinforced by presentation of the comparison stimuli which should serve as a conditioned reinforcer because whenever a correct comparison response is made, it is typically followed by reinforcement. But the sample-comparison delay would also delay reinforcement of responding or attention to the sample. For example, Grice (1948) demonstrated the deleterious effect of delay of reinforcement between a response and reinforcement in a simultaneous discrimination and D'Amato and Cox (1976) found that monkeys had more difficulty with delay of reinforcement in a simultaneous discrimination than with sample-comparison delay of the same duration in delayed matching. D'Amato and Cox proposed that in delayed matching, presentation of the comparison stimuli may serve as a cue (or reminder) that the sample is the basis for comparison choice whereas in the case of delay of reinforcement there is no such cue.

McCarthy and Davison (1986) tested the delay of reinforcement hypothesis more directly by using it in a delayed matching task, in a within-subject design, with delays either following the sample or the comparison response. Although there was considerable variability among the subjects, they generally found that delay of reinforcement after the comparison response was no worse than delayed matching. Curiously, they also found that although delayed matching accuracy declined systematically with increasing delay, the effect of post-comparison delay of reinforcement was much more variable. They concluded that the two locations of delay involved two very different processes (see also McCarthy & Davison, 1991; Sargisson & White, 2003).

When Sargisson and White (2003) separated the effects of sample-comparison delay from comparison-reinforcer delay, they found that although sample-reinforcer delay affected delayed matching independently of the sample comparison delay, sample-reinforcer delay could not account for all of the effect of sample-comparison delay. Similar results were found by Sargisson and White (2007).

Weavers, Foster, and Temple (1998) asked about the effect of delay of reinforcement in a somewhat different way. They manipulated both delay of reinforcement and post sample delay but held the sample-reinforcement delay constant. That is, with the sample reinforcement delay set at 8 s, they varied where in that 8 s the comparison choice appeared. Their results indicated that matching accuracy remained relatively flat as the post sample delay increased. Thus, their results suggest that much of the decrease in matching accuracy typically found with increasing retention interval may be attributable to the increase in sample-reinforcer interval.

Zentall, Clement, and Kaiser (1998) reported a result that offers indirect support for an effect of delay of reinforcement on the association between the sample and the correct comparison response. They trained pigeons on 0-s delayed matching with red and green samples and comparison stimuli and, in blocks of sessions, systematically increased the sample-comparison delay up to 16 s. Not surprisingly, they found that when the pigeons were transferred from the 0-s delay to the 1-s delay, matching accuracy improved between the first transfer session (at the 1-s delay) and second transfer session. However, when transferred to the 2-s, 4-s, and 8-s delays, matching accuracy did not improve between the first and second transfer session. And most surprisingly, when transferred to 16-s delays, matching accuracy actually showed a significant decline between the first and second transfer session. Not only would one expect to find an improvement in matching accuracy with additional delayed matching training but one might also expect to see an increase in matching accuracy resulting from the decrease in the novelty of the increased delay.

The implication of this finding is that at the 16-s delay, the first transfer session provided a relatively accurate measure of sample memory but it also exposed the pigeons to the longer delay of reinforcement and the additional delay of reinforcement may have resulted in partial extinction of the association between the sample and the correct comparison stimulus. Although sample-comparison delay has received considerable attention and some research has been directed to delay of reinforcement, the results of research on delay of reinforcement have been somewhat equivocal because in all cases it has been manipulated