Memory interval distribution effects in pigeons

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Pigeons were trained with two concurrent delayed conditional discriminations that involved different distributions of memory intervals, namely 1 and 5 sec in the "short" and 5 and 10 sec in the "long" distribution. Memory for the initial stimulus was much better after 5 sec in the short distribution than in the long one. The memory functions between the intervals within each distribution were essentially flat. These findings were replicated in a second study that involved differential outcomes; this procedure enhanced memory generally within trials so that memory intervals of 1, 9, and 19 sec could be used, with 9 sec serving as the common memory interval. The findings are interpreted on the basis of the subject's expectation of the likely duration of the upcoming memory interval and the associated delay of reinforcement.

In most working memory paradigms, stimuli that occur at the beginning of a trial can serve several functions. The discriminative stimuli, or *initial stimuli*, as I will call them, provide cues to the subject for the correct response to the test stimulus or test stimuli presented after the memory interval (MI). This information is formally sufficient for good performance, but working memory is modulated by other information provided at the same time. The most familiar is the association of different outcomes with the initial stimuli. This procedure enhances working memory. The differential outcomes effect is based upon anticipation of trial outcomes as mediators of improved performance (for reviews, see Honig & Thompson, 1982; Peterson, 1984; Peterson & Trapold, 1980).

Working memory is also affected by directed forgetting procedures (Grant, 1981; Maki, 1981; Stonebraker & Rilling, 1981). An "instantial" cue presented together with the initial stimulus on some trials indicates that the test stimulus or stimuli will be omitted following the MI. This results in a failure of performance on probe trials in which the test stimuli are actually presented. A reasonable explanation of the failure to remember the initial stimulus is that the subject anticipates the omission of reward when the instantial cue is presented.

Instantial cues also affect working memory when they signal specific MIs. This effect has been studied much less extensively than the differential outcomes effect or directed forgetting. Wasserman, Grosch, and Nevin (1982) have provided a clear example. In two experiments, they trained pigeons on a delayed conditional discrimination, in which orange and green served as the initial stimuli and as the singly presented test stimuli. MI duration was signaled in a correlated condition by horizontal and vertical lines that were superimposed on the colors

and extended throughout the MI. In an uncorrelated condition, the same stimuli were randomly associated with the different MIs. Memory functions were steeper in the correlated condition. Occasional probe trials were carried out in the latter condition, in which the wrong MI followed the horizontal or vertical lines. As a result, the pigeons performed rather poorly on short-MI trials that were cued to contain a long MI and better than expected when a long MI had been cued to be short. This finding was supported in a third experiment using a traditional delayed matching-to-sample procedure and auditory cues to indicate the duration of the MI.

Dodd and Honig (1981, described in Honig and Dodd, 1986) reported corresponding findings with a delayed simple rather than a delayed conditional discrimination. In their work, the signal for MI duration ended with the initial stimulus and did not continue through the MI. MacDonald and Grant (in press) have provided extensive replications of the effects of cuing memory intervals in delayed matching. Among other things, they studied the temporal placement of this instantial cue within trials, a matter that will be discussed below.

This line of research supports the notion that pigeons can learn to anticipate the duration of a MI within a trial. The anticipation is established by an instantial stimulus that is independent of the initial stimulus that cues the correct response. There is evidence as well for more general anticipation of the average, or expected value of the MI, even without the use of instantial cues. Honig and Wasserman (1981) observed that the accuracy of responding following a particular MI depended in part on the other MIs presented concurrently, even though there were no specific cues of MI duration. If a specific MI was contained in an unfavorable distribution of long MIs, performance with that MI was somewhat poorer than when the same value was included in a distribution with shorter MIs. This was observed even for a short MI of 1 sec, which normally results in little forgetting.

This finding was incidental to the main purpose of that research, and it was obtained from successive phases with

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different MI distributions. It is of interest to bring such an *MI distribution effect* under more direct control by working with two different MI distributions presented concurrently. These could be distinguished by the use of different instantial cues added to the initial stimuli, but in the present experiments, we simplified matters by using independent sets of initial stimuli for the two MI distributions. This method enabled us to study the MI distribution effect in some detail as a steady-state procedure.

EXPERIMENT 1

Three pigeons were trained concurrently with two independent delayed conditional discriminations. Different colors served as the initial stimuli, and line orientations served as test stimuli. In one discrimination, the MI distribution was "short" (1 and 5 sec); in the other, it was "long" (5 and 10 sec). The question of interest was whether the pigeons would be sensitive to the overall expected MI duration in each discrimination, and would respond with different levels of accuracy following the common MI of 5 sec. In the first phase, the two discriminations were presented on alternate training days. In the second phase, they were combined within sessions. In the third, the MIs in the two problems were interchanged, so that the initial stimuli that originally signaled the short distribution became associated with the long one, and vice versa. All phases involved extensive training, so that stable performance could be observed.

Method

Subjects. The subjects were three White Carneaux pigeons maintained at about 80% of their free-feeding body weights. Their prior experience involved discriminations of the general kind described here, so that preliminary training was unnecessary. These procedures did not involve any manipulations likely to affect the steady-state performance obtained in the present study.

Apparatus. Three standard pigeon chambers were used. Only the center key of three pecking keys was employed. Reinforcement at the end of positive trials was provided by 3-sec access to mixed grain. The stimuli were presented on the key by an in-line digital projector. The programs were controlled by a PDP/8-A computer.

Procedure. The MI distribution differentiated the two delayed conditional discriminations. One distribution was signaled by blue and white initial stimuli; the other was signaled by red and green. After an intertrial interval of 5 sec, a trial began with the presentation of the initial stimulus on the pecking key for 5 sec. The initial stimulus was followed by a MI in which the key light was off and the houselight was dimmed. The MI was, in turn, followed by a single test stimulus on the key; this was either a set of three horizontal or three vertical parallel dark lines on a white background. This stimulus ended automatically after 5 sec on a negative trial to lead into the ITI. On a positive trial, the first response after 5 sec produced grain. Responses that occurred in the first 5 sec of the test stimulus were counted. Each session consisted of 12 blocks of 8 trials each (2 initial stimuli $\times$ 2 MIs $\times$ 2 test stimuli).

Sequence of conditions. The subjects had acquired the discriminations before the experiment began. In all phases, the short MI distribution involved 1 and 5 sec and the long distribution involved 5 and 10 sec. The sets of initial stimuli were counterbalanced, to the extent possible with three subjects, across the two MI distribu-

tions. The first phase was the *separate discrimination phase*, in which the discriminations involving the short and the long MI distributions were presented on alternate days for 60 sessions each. This was followed by the *combined discrimination phase*, in which the two discriminations were combined within each session and within blocks of trials for 48 sessions. In the third, *reversal phase*, the two discriminations were still combined in the same session, but the MI distributions were exchanged between them, so that MIs of 1 and 5 sec now followed the initial stimuli that had preceded MIs of 5 and 10 sec, and vice versa. This phase lasted for 40 sessions.

Results

The principal measure of performance was the discrimination ratio (DR) based on the rate of responding to the test stimulus. For each MI within each condition, the number of responses to the test stimulus on positive trials was divided by the total responses to the test stimulus on positive and negative trials within a session. This yields a discrimination ratio of 1.00 if the discrimination is perfect, when a subject responds only on positive trials. It yields a ratio of .50 when rates of responding on positive and negative trials are equal, indicating either no discrimination between the initial stimuli or no memory for them. Pigeons are biased toward responding to the test stimulus; therefore, most errors are "errors of commission" on negative trials rather than failure to respond on positive trials.

The mean DRs obtained from the 3 subjects during the three phases of the study are presented in Figures 1 and 2, averaged across blocks of four sessions. Four aspects of the results obtained from the first phase are of interest (Figure 1): (1) The discrimination was consistently better following a 1-sec MI than following a 5- or a 10-sec MI. (2) Performance with the 5-sec MI was consistently better when that MI was contained in the short distribution. (3) The MI in the long distribution seemed to have no effect on performance; there was little or no forgetting between 5 and 10 sec. (4) There was, finally, some tendency for the data under the various conditions to converge, as the quality of performance with the short MI distribution declined in the course of this phase.

The data from the second, or combined phase, shown in the left panel of Figure 2, support the findings from Phase 1 with one major difference: The effect of the MI in the short distribution disappeared, and the DRs obtained with the 1-sec MI and its companion 5-sec MI were practically identical. The performance obtained from the two distributions diverged in the course of continued training, even though these data were now obtained within the same sessions. The reasons for the temporary decline in the sixth block of sessions are unknown. These results confirm the findings from the previous phase. They show that the differences in performance with the intermediate MI did not depend on a separation of the MI distributions between sessions.

The right panel of Figure 2 provides the data from the MI reversal phase. Not surprisingly, performance after

Figure 1. Mean discrimination ratios from the first phase of Experiment 1. The long and short MI distributions were in effect on alternating sessions.

Figure 2. Mean discrimination ratios from the second and third phases of Experiment 1. The MI distributions were combined within sessions. At the start of the third phase, the MI distributions were reversed between the two discriminations.

the 1-sec MI improved, with the initial stimuli now being what had up to that time preceded the 5- or the 10-sec MI. And performance with the 10-sec MI declined following stimuli that had not up to that time preceded such a long interval. The finding of major interest is the reversal of performance following the 5-sec MIs. Except for the first and the sixth blocks of trials, memory at that interval was better within the new short MI distribution than within the new long distribution. And again, the performances obtained with the 5-sec MI were more similar to those obtained with their companion MIs than they were to each other.

To provide a clearer view of the effects of the memory intervals, traditional MI functions were obtained from these data. The DRs were averaged across all blocks of sessions in the first and second phases of training. These are plotted as a function of the MI in Figure 3. (It made no sense to do this for the MI reversal phase.) Except for the short distribution in Phase 1, the MI functions are flat—an unanticipated result. It is confirmed for individual subjects in the left part of Table 1. For this table, data

were selected from successive blocks of training within each phase to represent stable overall performance. From the first phase, the data come from Blocks 2-6 for all subjects; from the second phase, they come from Blocks 8-12; and from the last phase, following the MI reversals, they come from only the last three blocks of sessions, after performance had stabilized. This table shows that the summary graph of Figure 3 represents individual data reasonably well. Furthermore, the same pattern of MI effects was obtained following the MI reversals in the last phase, even though the differences were reduced because of high levels of performance.

Discussion

These data provide a strong replication of the MI distribution effect observed in previous experiments between successive stages of training. Presumably, the initial stimuli from the two discriminations established different expectancies regarding the likely duration of the upcoming MI, and these expectancies modulated the rate of forgetting. This rate was much slower during the long MI

Figure 3. Mean discrimination ratios averaged across blocks of sessions in various phases of the research. Solid lines represent data from Experiment 1—open circles for the first phase and filled circles for the second. Dashed lines represent data from Experiment 2—open circles for the second phase and filled circles for the third.

Table 1
Selected Discrimination Ratios
(Means of Five Blocks of Consecutive Sessions)

Experiment 1					Experiment 2				
Subject	Memory Interval				Subject	Memory Interval			
	1 sec	5 sec (1)	5 sec (10)	10 sec		1 sec	9 sec (1)	9 sec (19)	19 sec
Separate Sessions									
0029	90.8	86.0	62.2	62.8	4381	86.2	82.6	70.8	64.0
1250	92.2	84.0	79.0	75.8	4393	81.6	82.6	69.4	73.2
5713	93.4	92.0	76.0	80.2	4379	84.0	85.4	83.2	82.2
Mean	92.1	87.3	72.4	72.9		83.9	83.5	74.5	73.1
Combined Sessions									
0029	86.0	87.0	67.2	65.2	4381	85.6	78.4	73.8	70.0
1250	95.0	89.4	81.2	82.8	4393	87.8	89.2	86.0	81.2
5713	89.2	91.0	90.2	87.2	4379	94.6	94.8	93.4	93.4
Mean	90.1	89.1	79.6	78.4		89.1	87.4	84.4	81.5
Reversal Sessions									
0029	87.7	87.3	69.3	72.0					
1250	86.3	98.2	89.0	86.0					
5713	88.0	92.3	94.3	94.0					
Mean	87.3	89.6	84.1	84.0					

Note.—Numbers in parentheses indicate the other memory interval from the same MI distribution.

of the short distribution than it was during the short MI of the long distribution, although the MI values were the same. The MI expectancies are presumably also responsible for the small amount of forgetting between the two MIs within each distribution—between 1 and 5 sec in the short distribution, and between 5 and 10 sec in the long distribution. The single exception is a moderate amount of forgetting in the first phase between 1 and 5 sec. Therefore, most of the forgetting seems to occur during the shorter MI within each distribution. This is by no means a necessary aspect of the MI distribution effect, which has been obtained previously with declining memory functions (Honig & Dodd, 1983; Honig & Wasserman, 1981).

EXPERIMENT 2

Experiment 2 is a systematic replication of Experiment 1 and involves the same general experimental strategy, with one important difference: different positive outcomes were correlated with the initial stimuli in each discrimination. As indicated in the introduction, the differential outcomes procedure enhances working memory. We could therefore hope to replicate the results from Experiment 1 with MIs beyond 10 sec. According to current theory, the differential outcomes effect is mediated by outcome expectancies that are cued by the initial stimuli and remain active during the MI (Honig, Matheison, & Dodd, 1984; Peterson, 1984; Wasserman, 1986). These expectancies might overshadow other aspects of the trial that could also be anticipated on the basis of cues provided by initial stimuli. In that case, the MI distribution effect demonstrated in Experiment 1 might not be observed when differential outcomes are incorporated in the procedure.

Method

Subjects and Apparatus. The subjects were three pigeons that had received extensive prior training on the delayed conditional discrimination used here. Grain and water had served as differential outcomes obtained on positive trials following red and green as initial stimuli. The experimental equipment was the same as that used in Experiment 1.

Procedure. The delayed conditional discrimination procedure and its significant parameters (except the MIs) were the same as those used in Experiment 1. The main difference was that the pigeons received 3-sec access to grain following one initial stimulus on positive trials and a few drops of water presented in a small dipper following the other initial stimulus.

As in Experiment 1, two discriminations involving different MI distributions were used concurrently. In Phase 1 (56 sessions), the MIs were the same as those used in Experiment 1: 1 and 5 sec in the short distribution, and 5 and 10 sec in the long distribution. These distributions were used on alternate sessions. With the differential outcomes procedure, discrimination was so good that few differences between the MI distributions were observed; therefore, the MIs were changed in Phase 2 as follows: The short MI remained at 1 sec, the common, intermediate MI was 9 sec, and the long MI was 19 sec. The two discriminations were presented in alternation for 72 sessions. In the third phase, the two discriminations were combined within sessions, as in the corresponding phase of Experiment 1. This procedure was carried out for 60 sessions.

Results and Discussion

The discrimination ratios are presented in Figure 4 for Phases 1 and 2. They were all high in Phase 1, and they were identical for the 1- and 5-sec MIs in the short distribution. The difference between those and the DRs obtained with the 10-sec MI were consistent but not large. During the first two blocks of sessions, the DRs from the intermediate, 5-sec MIs matched those of their companion MIs in the same distributions. However, a general im-

Figure 4. Mean discrimination ratios from the first two phases of Experiment 2, in which the long and short MI distributions were in effect on alternating sessions. The MIs were increased between Phases 1 and 2 from 1, 5, and 10 sec to 1, 9, and 19 sec.

provement of performance reduced differences obtained with the common, intermediate MI.

The results from Experiment 1 were replicated more clearly in the second phase, when the MIs of 9 and 19 sec replaced those of 5 and 10 sec. Performance declined generally throughout this phase. However, the main finding of interest from Experiment 1 was nicely replicated. The DRs obtained with the intermediate MI of 9 sec matched their companion DR value in each problem quite closely.

In the last phase, the two discrimination problems were integrated within sessions. This produced an initial depression of performance in the short MI distribution, followed by a more general recovery; the DRs rose under all conditions. Throughout these fluctuations, the DR following the 1-sec MI was consistently higher than after the 19-sec MI, and performance with the intermediate MI of 9 sec was largely determined by the problem in which it was incorporated.

Memory functions are shown in Figure 3 for the phases involving MIs of 1, 9, and 19 sec. (These were obtained, as before, by averaging DRs from all blocks of sessions from the second and from the third phase of the experiment.) Again, the functions within each distribution are flat; there was little forgetting between the short and the long MI. The difference between the functions was greater for the second phase, when the distributions were run on

alternate days, than it was during the third phase, when the distributions were combined within sessions. Thus, the demarcation of MI distributions between sessions enhanced the discrimination between them.

Data taken from blocks of sessions showing stable performance are shown for individual subjects in the right half of Table 1. Data from the first phase were not used, because of the ceiling effect that reduced differences among conditions. During the second phase, when the MIs were increased, there was an overall decline in performance. The data from Blocks 2-6 (9-13 in Figure 3) were chosen; although there was some variability between blocks, the overall decline during this period was relatively modest. From the last phase, the data were taken from Blocks 10-14, when the subjects had recovered from the initial depression in performance incurred by combining the discrimination problems within training sessions.

Again, these tables provide a pattern of results that indicates little forgetting between the two memory intervals tested in each distribution—between 1 and 9 sec in the short distribution and between 9 and 19 sec in the long distribution. The main findings of interest from Experiment 1 were therefore replicated with differential outcomes, which allowed the use of longer MIs. It does not appear that the anticipation of MI durations was overshadowed by outcome expectancies. The latter would be

Figure 5. Mean discrimination ratios from the third phase of Experiment 2, in which the MI distributions were combined within sessions.

differentiated *within* each discrimination on the basis of the initial stimuli, whereas the MIs would be distinguished *between* problems but not associated with specific initial stimuli. The pigeons appear to be able to anticipate these two aspects of a trial concurrently.

GENERAL DISCUSSION

The data from these experiments support the conclusion that working memory for initial stimuli is modulated on a long-term basis by the distribution of MI durations. Through the use of different sets of initial stimuli for two MI distributions, we have brought this *MI distribution effect* under stimulus control. Previously, this effect was based on comparisons among successive experimental phases with different MI distributions involving at least

one common MI (Honig & Dodd, 1983; Honig & Wasserman, 1981). The present method makes it possible to study this effect more explicitly, with concurrent training on the two distributions. For the most effective demonstration of this effect, a memory interval common to the distributions is certainly useful, although this is not a necessary aspect of the procedure.

There are two rather different findings from this research that require some explanation. The first is the MI distribution effect itself—that the performance following a given MI is affected by the MI distribution in which it is contained. In prior research with varying MI distributions, the initial stimuli served as discriminative stimuli for the correct response, but did not convey specific temporal information (Honig & Dodd, 1983; Honig & Wasserman, 1981). In the present work, the initial stimuli did

convey such information, but only regarding the MI distribution, not the specific interval on each trial. It is reasonable to suppose that these stimuli generated an expectancy of a range of MIs for a given trial, or of an average MI value. This resulted in better memory for the initial stimuli that preceded the shorter MIs.

It is not clear how this might have been accomplished by the subject. Perhaps the pigeon pecked more rapidly if it anticipated the MI to be shorter rather than longer, attended to it more closely, and thus remembered it better. We do not have records of the pecking rates to initial stimuli, so this notion is hard to verify directly. It could be tested by separating the cues for the correct discriminative response from the cues for the MI duration. This strategy was used by Wasserman, Grosch, and Nevin (1982) and more recently by MacDonald and Grant (in press). The latter authors signaled the duration of either a long or a short MI on each trial in delayed matching with pigeons. In one of their experiments, this cue for the upcoming MI was presented only *after* the initial stimulus, and quite briefly at that (for 1 sec). They tested the effectiveness of this cue on probe trials, in which the short MI followed the signal for the long one. This resulted in rapid forgetting, even though the subjects would presumably have attended to (and responded to) the initial stimuli to the same degree on the probe trials as they did on the regular trials. This research does not rule out the possibility, in our work, that the subjects attended more closely to the initial stimuli involved in the short MI distribution, but it is certainly not the only possible mechanism.

The MI distribution effect can perhaps be explained more readily by a motivational mechanism: The long MIs involve a relatively long delay of reinforcement. The subject needs to remember either the initial stimulus during this delay or a complex instruction regarding correct differential responding to the two test stimuli. The memorial process may be subject to the standard reinforcement variables, including delay of reinforcement. It would therefore be reinforced more strongly in the shorter MI distribution. Perhaps the effects of anticipating a long MI could be counteracted to some degree by increasing the amount of reinforcement for responding to the test stimuli in the long MI distribution.

If it is a motivational process that affects the quality of remembering during the MI, we may have identified here a *memory contrast effect*, which resembles behavioral contrast. In a reinforcement program involving multiple schedules (which are signaled by different discriminative stimuli), rate of responding on a constant schedule is modulated when there are changes in the density of the other schedule. If the latter is reduced, then rate of responding in the constant schedule increases; if the density of the varying schedule is increased, then rate in the former tends to decline (Reynolds, 1961; Schwartz, 1975). The current results suggest a similar modulation. There would appear to be a contrast between the two MI distributions that enhances memory for the common MI

in the short one and/or reduces it in the longer distribution. This interpretation is compatible with a motivational account of the MI distribution effect.

Behavioral contrast is usually demonstrated in the context of certain baseline, or control, conditions. We did not, unfortunately, carry out parallel procedures. It would have been desirable to equate the MI distributions within the two discriminations at some stage in training. This should have resulted in a convergence of memory functions in the two problems. Or else, training with either the short or the long distribution could simply have been discontinued. This should (in parallel with behavioral contrast) result in an improvement with the common MI from the long distribution in the former case, and a reduction in performance with the common MI from the short distribution in the latter. A memory contrast effect could and should also be studied in the simplest manner by using only a single MI in each problem. This would be kept constant in one problem and be varied in the other. The effect should be seen in the form of changes in performance with the constant MI.

A second significant finding from the present work is that the MI functions within each discrimination were flat, or almost flat, in most conditions. This is by no means a necessary aspect of the MI distribution effect, which requires no more than differential performance with a common MI value. Within each distribution, however, the memory functions could still have negative slopes. It is likely that the flatness of the functions was due to the concurrent training on the two problems. When MI distribution effects have been observed previously with delayed conditional discriminations (Honig & Wasserman, 1981), the memory functions were obtained successively. Memory of the initial stimulus declined as a function of the MI. It would, again, have been of interest in the present research to eliminate one MI distribution in some phases or to equate the MI values in the two distributions. I suspect that declining memory functions would then have reappeared.

Such an extension of the present work may identify a necessary condition for flat memory functions to be obtained, but that would not explain this unusual finding. It may be useful to recall the study by Wasserman et al. (1982) in this connection. In some phases of their work, they presented cues that were correlated with the MI. This produced much steeper memory functions than a control procedure in which the same cues were randomly associated with that variable. Our procedure in effect provided random cues for the MI within distributions, but differential cues between them. If the subject anticipates two different "average" MIs, one for each distribution, and if these expectancies determine the accuracy of the memory process, then the present results appear to be a reasonable outcome. Indeed, the process seems to be more strongly affected by the anticipation of a likely MI value than by the passage of time as such.

In this connection, it would be useful to examine, in greater detail, the course of forgetting within the differ-

ent MI distributions. If the subject anticipates a substantial MI in the long MI distribution, it may forget the initial stimulus rapidly. Then it should perform poorly even with a short MI on a probe trial. On the other hand, if the subject does not anticipate any long MIs in the short MI distribution, it might remember the initial stimulus rather well even past the long MI from that distribution. It would be useful to present appropriate short-MI and long-MI probe trials in further research with the present paradigm.

In order to facilitate further study of the processes involved in the anticipation of MI durations, it may again be desirable to separate the cue for the correct response from the instantial signal indicating the MI distribution. This method would be similar to the procedure used by Wasserman et al. (1982) and by Dodd and Honig (1981) to signal specific memory intervals. A single set of initial stimuli would control the conditional discrimination. This method would permit the omission of the instantial cues that signal the MI distribution. A baseline memory function could then be obtained, against which the effects of informing the pigeon of the likely value of the upcoming MI can be assessed.

REFERENCES

- DODD, P. W. D., & HONIG, W. K. (1981, June). *Effects of signaling the duration of a retention interval in a delayed discrimination*. Paper presented at meeting of the Canadian Psychological Association, Toronto.
- GRANT, D. S. (1981). Short-term memory in the pigeon. In N. E. Spear & R. R. Miller (Eds.), *Information processing in animals: Memory mechanisms* (pp. 227-256). Hillsdale, NJ: Erlbaum.
- HONIG, W. K., & DODD, P. W. D. (1983). Delayed discriminations in the pigeon: Role of within-trial location of conditional cues. *Animal Learning & Behavior*, **11**, 1-9.
- Honig, W. K., & Dodd, P. W. D. (1986). Anticipation and intention in working memory. In D. F. Kendrick, M. E. Rilling, & M. R. Denny (Eds.), *Theories of animal memory* (pp. 77-100). Hillsdale, NJ: Erlbaum.
- HONIG, W. K., MATHESON, W., & DODD, P. W. D. (1984). Outcome expectancies as mediators for discriminative responding. *Canadian Journal of Psychology*, **38**, 196-217.
- HONIG, W. K., & THOMPSON, R. K. R. (1982). Retrospective and prospective processing in animal working memory. In G. H. Bower (Ed.), *The psychology of learning and motivation* (Vol. 16, pp. 239-283). New York: Academic Press.
- HONIG, W. K., & WASSERMAN, E. A. (1981). Performance of pigeons on delayed simple and conditional discriminations under equivalent training procedures. *Learning & Motivation*, **12**, 149-170.
- MACDONALD, S. E., & GRANT, D. S. (in press). Effects of signaling retention interval length on delayed matching to sample in pigeons. *Journal of Experimental Psychology: Animal Behavior Processes*.
- MAKI, W. S. (1981). Directed forgetting in animals. In N. E. Spear & R. R. Miller (Eds.), *Information processing in animals. Memory mechanisms* (pp. 199-225). Hillsdale, NJ: Erlbaum.
- PETERSON, G. B. (1984). How expectancies guide behavior. In H. L. Roitblat, T. G. Bever, & H. S. Terrace (Eds.), *Animal cognition* (pp. 135-148). Hillsdale, NJ: Erlbaum.
- PETERSON, G. B., & TRAPOLD, M. A. (1980). Effects of altering outcome expectancies on pigeons' delayed conditional discrimination performance. *Learning & Motivation*, **11**, 267-288.
- REYNOLDS, G. S. (1961). Behavioral contrast. *Journal of the Experimental Analysis of Behavior*, **4**, 57-71.
- SCHWARTZ, B. (1975). Discriminative stimulus location as a determinant of positive and negative behavioral contrast in the pigeon. *Journal of the Experimental Analysis of Behavior*, **23**, 167-176.
- STONEBRAKER, T. S., & RILLING, M. (1981). Control of delayed matching-to-sample performance using directed forgetting techniques. *Animal Learning & Behavior*, **9**, 196-201.
- WASSERMAN, E. A. (1986). Prospection and retrospection as processes of animal short-term memory. In D. F. Kendrick, M. E. Rilling, & M. R. Denny (Eds.), *Theories of animal memory* (pp. 53-76). Hillsdale, NJ: Erlbaum.
- WASSERMAN, E. A., GROSCH, J., & NEVIN, J. A. (1982). Effects of signaled retention intervals on pigeon short-term memory. *Animal Learning & Behavior*, **10**, 330-338.

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