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**Differential Outcome Expectancies of
Reinforcement and Nonreinforcement and
Memory for Temporal and Nontemporal Stimuli.**

by

Mary Jo Ducharme

B.A. (Hons.), The University of Windsor, 1989

THESIS

**Submitted to the Department of Psychology
In Partial fulfilment of the Requirements
for the Master's Degree**

WILFRID LAURIER UNIVERSITY

1991

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Abstract

The effects of differential outcome expectancies of food and no-food on memory for temporal and nontemporal stimuli were examined. Pigeons matched short (2s) and long (8s) sample durations to red and green comparison stimuli, and vertical and horizontal lines to vertical and horizontal lines. In Experiment 1, the Nondifferential Outcome group (NDO) received food or no-food on a random half of all trials. The Differential Outcome groups (DO) received food for correct responding to one temporal sample and one nontemporal sample, and no-food following the other samples. In the Differential Outcome-Short-Food group (DO-SF), the short sample stimulus was followed by food, whereas in the Differential Outcome-Long-Food group (DO-LF), the long sample stimulus was followed by food. On line tilt trials, food followed vertical for half of the subjects in each DO group. During subsequent delayed matching-to-sample (DMTS) testing the NDO group displayed a typical choose-short bias. Other than at the 0s delay interval on no-food trials, the DO groups displayed equivalent biases to the most favourable outcome (choose-favourable bias). In Experiment 2 outcome expectancies were removed off-baseline for the DO groups, followed by a reintroduction of MTS with nondifferential outcomes for all groups. On session 1 of matching-to-sample (MTS), the DO groups performed less accurately than the NDO group. Performance of all groups was equivalent during delay testing. Apparently the performance of the DO groups had been guided by outcome expectancies which overshadowed sample stimulus control. These findings suggest that nonanalogical coding of event duration occurred.

Introduction

Perhaps the best way to introduce the significance of animal learning to psychology is by first eliminating a few misconceptions regarding the use of animals to answer psychological questions. The field of animal learning may be mistakenly perceived, for example, as a science that is interested in establishing a hierarchy of the intelligence of different species. As such, animal learning research might be interpreted as an attempt to emphasize differences between species. In fact, this area of research prefers to emphasize the established similarities between animals. It is well known that different species are unique in their reaction to certain stimuli. For example, a rat is well equipped to deal with labyrinthine structures (Roberts, 1979), and may appear much more *intelligent* in such a situation than a pigeon. However, the exceptional homing abilities of pigeons (Keeton, 1974) demonstrates that species react to different conditions in a unique manner. These differences are interesting to the ethologist or biologist. Animal learning theorists, on the other hand, are concerned with the similarities that animals at differing levels of the hypothetical evolutionary tree share. It is because of the established similarities between species that animal learning theorists have been able to generalize their findings to human psychology.

Why not simply examine the learning processes of humans? Although the study of human behaviour is also very informative, animals may be chosen as subjects for a number of reasons. It is assumed from Darwin's theories (1859) of natural selection that *homo sapiens* has evolved to become a more complex being than those lower on the phylogenetic tree. Basic behavioral laws may be more easily derived by studying the learning capabilities

of a less complex species. For example, Ivan Pavlov (1927) used his famous work with dogs on the conditioned reflex to later describe the development of language in humans. B.F. Skinner (1953) has used his renowned stimulus-response work with rats and pigeons as a basis for his cause and effect model of human behaviour. This work has been used in applied settings to control the maladaptive behaviours of delinquents, psychotics and the mentally retarded (Kazdin, 1976). These respected historical figures of psychology demonstrated that larger, more complicated, processes could be studied and understood through the development of basic laws and principles established through work with animals. Biologists traditionally study the systems of lower forms of life in order to better understand our own. The use of lower organisms for such studies is due primarily to the fact that the elaborate biological structures under study are simply easier to understand at a more elementary level. We may then begin to generalize this basic knowledge to other more complex species.

Recently, a specialized area of animal learning has developed that includes the *memory* of animals. Traditionally, the study of memory has been carried out with human subjects, yielding many interesting results. However, examining memory in humans is often a difficult process because of the intrusion of language capabilities. On the other hand, examining memory in animals eliminates the problem of language intrusions, but presents other obstacles. For example, it is possible that the memory processes of humans do not bear useful resemblance to those of animals. Therefore, Wright & Watkins (1987) suggested that replicating effects in both types of subjects enables researchers to transcend these barriers. The study of simpler animal memory processes is useful in establishing general and

basic laws of memory. Further, a very powerful tool of analysis is formed when parallels can be drawn between animal and human studies of memory.

The broad topic of animal memory will be discussed in several sections in the following literature review. A distinction in types of memory storage, based on the type and length of time information is retained, is reviewed. The discussion of this *working memory* and *reference memory* distinction will serve to demonstrate several experimental procedures that are vital to the study of animal memory. Following this, research dealing with the manipulation of trial outcomes is reviewed in light of *the differential outcome expectancy*. Finally this section will end with a discussion of the types of processing which animals may be using to maintain information in memory.

The ability of animals to time events and to maintain a representation of that duration in memory is of specific interest to the present study. Therefore, literature pertaining to animal memory for event duration will be reviewed prior to discussing the present study.

Animal Memory

Honig (1978) distinguished between two types of memory, based on their contents: working and reference memory. Working memory holds information for short periods of time and has limits to the amount of information which can be maintained. The contents of working memory are constantly being replaced with information that is more useful for the present time. In contrast, the primary characteristic of reference memory is that its contents remain relatively stable with time. This type of memory is used in learning to perform a task (Roitblat, 1987). The interaction of working and reference memory can be

illustrated with tasks used in animal learning studies. For example, a pigeon learning how to perform a certain task such as pecking a keylight for food requires a stable type of knowledge such as reference memory. In contrast, remembering the specific details of each trial, such as which keylight to peck, requires a more dynamic memory process such as working memory. Therefore these two types of memory can work together to affect behaviour (Roitblat, 1987).

Working memory has been studied by using such procedures as the delayed matching-to-sample task (DMTS). The DMTS takes place in a box developed by B. F. Skinner (1938) which contains devices such as levers for a rat or keys for a pigeon that, when properly activated by the animal, deliver reinforcement. Within the Skinner box or operant chamber, a sample stimulus is presented that typically represents information that, if remembered, will be valuable to obtain reinforcement later in the trial. After a delay, two other stimuli appear. Relevant information from the sample should now be matched to one of these keys. For example, in a hue matching task, if a red keylight were presented to a pigeon as the sample stimulus, after a delay, red and green keylights would appear. A correct response would be to peck the red keylight. At this point, reinforcement, typically in the form of food, is delivered to the subject. If the subject does not respond appropriately, then no reinforcement will be delivered. A variant of DMTS is delayed symbolic matching-to-sample (DSMTS) which involves the choice of a comparison stimulus that is not identical to the sample. For example, a red keylight sample may be matched to a vertical line, while a green keylight sample may be matched to a horizontal line.

The outcome of several years of experimenting with DMTS led Roberts and Grant (1976) to propose a theory of 'trace strength and decay'. The results from studies manipulating the length of the sample stimulus, the length of the delay interval, and the length of delay between successive sample stimuli on multiple sample trials, all seemed to point to one conclusion: a trace of the sample stimulus is created in memory through its presentation. Therefore, during DMTS, the subject chooses the comparison stimulus that most resembles the trace of the sample stimulus which has been created in memory. It was hypothesized that this trace grew in strength with lengthened exposure, and decayed during delays when the sample was not present.

Roberts (1972) varied length of exposure to the sample stimulus by presenting three different fixed-ratio (FR) requirements on the sample key (FR1, FR5, and FR15). A fixed-ratio schedule allows for reinforcement after a certain number of responses. For example, an FR25 means that every twenty-fifth response is reinforced (Schwartz, 1984). Also, Roberts and Grant (1974) varied the length of exposure to the sample by presenting it for different preset periods of time (.5s, 1s, 2s, 4s, and 8s). The results of both studies revealed that increasing the length of the exposure to the sample stimulus facilitated remembering of the sample. Roberts and Grant (1974) also demonstrated that the sample stimulus was remembered less with increasing delay intervals.

Also contributing to the trace strength and decay theory were results from studies manipulating the length of time between sample stimuli, or the interstimulus interval (ISI). Roberts and Grant (1974) factorially manipulated the length of a first sample (1s and 4s), the length of the ISI (0s, 2s and 5s), the length of a second sample (0s, 1s, 2s and 5s), and the

length of the delay interval between sample and comparison stimuli (0s and 2s). The results relevant to ISI revealed that increasing the time interval between samples decreased performance. Also, Roberts (1972) found that 8 successive presentations of samples increased memory performance more than 2 successive presentations. Finally, the commutativity of ISI's was examined by comparing two conditions of spacing 8 presentations of a sample stimulus. In the first condition (spaced-massed), 4 sample stimuli were presented with 10s ISI's and then 4 were presented with 0s ISI's. In the massed-spaced condition 4 sample stimuli with 0s ISI's were followed by 4 with 10s ISI's. Since, according to the theory, trace strength grows in the presence of the stimulus and decays in its absence, better performance was predicted in the condition receiving massed spacing last. Indeed, the spaced-massed condition yielded significantly better memory performance (Roberts, 1972).

This interpretation of working memory considers the organism to be passive because the trace strength is controlled by external factors, and intervention by the organism has no role. This theory has since been challenged with recent findings from directed forgetting studies, studies involving retroactive interference, and studies manipulating the expectedness of sample stimuli, all of which suggest that working memory operates in an active manner (Grant, 1981).

In directed forgetting studies, subjects are trained with additional stimuli (cues) in the delay interval which signal whether or not comparison stimuli will be presented. One type of cue, a remember cue, signals that comparison stimuli will be presented, while forget cues signal that the comparison stimuli will be omitted. During testing, occasional 'probe' trials are inserted during which the subject is signalled with a forget cue, but is subsequently

presented with choice stimuli. The results of such studies have revealed that subjects show a decrement in performance on forget cue probe trials which misleadingly signal that no comparisons will be presented. This procedure has provided numerous insights into the nature of the memory code.

Grant (1981) suggests that active processing is involved since, through directed forgetting studies, the rehearsal of information can be brought under stimulus control. To examine this, Grant (1981b) used a successive DMTS task in which the sample stimulus is followed by a delay interval, and then a single test stimulus. If the sample and the test stimulus match, responding to the test stimulus is reinforced, whereas if they do not match, responding to the test stimulus is not reinforced. Remember and forget cues were then inserted during the delay interval. To avoid the possibility that a decrement in performance on forget-cued trials is due simply to the absence of reinforcement, Grant presented response independent reinforcement on half of the trials. It was theorized that forget cues terminate the processing of the sample stimulus, whereas remember cues enhance or maintain processing. In support of this hypothesis, accuracy on forget-cued trials was found to be lower than on remember cued trials.

To examine the exact nature of the effects on processing, further experiments were carried out. It is not clear from the described studies whether the forget cues terminate processing, or whether remember cues enhance it, or both. Therefore another experiment was done in which the temporal position of the remember and forget cues within the delay interval was manipulated. It was hypothesized that positioning of the cues would affect the duration of processing. For example, forget cues presented early in the delay may terminate

rehearsal sooner. The results revealed that although manipulation of remember cues had no effect, the presentation of forget cues later in the delay minimized their effects.

Grant suggests that maintenance rehearsal of the sample takes place until the cue to forget is presented. This type of rehearsal is believed to maintain working memory for trial details, but does not alter reference memory. Maintenance rehearsal is viewed as a process that is under the control of the subject, and is a learned strategy that may only be utilized in specific situations such as DMTS (Grant, 1984). Therefore, Grant (1981) suggested that when the forget cue is presented late in the delay, an abundance of rehearsal has already taken place, lessening the impact of the cue. This stimulus control of rehearsal is a strong indication that working memory processing is active, rather than passive.

According to Grant (1981), evidence revealing retroactive interference in DMTS studies is also indicative of active processing. Retroactive interference occurs when a stimulus hinders the remembering of a previously presented stimulus (Schwartz, 1984). The occurrence of retroactive interference in DMTS indicates that a process is taking place which is more effortful than those suggested through trace strength theory.

Research has shown that any change in illumination level during the delay interval causes a performance decrement in pigeons (Roberts & Grant, 1978; Tranberg & Rilling, 1980). It was suggested that rehearsal of sample information is interrupted by the change in illumination (Tranberg & Rilling, 1980). The notion that the light itself, as well the chamber which it exposes is a distraction which absorbs memory capacity that would be used to maintain sample information is referred to as the "rehearsal/illumination" hypothesis (Roberts & Grant, 1978). The discovery that a change from light to dark conditions during the delay

interval also causes retroactive interference was grounds for the modification of the "rehearsal/illumination" hypothesis resulting in the "rehearsal/surprise" hypothesis.

According to the rehearsal/surprise hypothesis, the interference is due to the surprising nature of a change in illumination, not due to the effects of the illumination itself as is offered by the rehearsal/illumination hypothesis.

Grant (1988) tested the rehearsal/surprise hypothesis by examining the magnitude and persistence of the disruption in performance. After training one group of birds with an illuminated delay interval, and another with a darkened delay interval, extended testing (144 sessions) with half of the trials illuminated revealed results inconsistent with the rehearsal/surprise hypothesis. Grant reports that although an increase in chamber illumination during the delay causes a persistent disruption in performance accuracy, a decrease in illumination causes only temporary disruption (a disruption which lasted approximately 60 sessions). The rehearsal/surprise hypothesis would predict no difference in disruptions between groups receiving increases or decreases in illumination. Also, this theory would predict that prolonged experience with the changed illumination level would decrease its disruptiveness because it would no longer be surprising. Therefore, these results are not consistent with a rehearsal/surprise hypothesis. However, as suggested by Grant (1988) an amalgamation of both hypotheses could clarify these data. Two factors were proposed: (a) due to the distractions available in a lit chamber, rehearsal of sample information occurs more effectively in the dark, (b) a change in context during the delay interval could be disruptive of the rehearsal process. Most relevant to the present discussion, the interference effects of changes in illumination suggest an active rehearsal process is at work in DMTS.

The manipulation of the surprisingness of samples has also provided evidence of active rather than passive working memory processes. In such a study, Grant, Brewster and Stierhoff (1983) demonstrated that surprising samples were more memorable than expected ones. In this study, sample stimuli were the access to food or no-food (i.e. a blackout), and comparison stimuli were red and green keylights. A peck to the red keylight was correct after a food sample and a peck to the green keylight was correct after no-food. After acquiring this task, subjects were trained on a successive discrimination task in which a large triangle was followed by food and a small triangle was followed by no-food. Finally, the two types of trials described above were combined so that a triangle was presented for 10s before the conditional matching task. On 'expected' trials a small triangle was presented before a trial which would end in no-food, or a large triangle was presented before a trial which was to end with food. On 'surprising' trials the opposite arrangement existed. It was shown that less forgetting occurred on surprising trials than on expected trials. This 'surprisingness effect' is also consistent with the idea that surprising stimuli induce more active rehearsal and are therefore more memorable.

In summary, the literature from directed forgetting studies, studies manipulating retroactive interference, and studies involving unexpected sample stimuli all reveal evidence for an active maintenance rehearsal process. At this point it is necessary to review an area of research that has more direct relevance to the present study and will provide a basis for understanding the remainder of this literature review: the differential outcome expectancy.

The Differential Outcome Expectancy

The role of the outcome factor in operant responding was once considered to be less influential than it is currently. The reinforcer was considered to be no more than a catalyst that strengthened the stimulus-response association. More recent research suggests that manipulations involving the outcome affect the degree of conditioning which takes place (Trapold, 1970).

In a landmark study, Trapold (1970) established that in a two-choice discrimination, the reinforcement of one correct choice with pellets and the other with sucrose facilitates learning when compared to the reinforcement of all correct choices with either pellets or sucrose alone. This effect is now referred to as the Differential Outcomes Effect (DOE). In this initial work on the subject, Trapold suggested that subjects receiving different outcomes developed an expectancy of each outcome to follow. This expectancy aided correct choice behaviour by providing an additional cue.

To further examine this possibility, Trapold also manipulated the rate of discrimination learning by preestablishing expectancies that were either consistent with, or inconsistent with expectancies that would be developed during a subsequent discrimination. One group of rats were trained with pairings of tone-pellets and clicker-sucrose while another group received the opposite pairings of tone-sucrose, and clicker-pellets. Following this, subjects received discrimination training where responding to one lever was reinforced with sucrose in the presence of a tone, and responding to the other lever was reinforced with pellets in the presence of a clicker. The discrimination was learned faster by rats which received preexpectancy training that was consistent with expectancies developed during

discrimination training. Subjects that received a clicker conditioned stimulus (CS) for pellets and a tone CS for sucrose in phase 1 showed facilitated discrimination learning compared to the group that received the opposite arrangement. This result also lends support to the theory that outcome expectancies mediate choice behaviour. The distinct outcome that was paired with the stimulus preestablished an expectancy which later facilitated discriminative performance in those rats that received consistent phase 1 and 2 training. Trapold (1970) concluded that different reinforcers establish expectancies which function as discriminative cues.

Research involving the differential outcome effect (DOE) has supported this outcome-expectancy mediation hypothesis, although other theories have been presented. One such theory maintains that the DOE is due to the increase in distinctiveness of the sample stimuli causing them to become more memorable. This hypothesis views this distinctiveness as resulting from the sample-outcome associations, whereas the mediational view described above contends that an expectancy or anticipation of the outcome develops through the sample-outcome association.

Peterson (1984) trained subjects in DMTS with colours as sample stimuli and linetilts as comparison stimuli. One group (Group D) received differential outcomes of food and no food. For responding correctly to one comparison stimulus, Group D was presented a tone, while for responding correctly to the other comparison stimulus they received grain. Another group of pigeons (Group N) received food or no-food (with tone) equally often following each response. In a second phase, half of Group N and half of Group D were exposed to pairings of a circle stimulus with food and a triangle stimulus with no-food. The

other half of Group N and D also received equal numbers of pairings of a circle and a triangle with food or no-food. That is, the outcomes were presented equally often with each stimulus-in other words, they were presented nondifferentially. In this way four groups were created. Group DD (differential-differential) received differential outcomes on both the colour-linetilt discrimination trials in phase 1 and the geometric shape/outcome pairing trials from phase 2. Group DN (differential-nondifferential) received differential outcomes on the colour-linetilt discrimination trials but received food or tone equally often after either a circle or a triangle stimulus on the shape/outcome pairing trials. Group NN received nondifferential outcomes all the time, while Group ND only received differential outcomes on geometric shape/outcome pairing trials.

A transfer test was implemented where the geometric shapes used in phase 2 were substituted for the colour stimuli used in phase 1 as sample stimuli, while linetilts were maintained as the comparison stimuli. The DD group showed immediate transfer effects while all other groups fell to chance levels of performance. Presumably, both the colour and the shape stimuli evoked an expectancy that could be used to facilitate the stimulus transfer in Group DD. A theory of sample discriminability would predict the Phase 2 pairings of the geometric shapes with the different outcomes in the ND group would also facilitate discrimination performance in the transfer test. However, since this did not occur, an outcome expectancy is present. The Phase 2 pairings should have been enough to preestablish the discriminability of the geometric shapes. Other studies utilizing similar designs have also reported successful transfer of training (Edwards, Jagielo, Zentall & Hogan, 1982; Peterson & Trapold, 1980).

Urcuioli (1990a) points out a third possible origin of the DOE that has not yet been discussed. It is possible that differential outcome expectancies can control responding in addition to, and without changing the possible control of the sample stimulus. In the following study, it was demonstrated that the presentation of food and no-food as differential outcomes overshadowed the control of the sample stimulus in a matching-to-sample task. That is, since the salient expectancy cues cause information from the sample stimuli to be redundant, expectancy cues 'took over' control of responding. Urcuioli (1990a) demonstrated that compared to nonzero probabilities of food as differential outcomes, food/no-food outcomes caused the formation of stronger expectancies which can overshadow control of the sample stimulus.

Urcuioli (1990a) established a DOE using differential probabilities of reinforcement in Experiment 1A. In Experiment 1B a DOE was established using food and no-food differential outcomes. It was hypothesized that a larger DOE would be present in Experiment 1B because the presence or absence of food would be a more salient cue than nonzero (i.e. .2 or .8) probabilities of food. The results showed that those trained with food/no-food as differential outcomes learned faster, and had better retention than both the nondifferential outcome groups (from Experiment 1A and 1B) and the differential outcome (DO) group from Experiment 1A.

In the second set of experiments, the outcome expectancy cues were removed and performance was compared to subjects that never had expectancy cues. There were three predictions based on the three possible origins of the DOE that have already been discussed. First, if differential outcomes make the sample stimuli more distinctive, the DO group will

continue to display superior performance relative to the NDO group when the DO cue is removed. If overshadowing of sample stimuli has taken place, the DO group will perform poorly compared to the NDO group when the expectancy cues are removed. The third prediction was that if the expectancy cues exert additional stimulus control without alteration to the sample stimulus control, no difference in performance levels would exist between the DO and NDO groups.

Through the use of off-baseline sessions in which samples were simply paired with nondifferential outcomes, and no matching is required, Urcuioli (1990a) was able to remove the expectancy cues outside of the matching context. In the second experiment, subjects received nondifferential probabilities of food with each sample stimulus (Experiment 2A), or food/no-food on a random half of all pairings with each stimulus (Experiment 2B). Following this, subjects were returned to 0-delay matching-to-sample with nondifferential outcomes and subsequently, mixed delay matching-to-sample. Subjects in Experiment 2A received nondifferential probabilities of reinforcement, while subjects in Experiment 2B nondifferentially received food/no-food outcomes. The results for Experiment 2A revealed no performance differences between DO and NDO groups. This suggests that differential probabilities of reinforcement provided an additional stimulus control cue that did not alter the control of the sample stimulus. In contrast, results from Experiment 2B revealed that food/no-food outcomes overshadowed the control of the sample stimulus. Subjects initially trained with food/no-food outcomes performed poorly compared to those initially trained with nondifferential outcomes.

Finally, in Experiments 3A and 3B, to demonstrate that outcome expectancies were guiding choice behaviour in the previous experiments, a transfer test was administered. After reestablishing control of expectancies through the presentation of different outcomes, these outcomes were paired with new stimuli in off-baseline acquisition sessions. In the transfer phase, the new stimuli were substituted for the existing sample stimuli. The results revealed complete transfer. Thus, a DOE had indeed been in control of choice behaviour. Therefore, Urcuioli (1990a) demonstrated that when differential probabilities of reinforcement were employed, the DOE provided an additional source of stimulus control that did not affect control by the sample stimulus, however, when reinforcement and nonreinforcement were used as differential outcomes, the expectancy overshadowed the control of the sample stimulus and took exclusive control of choice behaviour.

Peterson, Linwick, and Overmier (1987) point out that perhaps comparing memories for neutral sample stimuli, such as keylights, with expectancies for such survival-relevant outcomes as food and no-food may be biased because it may be more efficient to closely attend stimuli that relate to food. Therefore, they compared memories for samples associated with the presentation of food or no-food before the comparison stimuli are presented, with outcome expectancies of food and no-food in a DMTS procedure. A 'Color Only' group received prechoice food and no-food events which were randomly presented with each sample stimulus, as well as nondifferential outcomes of food and no-food. Therefore, this group had only sample stimulus information (i.e. color) to aid in correct choosing. An 'Expectancy' group also received prechoice food and no-food events which were randomly presented with each sample, however, this group received differential outcomes of food and

no-food. This group had the additional aid of expectancies to guide choice behaviour. A 'Memory' group received prechoice food and no-food events which were perfectly correlated with the sample stimulus, and nondifferential outcomes. If food and no-food events as sample stimuli are as salient as outcome expectancies of the same, this group should perform similarly to the Expectancy group. A 'Synergism' group received prechoice food and no-food events perfectly correlated with the same samples that the outcome expectancies of food and no-food were, whereas an 'Antagonism' group received prechoice food and no-food events that were perfectly correlated with the opposite sample that the outcome expectancies of food and no-food were. That is, the Synergism group always receives a prechoice food event with the green sample followed by an outcome of food, whereas the Antagonism group always receives a prechoice food event on green samples trials, followed by an outcome of no-food. With extended delay intervals of up to 35s, large differences between some of the groups emerged. However, the Expectancy group performed similar to the Synergism group at all delay intervals. This result provides further support for the view that when outcome expectancies are available to aid in choice behaviour, information from sample stimuli is ignored. If subjects were utilizing sample information in this instance, performance in the Synergism group should have been more accurate than the Expectancy group. Further, the Antagonism group performed more accurately at extended delay intervals than the Memory group, suggesting that even when memories of prechoice food and no-food events were inconsistent with outcome expectancies of food and no-food, more cues were available for correct responding than when only memories of prechoice food

and no-food events were available. Finally, the Color Only group did not maintain accurate performance (fell to chance levels) with extended delay intervals.

These results provide strong evidence that outcome expectancies (of food and no-food in particular) are very salient cues to aid in responding for reasons other than that they are survival-relevant. That is, outcome expectancies are more salient than sample stimulus information in guiding choice behaviour even when sample stimuli are also presented with survival relevant (food or no-food) stimuli. Therefore, the established saliency of outcome expectancies that was demonstrated in Urcuioli's study (1990a) was not due simply to the possibility that next to neutral stimuli such as durations and line orientations, outcome expectancies of food and no-food controlled matching performance because of their relevance to survival.

Urcuioli (1990b) further examined the role of sample discriminability and outcome expectancies in the DOE. Two separate groups were trained on a many-to-one matching-to-sample task with differential probabilities of reinforcement as outcomes. In a many-to-one task, several samples are matched to one comparison. For example, a peck to a red comparison stimulus may be correct after a blue or a vertical sample. For one group (Group Correlated) the different outcomes were perfectly correlated with the correct comparison choice. For Group Uncorrelated the different outcomes were inconsistent with the correct comparison choice thus making it unfeasible for this group to utilize expectancy cues. For the uncorrelated group to perform accurately, expectancies would have to be abandoned, presumably for reliance on cues from sample stimuli. Therefore, if expectancies are typically guiding behaviour in a DO paradigm, a performance decrement may occur in Group

Uncorrelated when compared to Group Correlated. If sample discriminability is responsible for the DOE, no difference in performance accuracy or retention would occur between the two groups. The results revealed that Group Correlated performed more accurately and showed better retention than Group Uncorrelated therefore ruling out the possibility of sample discriminability causing the DOE, and suggesting that outcome expectancy cues may have been guiding choice behaviour.

In order to examine the amount of control the sample stimulus possessed in both groups, Experiment 2 involved the removal of expectancies through an off-baseline procedure (Urcuioli, 1990a), followed by many-to-one matching-to-sample with nondifferential outcomes. It is possible that in Experiment 1, the DO expectancy of Group Correlated caused sample stimulus information to be overshadowed, resulting in ignorance of the samples. Therefore, when expectancy cues are removed and Group Correlated is forced to rely on sample stimulus information alone for the first time, their performance when compared to Group Uncorrelated will be less accurate. The results revealed a large drop in the performance of both groups, and Group Correlated maintained superior accuracy and retention. Urcuioli suggested that the most plausible hypothesis for this puzzling finding is the possibility that sample stimulus control is a byproduct of the more frequent reinforcement of responding which Group Correlated received. Since Group Uncorrelated did not perform as accurately during initial training, for them reinforcement of responding did not occur as often as in Group Correlated.

To examine this possibility, in Experiment 3 the groups were shifted so that subjects from Group Correlated now received uncorrelated differential outcomes training and vice

versa. Following this, expectancy cues were removed by pairing sample stimuli with nondifferential outcomes off-baseline (Urcuioli, 1990a) and then subjects again received many-to-one mixed-delay matching-to-sample with nondifferential outcomes. It was predicted that if the sample stimulus control demonstrated in Experiment 2 was a byproduct of the frequent reinforcement of responding, the advantage would carry through even though the groups were shifted. If the advantage was due to the prior training with correlated outcomes and correct choices, the difference in the groups should be eliminated or even reversed. The results from the nondifferential matching test revealed a reversal of effects. The performance accuracy of Group Correlated-Uncorrelated dropped after uncorrelated training and the performance accuracy of Group Uncorrelated-Correlated increased after correlated training. Thus, the increased accuracy of Group Correlated after nondifferential training is not due to the frequent reinforcement for responding as was suspected.

Although the superior performance of Group Correlated after nondifferential training in Experiment 2 is difficult to explain by either a mediational or a sample discriminability view, the results in large part are supportive of the notion of an expectancy mediating choice behaviour. When expectancies are no longer predictive of the correct choice, matching performance suffers.

Urcuioli (1991) presented additional strong evidence against the sample discriminability hypothesis. In this study, Urcuioli compared the performances of a DO group, in which outcomes were correlated with the correct comparison, and a DO group, in which the outcomes and correct comparisons were uncorrelated, with the performance of an NDO group. It was hypothesized that if an increase in sample discriminability was the reason

for the increased accuracy in DO groups, then whether the outcomes were correlated with the correct comparison would not affect performance. On the contrary, the uncorrelated DO group actually learned the discrimination slower than the NDO group, whereas the correlated DO group learned the discrimination faster than the NDO group. This result suggests that expectancies were guiding choice behaviour, because when expectancies were inconsistent with correct choice, as in the uncorrelated DO group, acquisition was slower than in an NDO group.

In summary, research involving the origins of the robust DOE has unveiled several facts. Through experience, an expectancy of the reinforcer to follow develops, and this expectancy facilitates the acquisition of the discrimination. Peterson (1984) and Urcuioli (1990b) present evidence that suggests that the DOE is not due simply to an increase in the distinctiveness of the sample stimuli, but that expectancies of different outcomes guide choice behaviour. Urcuioli (1991) presents evidence that suggests that an increase in sample discriminability is not responsible for the increase in accuracy that comes with differential outcomes. However, evidence presented by Urcuioli (1990a) demonstrates that the sample stimulus plays a role of variable importance depending on the level (nonzero probabilities of food, or food/no-food) of reinforcement.

Retrospective and Prospective Processing

Evidence has been reviewed that suggests that information is held in working memory through an active process. There are two different forms of information which animals may actively maintain in memory to perform accurately in tasks such as DMTS. One type of

information would result if the animal decided early in the trial, perhaps as soon as the sample appears, what response to make to the comparison stimuli. This could occur through the repeated presentation of samples and comparisons such that the subject develops an anticipation of trial details. If the animal were matching hues, when a red sample appeared a decision to choose red could be made immediately in anticipation. Therefore, during the delay interval only that response decision would have to be rehearsed or remembered. This type of processing has been referred to as *prospection* because the animal anticipates responding to a certain comparison stimulus (Honig & Thompson, 1982; Honig & Wasserman, 1981; Roitblat, 1987). Traditionally, accurate performance on DMTS has been considered to be due to a retrospective memory process. In this type of processing no response decisions are made early in the trial but are postponed until the comparison stimuli are presented. At this point the animal will use the information gained from the sample stimulus which has been maintained over the delay interval (Honig & Thompson, 1982; Honig & Wasserman, 1981).

Other similar types of procedures are often used to study working memory. For example, the delayed simple discrimination (DSD) and the delayed conditional discrimination (DCD) are procedures frequently used to examine the nature of the memory code maintained in working memory. Modifications of standard matching paradigms have also been useful; these include manipulations of stimulus discriminability, the number of sample and comparison stimuli, as well as comparison dimension signalling.

In the procedure referred to as a delayed simple discrimination (DSD), typically one of a set of stimuli, the initial stimulus, is presented to the subject which signals what type of

response will procure reinforcement later in the trial. After a delay, a second stimulus, the test stimulus, appears and the response is performed. In this type of procedure the subject can decide early in the trial, as soon as the initial stimulus appears, what response is required later in the trial. Therefore this type of procedure may be conducive to the use of prospective memory. In contrast, in a delayed conditional discrimination (DCD) both the initial stimuli and the test stimuli hold information which must be considered conjointly in order to perform accurately. For example, a correct response in this situation might be to respond to the test stimulus only if it matches the initial stimulus on some relevant dimension. Since information from the test stimulus in relation to the initial stimulus is required, prospection would not be useful. This design may therefore be facilitative of retrospective coding of information. When these two varieties of discriminations are compared, performance on the DSD has been shown to be more accurate than on the DCD at increasing delay intervals (Honig & Wasserman, 1981; Smith, 1967). This result may indicate that prospection is more robust than retrospection (Honig & Thompson, 1982).

It is obvious from the description above that serious procedural differences have been employed in testing these two types of discriminations. The DSD requires only that some type of information regarding the initial stimulus be used, while the DCD requires information regarding both the initial and the test stimuli. Therefore the DSD requires less information to be remembered and may require less memorial effort, as well as possibly being prone to a different type of processing, prospection.

Honig and Dodd (1983) confronted this problem by designing two different types of conditional discriminations. In a discrimination intended to facilitate prospective processing,

the conditional stimuli were presented initially. Therefore the subject, although still forcibly performing the conditional discrimination, may maintain a response decision over the delay interval. Performance on this procedure was contrasted with that of a regular conditional discrimination. Indeed, at lengthened delay intervals, performance on the conventional conditional discrimination became significantly lower than that of the modified discrimination. If it is assumed that strictly prospection is taking place in the altered conditional discrimination while strictly retrospection takes place in conventional conditional discriminations, such results may indicate that prospection is the more durable memorial process.

The possibility of subjects utilizing differential outcome expectancy codes to perform more accurately in the DSD as opposed to the DCD has also been suggested by Honig and Thompson (1982). On only half of the DSD trials does reinforcement follow. This difference between positive (reinforcement ending) trials and negative (nonreinforcement ending) trials could provide a differential outcome expectancy (DOE) cue thereby producing superior performance on DSD's. In an examination of this possibility, Urcuioli and Zentall (1990) altered the typical DSD procedure in order to allow for the possibility of reinforcement on all trials. That is, on matching trials in DCD's and positive trials in DSD's subjects were reinforced for responding, and on nonmatching (DCD) or negative (DSD) trials all subjects were reinforced for not responding for a period of 5 seconds. In this way both the DCD and DSD end in reinforcement on all trials during which the subject responds appropriately. The data revealed that when the two procedures are equated in this manner, no difference in performance accuracy exists. It is possible that the apparent difference in

performance accuracy reported for these two discrimination procedures has been primarily due to differences in outcome expectancies, not to hypothetical differences in retrospective and prospective processing.

In contrast, the results of Pontecorvo (1985) suggest that the performance differences between the DSD and DCD are not due solely to a DOE. Subjects were expected to peck the left side keys when the two samples matched and peck the right side keys when they did not. Since reinforcement was available on every trial, the possibility of the development of a DOE was eliminated. As had been previously reported in other studies, greater retention was found for pigeons required to complete DSD rather than a DCD trials indicating that response instructions, not expectancies, were generating the performance difference. Urcuioli and Zentall (1990) point out that the design used by Pontecorvo may not necessarily be indicative of the use of response intentions. Instead subjects in the DSD group simply encoded whether or not the second stimulus was different than the first stimulus. If this retrospective strategy is easier, this may account for the apparent difference in performance. Therefore, the DSD and DCD may not inherently motivate different types of processing, and can not be used to examine aspects of retrospective and prospective processing.

As previously mentioned, manipulating the quantity of stimuli in the DMTS procedure is a method of examining the nature of the memory code. Santi and Roberts (1985a) manipulated the number of sample and comparison stimuli to derive two types of mapping conditions. In the many-to-one condition (MTO) three different types of sample stimuli were mapped onto one comparison stimulus. That is, after a red, vertical or circle sample, the red comparison key was correct, whereas after a green, horizontal or triangle sample, the green

key was the correct choice. In the one-to-many (OTM) mapping condition there were three correct choices for each of the sample stimuli. A peck to a red, vertical or circle keylight was correct after a red sample and a peck to a green, horizontal or triangle keylight was correct after a green sample stimulus.

Santi and Roberts (1985a) combined the above design with a differential outcome (DO) procedure which manipulated the probability of reinforcement. In the DO condition, a probability of reinforcement of either 0.2 or 1.0 was associated with one set of sample and comparison stimuli, while the other probability was associated with the other set. The DO condition was compared to one in which a constant probability of reinforcement of 0.6 was given (NDO condition). Therefore, four groups were created for study: MTO-NDO, MTO-DO, OTM-NDO, OTM-DO.

The rationale for this design was twofold. First, it was suggested that if prospective processing were taking place there would be a difference in memory loads in the two mapping conditions, whereas if retrospection were taking place, no differences in memory load would exist. If subjects are prospecting in a one-to-many condition, they must remember three response codes, whereas prospecting in a many-to-one condition requires the maintenance of only one response code. If subjects retrospect, both many-to-one and one-to-many conditions require the maintenance of the sample stimulus. Therefore, if the pigeons prospect, a faster rate of forgetting over the delay interval is expected for the OTM groups. Secondly, it was predicted that subjects would develop a DOE much like that described earlier. As has been shown, through the development of expectancies of reinforcement, the memory load requirements of the task for the DO groups would be lower. Instead of

remembering sample details or response instructions, they must simply maintain one expectancy code.

As predicted by the prospective coding hypothesis, both MTO groups performed significantly better than both OTM groups when colours, line tilts or shapes served as either sample or comparison stimuli. Also, superior performance was found in the DO groups as compared to the NDO groups. It was concluded that there was a difference in the difficulty of the OTM and MTO tasks and that this favoured a prospective processing point of view.

The superior performance of the MTO groups may have been due to the common coding of sample stimuli. Common coding refers to the coding of sample stimuli as similar because of their association with shared outcomes or comparison stimuli. Grant (1982) presented pigeons with two different associative sets of sample stimuli. One associative set of food, 20 responses to a white circle on a keylight, and red samples were mapped onto a red comparison, whereas the other associative set of no-food, 1 response to a white circle on a keylight, and green samples was mapped onto a green comparison. Each trial could include the presentation of 1, 2, or 3 of the sample stimuli from one associative set. On trials including more than one sample, the same sample stimulus could appear twice or three times. For example, a trial could begin with red, food, and red sample stimuli. Performance was found to be most accurate on multiple sample trials but it did not matter how many times one particular sample stimulus was repeated within the trial. Grant took this as evidence that subjects were prospectively coding stimuli from the same associative set as one common response instruction. If subjects were retrospectively coding, the multiple occurrences

of one particular sample stimulus on the same trial would lessen memory load and therefore increase performance accuracy. Since this did not occur, this study is taken as evidence of a prospective process.

While many studies have found evidence for common coding (Grant, 1982; Santi & Roberts, 1985b; Urcuioli, Zentall, Jackson-Smith & Stiern, 1989; Zentall, Urcuioli, Jagielo, & Jackson-Smith, 1989), the nature of this code is still under question. Recent evidence has been presented to suggest that it is an intermediate code which does not hold information pertaining to prospective response instructions, or retrospective sample stimulus information, but rather contains associative information between both of these. For example, subjects may be coding associatively related samples as "Sample A" or "Sample B" (Urcuioli, Zentall, Jackson-Smith & Stiern, 1989).

For the purpose of establishing the circumstances under which retrospection and propection occur, the manipulation of the discriminability of the initial and comparison stimuli has been useful as well. Roitblat (1980, Experiment 3) analyzed the confusion errors of pigeons in a DMTS task where easily discriminable samples were mapped onto more difficult comparison discriminations and vice versa. Specifically, colour sample stimuli were mapped onto three linetilt comparisons and vice versa. Therefore, if subjects committed an increased number of confusion errors on trials commencing with difficult sample discriminability, retrospective processes may be at work. With increasing delay intervals the already difficult discrimination will become even more so. However, a decrement in performance on trials with difficult comparison discriminations was found providing evidence in favour of a prospective processing viewpoint.

Evidence from studies signalling the comparison stimulus dimension have also contributed to the examination of distinctions in processing. In a DMTS procedure, Stonebraker and Rilling (1984) presented subjects with a cue superimposed on the sample stimulus, that remained on during the delay, signalling the dimension of the comparison stimuli. Following acquisition of this task, occasional probe tests which incorrectly cued the comparison dimension were presented. Subjects will presumably, if they are prospectively coding, perform poorly on incorrectly cued trials because the information needed to respond correctly was not maintained. Indeed, results revealed a performance decrement on incorrectly cued trials. However, subjects' performance on incorrectly cued trials was still above chance. Not only does a prospective processing explanation have difficulty with this finding, but these results can also be explained with retrospective processing. Subjects may be remembering the sample and the cue as a compound stimulus. When the unexpected comparison dimension appears, subjects retrieve the needed information, but not as reliably as on correctly cued trials. (D'Amato, 1973, as cited in Honig and Thompson, 1982).

To distinguish between these two possibilities, Santi, Musgrave and Bradford (1988) performed a similar study and included no-cue probe trials. This method generates opposing predictions from prospective and retrospective viewpoints. If subjects are prospecting, the only information maintained in working memory over the delay interval is the response instruction. Therefore, when an incorrectly cued trial appears, subjects have maintained no information to respond correctly and performance should drop to chance. However, on no-cue trials, the performance of the subjects will be similar to performance on correctly cued trials, if prospective processing is taking place. If subjects are retrospecting, performance on

incorrectly cued and no-cue trials will be similar because the same information is available to both. That is, information regarding the actual sample stimulus is being maintained over the delay.

Santi *et al.* reported results consistent with this retrospective viewpoint in Experiment 1, which utilized a brief postsample cue. However, in Experiments 2 and 3 the cue was superimposed onto the stimulus and the cue remained on during the delay, similar to Stonebraker and Rilling's (1984) procedure, and a different result was found. Performance on incorrectly cued trials was lower than on correctly cued or no-cue trials. Therefore, it was concluded that subjects may use different coding processes in different situations. When the cue was presented after the sample only, subjects did not use it. However, simultaneous presentation of the cue and the sample stimulus was more useful, allowing subjects to maintain a single response instruction (prospective processing).

Through this review of the literature, several conclusions regarding general animal memory can be drawn. It has been shown that animal working memory entails active processes rather than passive ones like those described by the trace strength theory. A discussion of research involving the origins of the DOE led to the conclusion that expectancies of outcomes actually guide choice behaviour, and that an increase in sample discriminability is not responsible for the increased matching accuracy associated with the presentation of differential outcomes. Also, considering the information that has been reviewed, it seems possible that retrospection and prospection are separable processes that may be used in different situations. This possibility has been suggested by others (Cohen,

Galgan & Fuerst, 1986; Urcuioli & Zentall, 1986). The results of Santi *et al.* (1988) emphasize this possibility.

Animal Memory for Event Duration

The study of the timing abilities of animals is important for several reasons. Since all events have duration, knowledge of the strategies which are used to process time is valuable. Temporal memory can therefore be studied using a variety of stimuli. In the natural environment of the animal, such life sustaining activities as mating and foraging require mechanisms that can measure duration (Roitblat, 1987). Even classical conditioning, a process for which sensitivity is vital for survival, requires an ability to time events.

The study of memory for event duration in animals was only initiated about ten years ago (Church, 1980) as a branch of the investigation of the ability of animals to time events (Roberts & Church, 1978). Two types of procedures are used to examine memory for event duration in animals. Estimation procedures involve conditional discriminations not unlike DCD and DMTS; however, in the case of an estimation procedure, the sample or initial stimuli are temporal durations. For example, in a DMTS situation, 2s and 8s durations of houselight (the overhead light in the operant chamber), serve as sample stimuli. Short (2s) durations might be matched to a red comparison stimulus, and long (8s) durations might be matched to a green comparison stimulus.

Gibbon and Church (1982) used an estimation procedure to examine timing in rats. In a procedure referred to as a temporal generalization, rats were presented with a stimulus duration followed by the presentation of a lever. If the stimulus duration matched that of a

reinforced duration and the animal responded, reinforcement followed. The subjects showed some generalization to the presented durations of values which were similar to the reinforced duration. That is, they responded most often to the correct duration, and often to durations only slightly longer or shorter (Roitblat, 1987).

Production procedures require the animal to reproduce the sample stimulus duration in some way. One type of production procedure, the peak procedure, involves a fixed interval (FI) schedule of reinforcement. In an FI schedule, reinforcement is delivered only if the correct response is made following a fixed period of time. Once the animals have been trained on an FI schedule, they are given probe trials to determine their ability to estimate the passage of time. On probe trials, reinforcement is not delivered following the appropriate response on the FI schedule. Typically, on these probe trials there is a peak in responding (the peak rate), at the time (the peak time) when the FI would normally allow reinforcement. A peak time of responding equalling the FI on this procedure demonstrates the animal's ability to time events (Roitblat, 1987).

The study of animal memory for event duration often utilizes the estimation procedure (Kraemar, Mazmanian & Roberts, 1985; Parker & Glover, 1987; Spetch & Sinha, 1989; Spetch & Wilkie, 1983). For example, subjects are presented with a 2s or 8s sample stimulus of houselight followed by comparison stimuli, typically of colours such as red and green. Pigeons can choose which comparison stimulus is associated with which sample stimulus quite accurately. However, this accuracy is quickly reduced when variable length delay intervals are inserted after the sample stimuli. As the delay interval increases pigeons tend to peck the comparison stimulus corresponding to the short duration sample more often.

This robust phenomenon has been referred to as the "choose-short bias" (Spetch & Wilkie, 1983) and has inspired a number of theories.

In an attempt to explain this choose-short phenomenon, the "subjective shortening" model suggests that during initial training at a constant delay interval, usually 0s (or no delay), a reference memory of the event duration is established that contains temporal or "analogical" information. If the delay interval of a trial is lengthened from that used in training, the working memory representation of the duration seems to foreshorten. That is, as the delay interval of a trial increases, the subjective duration maintained in working memory seems to decrease. Therefore when the comparison stimuli appear, the subjectively foreshortened working memory version of the event duration is compared to the intact original reference memory of the duration. This foreshortening process results in the perception of remembered long sample durations as short and remembered short sample durations as short as well. Since the memory of the long duration has been shortened in working memory, it now most closely resembles the short duration available in reference memory and is so evaluated. If a substantial percentage of the trials that the animal is exposed to remains at the original training delay, this reference memory of the original duration will remain intact, therefore maintaining the choose-short bias (Spetch & Wilkie, 1983). The subjective shortening model therefore claims that the information carried across the delay interval is retrospective, containing analogical information, and not simply prospective, containing response instructions.

Spetch and Wilkie (1983) have established the robust nature of the choose-short bias by demonstrating its occurrence in a multitude of situations: with samples of food or light

durations, with naive or experienced pigeons, and with two and three choice procedures. Spetch and Wilkie (1983) also explored the credibility of the subjective shortening model. As stated earlier, when the delay interval is increased in a stepwise fashion, a choose-short bias occurs. This effect is mirrored by a choose-long bias when the delay interval is decreased from the training value in a stepwise fashion. This result supports the viewpoint that memory codes for temporal information are analogical, a basic tenet of the subjective shortening model. When a delay greater than 0s is held constant during training and on a large number of trials, and smaller delays are introduced on a few of the trials, the reference memory version of the durations is gradually re-established. Then, when smaller delay intervals are presented, the working memory of the durations are compared to the shorter reference memory durations, and are categorized as longer, thereby resulting in a choose-long bias. Another important success for this model is that when a delay interval is held constant, the bias dissipates (Spetch & Wilkie, 1983). This is because the reference memory version of the durations is re-established to match those of the working memory.

An alternate theory often referred to when explaining this choose-short phenomenon is the categorical coding model, which states that coding of duration samples is categorical and prospective in nature (Kraemar, Mazmanian & Roberts, 1985). That is, when an animal is exposed to the sample duration a categorical code resembling "choose the comparison associated with short" or "choose the comparison associated with long" is formed. This categorical code no longer holds veritable temporal information from the original duration, but holds a type of response instruction. As the delay interval between the sample and comparison is increased, this code is simply forgotten. This model assumes that the absence

of a code is most like the short comparison stimulus, and therefore a choose-short bias results.

The categorical coding model can also account for the previously discussed choose-long bias which occurs when delays are decreased in a stepwise fashion. This model assumes that subjects remember long samples better because they are presented for a longer period of time, but that subjects choose short when they forget what the sample was. Therefore, when the delay interval decreases from that of training, subjects will not forget as often, thereby decreasing the tendency to choose short because they have forgotten the sample, as well as increasing the tendency to choose-long because long samples are remembered better. The combined effects of these two occurrences results in a choose-long bias. This model cannot explain the dissipation of the choose-short bias when the delay interval is held constant.

Kraemar, Mazmanian, and Roberts (1985) present evidence in favour of a categorical coding model. In a DMTS procedure subjects were required to match houselight durations of short and long to coloured keys. Unique to this study was the inclusion of trials with no sample, when a peck to a third comparison stimulus was the correct response. The subjective shortening model and the categorical coding model predict contrasting results in this situation. Both models predict that on long sample trials preference for the long comparison key will decrease and preference for the "no sample" key will increase, as the delay interval is increased. The two models differ when it comes to predicting preference for the short comparison key on long sample trials. The subjective shortening model would predict that as the long sample foreshortens in memory it must pass through a value that is

similar to the short sample stimulus. At this point responding on the short comparison key will reach a peak. This value will further foreshorten and will now most resemble the no sample (0s) situation. Categorical coding models predict a constant low level of responding to the short comparison key. If the sample is forgotten on long sample trials, then the subjects should simply respond to the no sample (0s) comparison key. The results clearly supported the categorical coding model. The pigeons responded at a greater rate on the no sample key than on the short sample key. On long sample trials rates of pecking on the short comparison key remained stable and did not increase and then decrease as would be predicted by the subjective shortening model.

Further evidence for a categorical coding model of memory for event duration comes from Parker and Glover (1987). Pointing out that memory for temporal duration may be unique in that it is amodal, they examined whether memory for temporal duration was affected in a similar fashion by events that interfere with memory for modal information. The effect of manipulating illumination during the delay interval was examined. The categorical coding model would predict that changes in delay interval illumination would cause a performance decrement. An analogical viewpoint would contend that delay interval illumination changes could not affect the memory of amodal analogical information. Pigeons were trained to match a 2s keylight duration to red and a 6s duration to green with variable delay intervals of 0s, 4s, and 8s. Half of the birds were trained in this procedure with the houselight remaining on during delay interval, while the other half were trained with it off. During testing, delay interval illumination was manipulated. On 50% of the 4s and 8s delay trials, illumination during delay was changed from that of training, while no changes were

made to the 0s trials. Also, the houselight condition during all other aspects of the trial remained unchanged from that of baseline. Consistent with a categorical coding viewpoint, performance deteriorated on those trials in which an illumination change occurred. Parker and Glover (1987) suggested that this result indicates that the memory code maintained over the delay interval is not an amodal analogical one, since it is affected by the same type of stimuli as is the coding of modal stimuli. However, it is possible that a change in illumination during the delay interval caused subjects to recommence timing, since both the sample durations of light, and the change in illumination during the delay interval are visual events.

Support for subjective shortening is found in another study that presents a situation in which the coding model and the subjective shortening model predict conflicting results (Spetch & Sinha, 1989). Short (2s) and long (10s) sample durations were mapped onto red and green comparison stimuli. A short or long stimulus duration presented before the sample duration (a presample), was inserted on test trials which were intermixed with baseline trials (trials during which no presample was presented).

The two models that we have discussed predict different outcomes in this situation. According to the categorical coding model, trials in which the presample and the target sample were consistent (short-short or long-long) would be less confusing and should produce higher accuracy than would trials in which the presample and the target sample were inconsistent (long-short or short-long). If pigeons were analogically coding the event durations, it was hypothesized that the pigeons may sum the presample and the target sample. The subjects would overestimate the length of all target samples. Therefore, performance

would be more accurate on trials with a long target sample (short-long and long-long) and less accurate on trials with a short target sample (short-short and long-short).

The prediction of the analogical model is not consistent with results reported by Roberts, Cheng and Cohen (1989), which suggested that pigeons do not sum stimuli presented separated by short delays, but rather, they reset and time the stimuli separately. In Spetch and Sinha's study (1989), the data indicated that the pigeons did in fact sum the two separate stimulus events and respond accordingly. This result supports an analogical and not a categorical coding view of memory for temporal events. The summing of the two durations confirms that temporal information in the form of an analogical code is being extracted for memory.

Wilkie and Willson (1990) provided further evidence of a retrospective and analogical code. Subjects were to match houselight duration samples (2s, 8s, or 10s) to colour comparison stimuli (red, orange, and green, respectively). Since some samples (8s and 10s) and some comparisons (red and orange) are more difficult to discriminate than others, it is possible to investigate the occurrence of retrospective or prospective processing through the analysis of errors made. Easily discriminable samples (2s and 10s) were matched to comparison stimuli which were more difficult to discriminate (red and orange). Likewise, samples that are difficult to discriminate (8s and 10s) are matched to comparison stimuli which are easily discriminable (green and red). Therefore, an analysis of the frequency of red-orange errors compared to green-orange errors allows examination of the type of processing used. Since prospective processing entails the maintenance of response instructions, confusions with discriminably difficult comparisons (red-orange errors) are

indicative of this type of processing. However, retrospection involves the maintenance of sample details. Therefore, since green is the correct choice for a 10s sample stimulus, and orange is the correct choice for an 8s sample stimulus trial, an increased amount of green-orange errors would indicate a retrospective process. The results indicated an increased amount of green-orange errors compared to red-orange errors suggesting a retrospective coding process.

These results were supported by a further experiment which utilized an intratrial proactive interference design. This experiment was similar to that described above. Again, houselight durations of 2s, 8s or 10s were mapped onto red, orange and green comparison stimuli respectively. Discriminably difficult (8s and 10s) samples were mapped onto easier discriminations (orange and green). On 8s trials only, a 2s presample was presented. This design presents opposing predictions from the subjective shortening and the categorical coding viewpoints. Advocates of subjective shortening would hold that an increase in green errors would occur because subjects will sum across the presample and sample durations. From the categorical coding viewpoint, more red-orange errors will be committed due to the proactive interference from competing red and orange memory codes. The results clearly supported the subjective shortening model, with subjects performing more green than red-orange errors.

Evidence reported by Santi, Bridson and Ducharme (1991) has implications that affect the interpretation of the results of both Spetch and Sinha (1989), and Wilkie and Willson (1990). Experiment 3 of Santi *et al.* also utilized an intratrial proactive interference design, however, in this study subjects summed the presample and the sample on both

temporal and color presample trials suggesting that temporal summation occurs regardless of the nature of the memory code for temporal samples.

This review of the memory for event duration in animals has accomplished several objectives. An outline of the methods and procedures used to study temporal memory have been presented, as well as some of the phenomena which these methods have uncovered. It was established that the choose-short bias is a robust effect which has inspired two opposing models to explain and describe it. The categorical coding and subjective shortening models were reviewed, and evidence for each was evaluated. The subjective shortening model claims the most extensive as well as the most convincing support from the research presented. Evidence for a retrospective and analogical memory code for event duration is considerable.

The Present Study

The present study examines the flexibility with which pigeons encode memory for event duration. In what situations do pigeons abandon the analogical coding process that they seem to be using? Specifically, what effect will the development of an outcome expectancy have on memory for temporal events? Previous research has yielded interesting results that encourage further investigation.

Santi, Ducharme, and Bridson (in press) have presented evidence of the alteration of an analogical code with a design similar to that of the present study. These experiments examined the effects of differential outcome expectancies on pigeons' memory for temporal as well as nontemporal stimuli. In Experiment 1, short (2s) and long (8s) houselight

durations served as sample stimuli and each was associated with a high (1.0) or a low (0.2) probability of reinforcement for the two differential outcome groups. The DO-short group received a high probability of reinforcement on short sample trials, whereas the DO-long group received a high probability of reinforcement on long sample trials. For the nondifferential outcome group (NDO) each sample was associated with a probability of reinforcement which was 0.6. The testing involved the addition of randomly occurring delay intervals of either 0s (on 75% of trials), 1s, 3s, or 9s (on the remaining 25% of trials). The data of particular interest concerns the DO groups. If responding in these groups was guided by expectancies alone, no choose-short bias would occur and overall performance in the DO groups would be more accurate than the overall performance of the NDO group.

The results showed a typical choose-short bias for the NDO group. The DO-short group displayed a choose-short effect that occurred sooner than that in the NDO group, and accuracy on short sample trials was unaffected by delay, unlike that of the NDO and DO-long groups. The DO-long group did not display a choose-short bias, and at the 3s delay, a choose-long bias occurred. It appears that the choose-short bias was strengthened by the DOE in the DO-short group, and eliminated by the DOE in the DO-long group. Therefore, the DO groups did not exclusively rely on either a temporal memory code or an outcome expectancy code. Instead, the resultant code incorporated both expectancy and temporal attributes. Since the DO groups each responded differently to the differential outcomes, these data cannot be interpreted by expectancies alone.

The existence of a bias to the sample associated with a high probability of reinforcement was documented by Santi and Roberts (1985b). They reported that birds

receiving differential outcomes on a DMTS task involving red and green sample and comparison stimuli displayed higher accuracy across all delays than birds receiving nondifferential outcomes. Within the DO group, performance was found to be more accurate on trials commencing with a sample associated with a high probability of reinforcement than on trials commencing with a sample associated with a low probability of reinforcement. This effect can be seen in the results reported by Santi, Ducharme, and Bridson (in press). The choose-short effect displayed by the DO-short group is much greater than that displayed by NDO group. This can be explained through the combined effects of a bias to the sample associated with a favourable outcome (a choose-favourable bias) like that reported by Santi and Roberts (1985b), an outcome expectancy, and a choose-short bias. On short sample trials, the DO-short group experiences a bias to choose favourably, which is short, a choose-short bias to choose short, and a differential outcome expectancy to choose correctly, which is short. The lack of a choose-short effect, and the lack of a consistent choose-long effect in the DO-long group can be explained similarly. On short sample trials, the DO-long group experiences a choose-favourable bias to choose-long, however, they experience both a temporal coding bias to choose short, and a DO expectancy to choose correctly, which is short. These factors conflict, and may be cancelling each other out to cause these effects.

Experiment 2 examined this finding further by using nontemporal stimuli and shifting half of the NDO group to each of the DO groups. As in the first experiment, short (2s) and long (8s) houselight durations as samples were mapped onto red and green comparison stimuli that resulted in a high (1.0) or a low (0.2) probability of reinforcement. As well, all subjects received nontemporal stimuli of vertical and horizontal line tilts as both samples and

comparisons which resulted in differential outcomes of 1.0 or 0.2 probabilities of reinforcement. The inclusion of nontemporal stimuli was intended for direct comparisons of the effects of DO on temporal and nontemporal coding as well as an examination of the possibility of common coding occurring. Subjects may encode the two sample stimuli (one line tilt and one duration) associated with the same outcome as similar. This would result in the lack of a choose-short bias because temporal coding is no longer taking place. Therefore a bias to the sample associated with a favourable outcome (a high probability bias) would remain.

The results from the trials commencing with temporal samples replicated those of Experiment 1. A strong choose-short bias was found that could be due to the collaborative effects of a DO expectancy to choose short, a choose-favourable bias to choose short, and a choose-short bias. Also, the DO-long group did not display a significant choose-short effect. Again, this could be due to the combined effects of a choose-short tendency, and the effects of a DOE to choose long and a choose favourable bias to choose long that may serve to 'cancel' the choose-short bias out. The results from the trials commencing with nontemporal stimuli replicated Santi and Roberts (1985b). With nontemporal stimuli, performance was superior on high probability trials, and accuracy on both high and low decreased over delay in a parallel fashion. Therefore, again it appears that a DO expectancy, a choose-favourable bias, and a choose-short bias are evidently at work.

In another study examining the flexibility of the analogical code, Santi, Bridson, and Ducharme (1991) studied the possibility of a common code occurring with temporal and nontemporal samples. In Experiment 1, temporal samples of 2s and 8s houselight durations,

and red and green keylights were matched to vertical and horizontal lines as comparisons. Supporting a common coding hypothesis, the retention functions of the two types of samples (duration and color) were found to be similar, and no choose-short effect was in evidence. However, Experiment 2, which involved the examination of transfer effects between temporal and color samples, presented evidence suggesting that a more complex process is at work. In Phase 1 of Experiment 2 half of the subjects were required to match temporal samples to shape comparisons (circle and triangle), while the other half were required to match color samples to shape comparisons. In Phase 2, the samples that each group had been trained with were switched. These two groups were further divided such that half of each group received sample-comparison mapping that was consistent with a possible common code (designated as Group Consistent), while the other half of each group received sample-comparison mapping that was inconsistent with a common code (designated as Group Inconsistent). A common coding hypothesis would predict that positive transfer would occur in Group Consistent, while negative transfer would occur in Group Inconsistent. If analogical coding were occurring, no transfer would take place. The results revealed that Group Consistent performed more accurately than Group Inconsistent when color samples were matched to shape comparisons, however, when temporal samples were matched to shape comparisons Group Consistent and Group Inconsistent performed similarly. Therefore, the results of Experiment 2 suggest that in a many-to-one procedure, the memory code maintained has both common coding and analogical coding attributes. In Experiment 3, half of the birds received a many-to-one mapping procedure with temporal and color samples and line comparisons, while the other half received a one-to-one (OTO) procedure with

temporal samples mapped onto line comparisons and color samples to color comparisons. In addition, Experiment 3 used an intratrial interference design which involved the presentation of short (2s) or long (8s) durations of houselight and colors (red and green) as presamples. The results revealed that the MTO and the OTO groups showed similar retention functions and neither group displayed a choose-short effect. Also, subjects summed the presample and the sample on both temporal and color presample trials. Therefore, the evidence of asymmetrical transfer, the absence of a choose-short effect, and evidence of the summation of both temporal and color presamples with temporal samples suggests that the memory code has both analogical and common coding properties.

As was discussed, the use of probabilities of reinforcement as differential outcomes (Santi et. al., in press) did not completely alter the analogical coding process. These findings suggest further examination is necessary. Recent research (Urcuioli, 1990a) has suggested that differential food and no-food outcomes provide more salient DO cues than do differential probabilities of reinforcement as outcomes. Therefore, the present study examines this flexibility by utilizing a differential outcomes procedure of food and no-food reinforcement.

Experiment 1

The present study used differential outcomes of food and no-food. Short (2s) and long (8s) houselight durations as well as line orientations served as samples for all subjects. In a symbolic matching-to-sample procedure, short and long samples were matched to red and green comparison stimuli, whereas vertical and horizontal lines were matched to vertical

and horizontal comparisons. After training, delay intervals of 5s, 10s and 15s were implemented for testing. Three groups were employed, two of which received differential outcomes.

On temporal trials, the DO-SF group received food for correctly responding on short sample trials and no food (the hopper light with no food access) for correctly responding on long sample trials. The DO-LF group received food for correctly responding on long sample trials and no food (the hopper light with no food access) for correctly responding on short sample trials. On nontemporal trials half of each DO group received food reinforcement for correct responses on vertical trials while the other half received it on horizontal trials. A nondifferential outcome group (NDO) was included that also received both line tilt and duration samples. This group received food on a random half of correctly completed trials and a hopper light with no food access on the other correctly completed trials.

Considering the evidence that has been reviewed, several predictions follow from the design proposed. First, it is predicted that a DOE will develop in the two DO groups and that this expectancy should overshadow the control of both the temporal samples and the line tilt samples. If this occurs it would be manifested in three events: 1. The performance of the DO groups would be superior to that of the NDO group. 2. The DO groups would not demonstrate a choose-short bias on temporal trials. The choose-short bias, which can be taken as evidence of analogical temporal coding taking place, would be eliminated since the temporal samples would not directly control choice behaviour. Instead, an equivalent choose favourable bias would develop. 3. Since expectancies are guiding choice behaviour and

sample stimulus information is not, retention functions for the DO groups should be similar for both dimensions.

In the case of the above results, verification that the sample has indeed been overshadowed must be established through a second experiment using off-baseline methods similar to that of Urcuioli (1990a). The expectancy cues will be removed in a nondisruptive fashion which involves trials of pairing sample stimuli with nondifferential outcomes. This off-baseline procedure will distinguish, whether the sample stimulus has been overshadowed completely, or whether the expectancies are exerting additional stimulus control without changing the control of the sample stimulus.

Another possible result of Experiment 1 is that the DOE will overshadow sample control only on the nontemporal trials. The resistance of temporal samples to complete control by the DO expectancies has been demonstrated by Santi, Ducharme, and Bridson (in press). This result would be demonstrated by the superior performance of the DO groups on linetilt trials only, and a choose-short bias would exist on temporal trials in the DO-SF group.

The NDO group was expected to display a typical choose-short bias on the temporal dimension in Experiment 1. On the linetilt dimension, accuracy on vertical and horizontal samples would be similar and would decrease with increasing delay.

Method

Subjects

Subjects were 24 DMTS-experienced White Carneaux pigeons aged between 1 and 12 years. For the duration of the experiment the animals were housed individually with grit and water continuously available and were exposed to a 12/12 hour light/dark cycle.

Experimental sessions took place during the subject's light cycle between 1200h and 1700h, 5 to 7 days a week.

Apparatus

Four Colbourn modular operant chambers (Model E10-10) contained in isolation chambers (Model E10-20) equipped with a ventilation fan and baffled air intake and exhaust system were used. Within each operant chamber are three clear plastic pecking keys on the front wall which display the comparison, warning and sample stimuli (red or green, white vertical or horizontal line on a black background, or a black dot on a white background).

Directly above the centre plastic pecking key is the chamber houselight which also served as a sample stimulus in the present study. The hopper, which was illuminated upon operation, is located directly below the centre pecking key. All parameters of the present study were controlled by a microcomputer located in an adjacent room.

Procedure

Pretraining: Due to the differing experimental histories of the 24 birds, a phase of DMTS pretraining was included. Linetilt (vertical and horizontal lines) and temporal (2s, and 8s houselight durations) samples were used and their occurrence was randomized over trials. Linetilt sample stimuli were mapped onto linetilt comparisons, while temporal sample

stimuli were mapped onto red and green comparison stimuli. Position of the comparison stimuli (left or right keylights) was counterbalanced over trials. On trials commencing with linetilt samples, a 'warning' keylight that consisted of a small black dot on a white background was presented and terminated only after a peck to the stimulus was registered. The warning keylight is intended to ensure that the subject is looking at the appropriate keylight before the sample appears. Linetilt samples were presented for 4s (the geometric mean of the houselight durations). Upon termination of the sample stimuli, two side keys were illuminated with the comparison stimuli. During this phase, all correct responses were rewarded with 3-second access to mixed grain in an illuminated hopper.

Of the 24 birds, 12 were required to peck red after a short sample stimulus and green after long, and 12 were required to peck green after short and red after long.

Darkened intertrial intervals were a constant 15s in length. Each session consisted of 80 trials (40 commencing with temporal samples, and 40 commencing with nontemporal line orientation samples). Pretraining continued for 40 sessions. A correction procedure was in place for the duration of the pretraining so that if subjects did not perform the correct choice of comparison stimuli on first exposure to a trial, reinforcement was withheld and the trial was immediately started over until the correct response was attained. The mean performance levels on the temporal dimension on the last three days of pretraining for each group were 95.1, 94.3, and 93.5 for DO-LF, DO-SF and NDO respectively. On the nontemporal dimension, the mean performance levels on the last three days were 77.9, 84.2, and 81.0, for group DO-LF, DO-SF, and NDO respectively. To ensure that the groups were not systematically differing at this point in the study, an ANOVA with group (DO-SF, DO-LF

and NDO), and dimension (temporal and nontemporal) was performed revealing no significant differences between the groups [$F(2,20) = < 1$], and no dimension by group interaction [$F(2,20) = < 1$].

Training: All 24 birds were trained in a DMTS procedure with parameters identical to the pretraining except for the following. Three separate groups of birds were formed (DO-SF, DO-LF, and NDO), each varying in the type of outcome manipulation they experienced. Upon correct matching-to-sample on short sample trials, all 8 birds in the DO-SF group received 3s access to mixed grain in an illuminated hopper. For this group correct matching on long sample trials yielded no-food, but a 3s presentation of the hopper light with no access to mixed grain. The 8 birds in the DO-LF group received 3s access to reinforcement for correct matching-to-sample on long sample trials and no reinforcement, but a 3s hopper light for correct matching on short sample trials. The NDO group of 8 birds received 3s access to mixed grain in an illuminated hopper on a random half of the correctly matched trials. On the other half of the correctly matched trials, the NDO group received a hopper light with no access to mixed grain.

On linetilt trials, half of each DO group was reinforced for correct matching with food on trials commencing with vertical samples, while on horizontal samples they received no food, but a 3s hopper light. The other half of each DO group received food for correctly matching on trials commencing with horizontal samples, while on vertical sample trials they received no food, but a 3s hopper light. As on temporal sample trials, the NDO group received food on a random half of the correctly matched trials. On the other half of the correctly matched trials, the NDO group received a hopper light, but no food.

Half of all the subjects were required to peck red after a short sample trial and green after a long sample trial. The other half were required to peck green after a short sample trial and red after a long sample trial. Complete counterbalancing is schematized in Table 1 for both DO groups and Table 2 for the NDO group.

Intertrial intervals remained at 15s, and each session consisted of 80 trials. Training continued for 25 sessions. The mean performance levels for each group on the last three days of training on the temporal dimension were 82.6, 88.0, and 95.7 for DO-LF, DO-SF and NDO, respectively. On the nontemporal dimension, the group means for the last three days were 73.4, 85.2, and 87.1, for Groups DO-LF, DO-SF and NDO, respectively. In order to examine the equivalence of group performances during training, an ANOVA with group (DO-SF, DO-LF and NDO) and dimension (temporal and nontemporal) as factors was performed revealing a main effect of group [$F(2,21)=4.26, p<.05$]. Subsequent Neuman-Keuls tests revealed that the NDO group is performing more accurately than the other groups. A correction procedure was in place for the duration of training identical to that described for pretraining. Peterson, Wheeler and Trapold (1980) suggested that a correction procedure must be in place in order to obtain a DOE with food/no-food as outcomes because subjects may stop trying to maintain stimulus information when no food reward follows.

Testing: All subjects in all groups were exposed to randomly presented delay intervals of 0s, 5s, 10s, and 15s. Of the 96 trials per session presented, 72 had a 0s delay (no delay) and each of the three delays were presented on 8 trials. All other parameters were identical to the training phase. Testing continued for 20 sessions.

Table 1. The complete counterbalancing of the DO
groups in Experiment 1.

GROUP	# of Ss	SAMPLE TYPE	CORRECT COMPARISON	OUTCOME
DO-SF	2	SHORT LONG VERTICAL HORIZONTAL	RED GREEN VERTICAL HORIZONTAL	FOOD NO FOOD FOOD NO FOOD
	2	SHORT LONG VERTICAL HORIZONTAL	RED GREEN VERTICAL HORIZONTAL	FOOD NO FOOD NO FOOD FOOD
	2	SHORT LONG VERTICAL HORIZONTAL	GREEN RED VERTICAL HORIZONTAL	FOOD NO FOOD FOOD NO FOOD
	2	SHORT LONG VERTICAL HORIZONTAL	GREEN RED VERTICAL HORIZONTAL	FOOD NO FOOD NO FOOD FOOD
DO-LF	2	SHORT LONG VERTICAL HORIZONTAL	RED GREEN VERTICAL HORIZONTAL	NO FOOD FOOD FOOD NO FOOD
	2	SHORT LONG VERTICAL HORIZONTAL	RED GREEN VERTICAL HORIZONTAL	NO FOOD FOOD NO FOOD FOOD
	2	SHORT LONG VERTICAL HORIZONTAL	GREEN RED VERTICAL HORIZONTAL	NO FOOD FOOD FOOD NO FOOD
	2	SHORT LONG VERTICAL HORIZONTAL	GREEN RED VERTICAL HORIZONTAL	NO FOOD FOOD NO FOOD FOOD

**Table 2. The complete counterbalancing of the NDO
group in Experiment 1.**

# of Ss	SAMPLE TYPE	CORRECT COMPARISON	OUTCOME
4	SHORT LONG VERTICAL HORIZONTAL	RED GREEN VERTICAL HORIZONTAL	FOOD/NO FOOD FOOD/NO FOOD FOOD/NO FOOD FOOD/NO FOOD
4	SHORT LONG VERTICAL HORIZONTAL	GREEN RED VERTICAL HORIZONTAL	FOOD/NO FOOD FOOD/NO FOOD FOOD/NO FOOD FOOD/NO FOOD

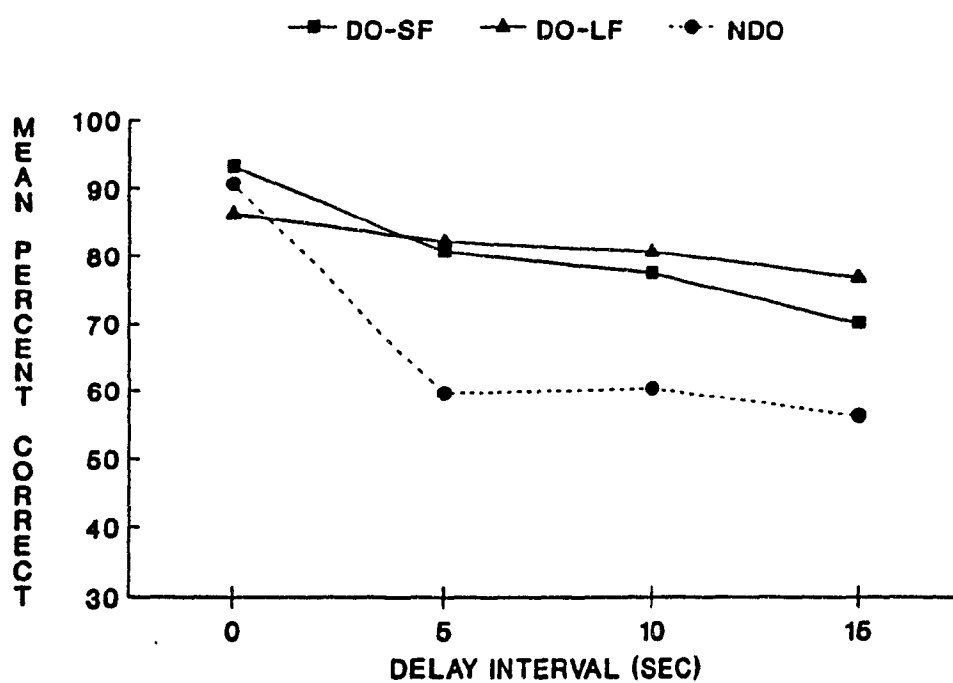
Results

In order to establish whether there were significant overall effects associated with differential outcomes, the data were collapsed across sample type (short/long and vertical/horizontal), and are shown in Figure 1. The upper graph represents data for temporal sample trials, and the lower graph represents the data for nontemporal sample trials. On both types of trials it appears that the DO groups perform more accurately than the NDO at delays greater than 0s. An analysis of variance with group (DO-SF, DO-LF, and NDO), dimension (temporal and nontemporal), and delay (0s, 5s, 10s, and 15s) as factors revealed a main effect of group [$F(2,21)=14.40, p<.0001$], and delay [$F(3,63)=165.87, p<.0001$], as well as a delay X group interaction [$F(6,63)=26.70, p<.0001$]. Neuman-Keuls (1939) tests at the .05 confidence level revealed that at the 5s, 10s and 15s delay interval, the two DO groups outperformed the NDO group. These data show that in terms of overall accuracy, the two DO groups matched more accurately than the NDO group at delays greater than 0s, which replicates the usual effect of differential outcome expectancies on memory.

In order to assess the effects of differential outcome expectancies on memory for temporal and nontemporal events, the data for the two DO groups were compared with outcome (food/no-food) as a factor. Figure 2 displays the data for temporal sample trials on the top, and the data for nontemporal sample trials on the bottom. As can be seen, the two DO groups seem to be performing with similar accuracy at delay intervals greater than 0s. An analysis of variance with group (DO-SF and DO-LF), dimension (temporal and nontemporal), outcome (food and no-food), and delay (0s, 5s, 10s, and 15s) as factors was

Figure 1. Mean percent correct delayed matching-to-sample accuracy on trials commencing with temporal samples (upper) and those commencing with nontemporal samples (lower) in Experiment 1.

TEMPORAL SAMPLES



NONTEMPORAL SAMPLES

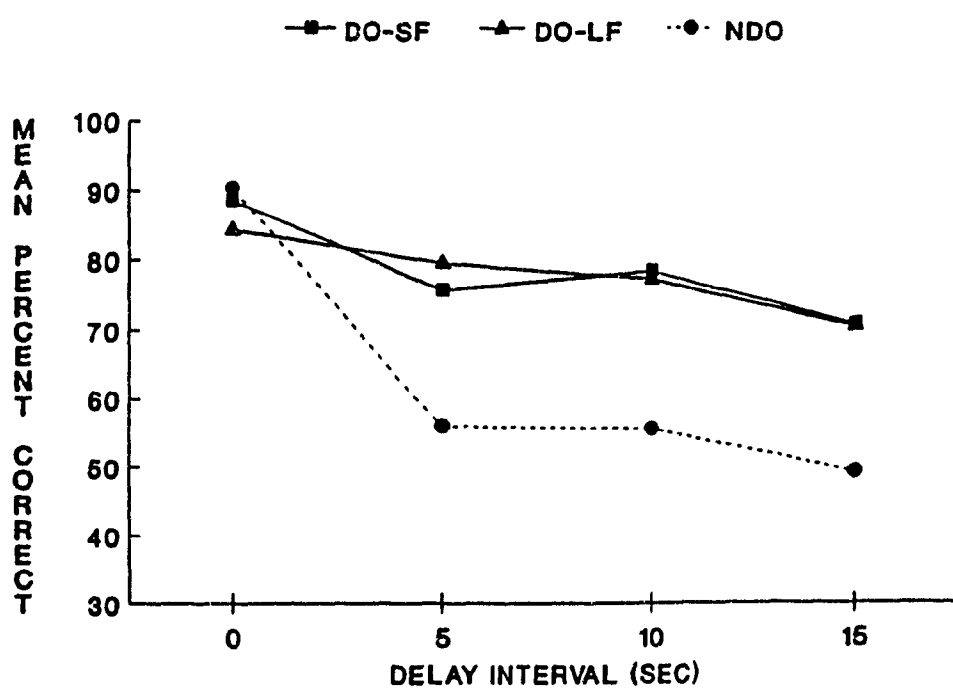
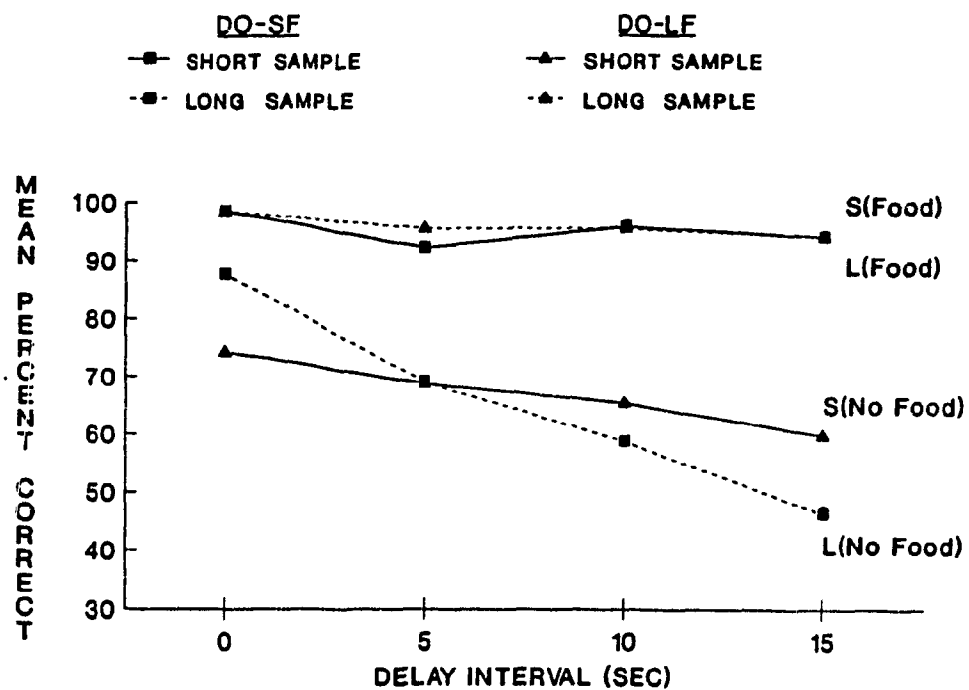
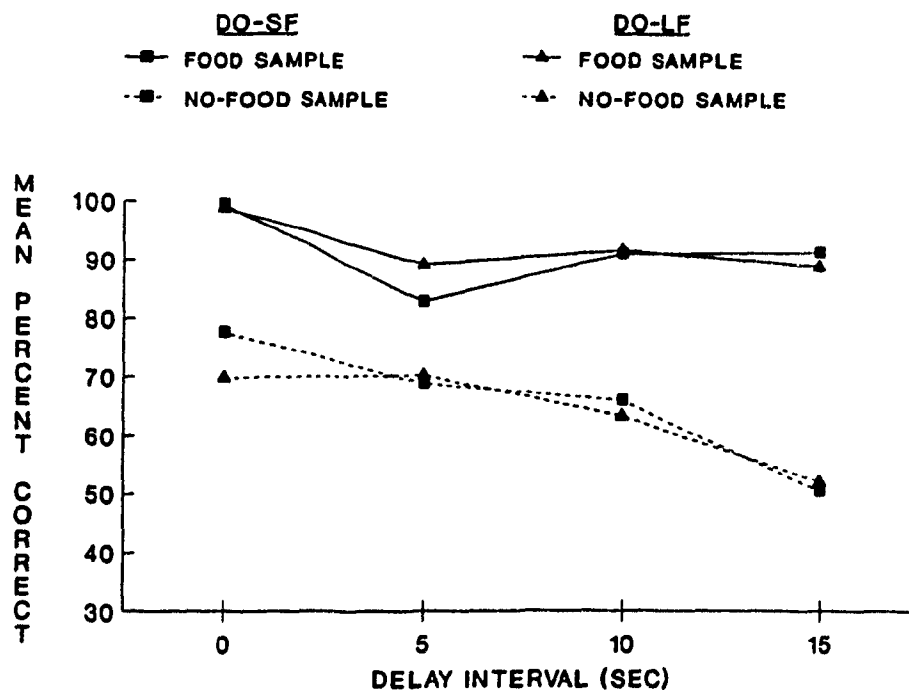


Figure 2. Mean percent correct delayed matching-to-sample accuracy of both DO groups on trials commencing with short (2s) and long (8s) samples (upper), and nontemporal trials commencing with linetilt samples associated with food or no-food outcomes in Experiment 1.

TEMPORAL SAMPLES



NONTEMPORAL SAMPLES



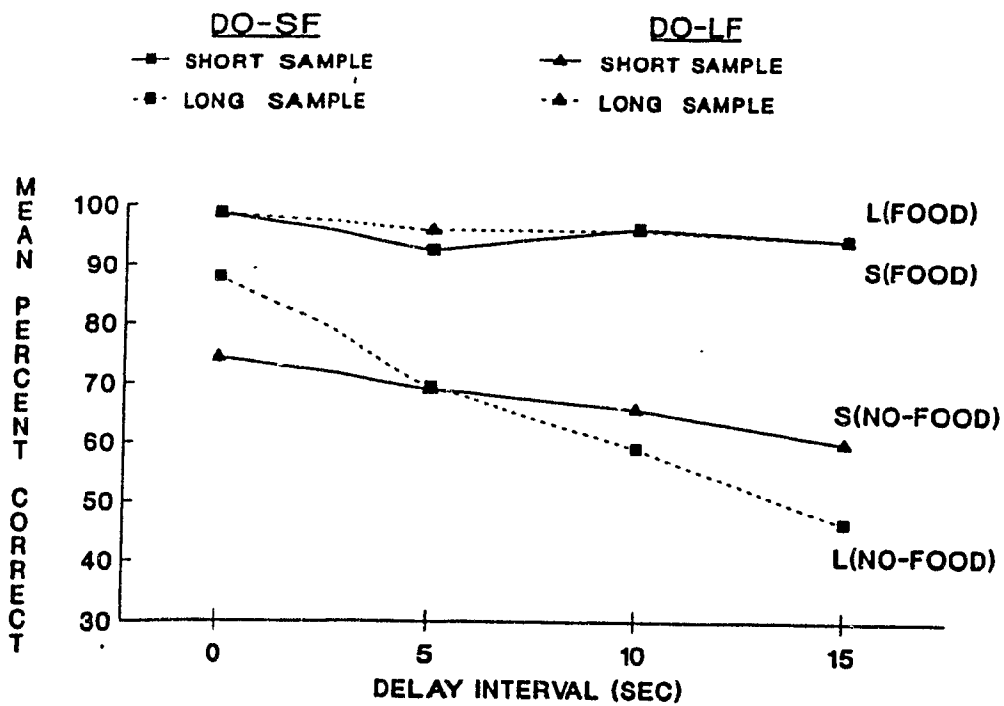
conducted and revealed two three-way interactions. An outcome X delay X group interaction [$F(3,42)=6.15, p<.01$], was due to a significant interaction of delay X groups when the outcome was no-food, but not when the outcome was food. When the outcome was no-food, the performance of the two groups was similar at all delays, except 0s. At the 0s delay, the DO-SF group performed better than did the DO-LF group. A possible explanation for this result, which will be discussed in greater detail later, assumes that subjects are expecting food on every trial. Therefore, subjects in the DO-SF must wait an extra six seconds on temporal trials to be informed that the outcome will be no-food, thereby diminishing this expectancy of food. In summary, the DO groups performed equivalently under all conditions except at the 0s delay when the outcome was no-food.

The second 3-way interaction, as seen in Figure 2, was dimension X outcome X delay. This interaction was due to a dimension X outcome interaction which was significant at the 0s delay [$F(1,14)=10.50, p<.05$] and 5s delay [$F(1,14)=5.94, p<.05$], but not at 10s [$F(1,14)= < 3$] and 15s [$F(1,14)= < 1$] delay intervals. Performance on temporal trials was significantly more accurate than nontemporal trials at the 0s delay on no-food trials [$F(1,14)=9.58, p<.01$], and at the 5s delay interval on food trials [$F(1,14)=5.51, p<.05$]. Matching accuracy decreased significantly as a function of increasing delay interval [$F(3,42)=57.29, p<.0001$].

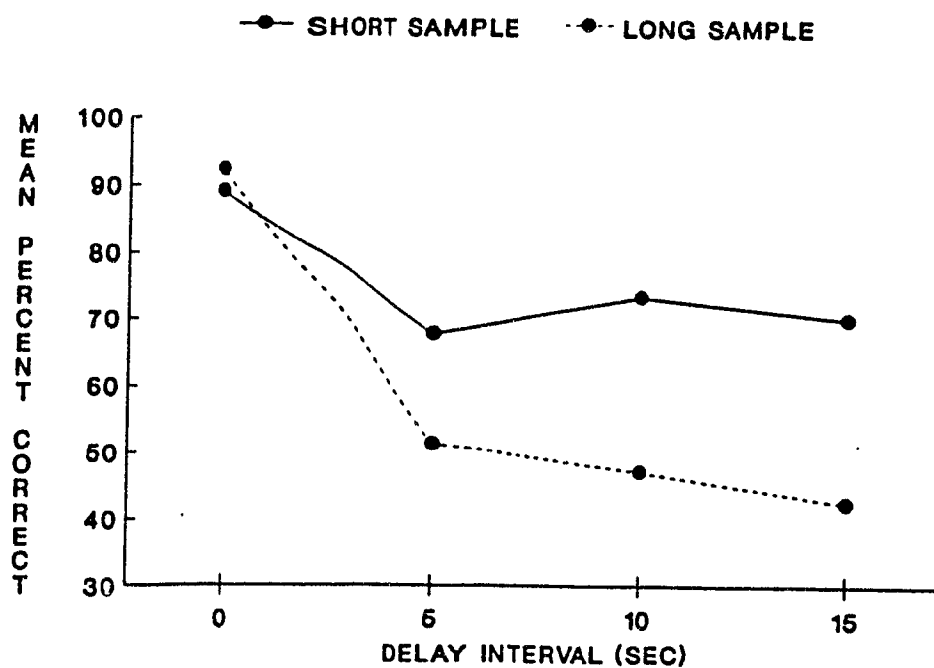
Finally, the data for the temporal dimension were subjected to an analysis of variance with group (DO-SF, DO-LF, and NDO), duration (short and long), and delay (0s, 5s, 10s, and 15s) as factors. Data for the DO groups are displayed on the top of Figure 3, and data for the NDO group are displayed at the bottom. It appears that the two DO groups are

Figure 3. Mean percent correct delayed matching-to-sample accuracy on trials commencing with temporal samples for the DO groups (upper) and the NDO group (lower) in Experiment 1.

DO GROUPS



NDO GROUP



performing similarly on food and no-food trials while the NDO group appears to display a typical choose-short effect. An ANOVA revealed a three-way interaction of group X duration X delay [$F(6,63)=9.34, p<.0001$]. An analysis of simple main effects revealed that the 3-way interaction was due to a duration X delay interaction which was significant for group DO-SF [$F(3,63)=18.59, p<.0001$], and group NDO [$F(3,63)=14.39, p<.0001$], but not for group DO-LF [$F(3,63)= <2$].

For the NDO group, a significant choose-short effect was found at the 15s delay interval [$F(1,21)=27.38, p<.0001$], the 10s delay interval [$F(1,21)=18.63, p<.001$] and at the 5s delay interval [$F(1,21)=9.43, p<.01$], as exhibited in Figure 3. However, at the 0s delay interval no choose-short effect occurred [$F(1,21)= <1$]. Also, delay was significant on both long [$F(3,63)=80.50, p<.0001$] and short [$F(3,63)=14.04, p<.0001$] sample trials. For group DO-SF, a bias to the sample associated with a favourable outcome (a "choose favourable outcome" bias) was significant at all delay intervals, however, the difference in accuracy increased with increasing delay intervals, due to a decrease in accuracy on the no-food trials. At the 0s delay interval the choose favourable outcome bias was significant [$F(1,21)=9.79, p<.01$], and this effect increased at the 5s [$F(1,21)=18.38, p<.001$], 10s [$F(1,21)=37.39, p<.0001$], and 15s delay interval [$F(1,21)=82.77, p<.0001$]. Group DO-SF also showed a significant effect of delay on long sample trials [$F(3,63)=47.10, p<.0001$], but not short sample trials [$F(3,63)= <2$]. For group DO-LF, a significant choose favourable outcome bias occurred at the 0s, 5s, 10s and 15s delays [$F(1,21)=42.78, 24.58, 24.80, 48.96$ respectively]. Delay was significant on short sample trials [$F(3,63)=5.63, p<.01$], but not on long sample trials [$F(3,63)= <1$] for group DO-LF. In

summary, these analyses indicated that the DO groups demonstrated the choose favourable outcome bias which is typical of differential outcome experiments, while the NDO group displayed a choose-short bias. The ANOVA summary tables for the analyses carried out in Experiment 1 are in Appendix A.

Discussion

The results of the first experiment are consistent with the possibility that outcome expectancies are controlling choice behaviour, and are overshadowing the control of the sample stimulus. Four main results are compatible with this concept.

First, the superior performances of the DO groups on both temporal and nontemporal trials compared to the NDO group suggests that differential outcome expectancies are aiding choice behaviour in some way for the DO groups. This result is consistent with the possibility that outcome expectancies have overshadowed the control of the sample stimulus. It has been shown that differential outcomes enhance matching accuracy (Trapold, 1970).

Second, the DO groups responded similarly to the differential outcomes of food and no-food. On both dimensions, both the DO-SF group and the DO-LF group performed equivalently on trials commencing with samples associated with food. Third, except at the 0s delay interval, on both dimensions, both DO groups performed similarly on trials which commenced with samples associated with no-food. Thus, two types of evidence suggest that no temporal coding has taken place. First, the DO groups did not perform differently on trials commencing with temporal samples than on trials commencing with nontemporal samples. Also, the DO groups demonstrated proportionate choose favourable biases. The

lack of evidence for temporal coding is consistent with the possibility that the control of the sample stimulus has been overshadowed by the differential outcomes of food and no-food on temporal sample trials. However, this possibility will be examined further in Experiment 2.

Fourth, a typical choose-short effect was displayed by the NDO group on the temporal dimension. The performance of the NDO group serves as a demonstration of the effects of temporal, and nontemporal coding without the influence of differential outcomes.

The superior performance of the DO-SF group compared to the DO-LF group at the 0s delay interval on no-food trials was an unexpected outcome. A possible explanation assumes that the animal, unless otherwise informed, defaults to expecting food on every trial. On no-food trials, Group DO-SF is responding to a long sample stimulus, whereas Group DO-LF is responding to a short sample stimulus. Therefore, Group DO-SF must wait an extra six seconds for the outcome of the trial. Assuming animals are always expecting food, on long sample trials, the DO-SF group's expectancy of food may diminish to no-food. When the comparison stimuli appear, an expectancy for no-food will guide correct choice behaviour.

As has been discussed, there are two main possible origins of the differential outcome effect. Briefly, one account suggests that an expectancy of the outcome, which develops through stimulus-outcome associations, mediates choice behaviour (Trapold, 1970). Another account suggests that it is possible that the DO exerts additional stimulus control without changing the possible control of the sample stimuli (Urcuioli, 1990a). The present experiment utilizes analogical temporal coding, as evidenced by the choose-short effect, as an instrument to gauge the amount of control the sample duration stimuli have. The fact that

the DO groups, except at the 0s delay on no-food trials, are performing similarly on trials commencing with temporal and nontemporal stimuli suggests that the sample stimuli are not solely controlling responding on temporal trials.

The results of the first experiment seem to indicate that overshadowing of the sample stimuli has occurred, however, Experiment 2 will examine this possibility more thoroughly.

Experiment 2

Several results of Experiment 1 suggest that, as predicted, the DOE overshadowed control of the sample stimuli. This was displayed by the superior performance of the DO group compared to the NDO group, an equal "choose favourable bias" displayed by the DO groups, and similar retention functions on both temporal and linetilt trials. In order to make certain that the DOE is genuinely overshadowing the control of the sample stimulus, Experiment 2 removed the expectancy cues through pairing nondifferential outcomes with the sample stimuli. This procedure was done out of the matching context or "off-baseline" because disruptions in performance may have occurred if nondifferential outcomes were immediately introduced into the discrimination.

Other studies have presented evidence which suggests that overshadowing the control of the samples occurs when expectancy cues are available (Peterson, Wheeler, & Armstrong, 1978; Peterson, Wheeler, & Trapold, 1980). However, as Urcuioli (1990a) points out, since on-baseline shifts were used in these studies, the disruption in performance may have been due to the effects of surprising changes in outcomes, or because one of the cues that was previously relied upon had changed, rather than having been due to overshadowing.

Therefore, the method of removing the expectancy cue outside of the matching context avoids the interpretive difficulties that are presented by a disruptive on-baseline shift to nondifferential outcomes.

Experiment 2 began with a return to baseline (identical to the training phase of Experiment 1), followed by off-baseline sessions of samples presented with nondifferential outcomes. Following this, 0-delay matching-to-sample with nondifferential outcomes was presented to all groups. This method was designed to remove or, in a sense, extinguish differential outcome expectancies. Although in Experiment 2, all groups received nondifferential outcomes, the groups will still be referred to as DO and NDO, to represent their relevant history from Experiment 1.

Experiment 2 was designed to distinguish between two possible reasons for the results in Experiment 1. First, it was possible that the DOE exerted additional stimulus control without altering any control which the sample stimulus may have had, or the 'residual direct control' (Urcuioli, 1990a). In this case, the removal of the differential outcome expectancies in Experiment 2 should reveal similar performances by the NDO and DO groups. Since the sample was not overshadowed, it should maintain control, similar to the NDO group.

The second possibility was that the outcome expectancies overshadowed the control of the sample stimulus. If choice behaviour was guided by expectancies alone, information from the sample stimuli should be ignored because it was not useful for responding. When the expectancy cues were removed, the DO group had less information than the NDO group with which to respond appropriately. Therefore, performance of the DO groups should be inferior to that of the NDO. The performance of the NDO group should stay the same

because, for this group, the same cues are present.

A delay test with nondifferential outcomes was also included in Experiment 2. It was predicted that if overshadowing initially occurred and continued through the MTS phase, performance of the DO groups should be below that of the NDO. Also, no evidence of temporal coding should be present (i.e. There should be no choose-short effect) for the DO groups, but the NDO group should display a typical choose-short effect.

Method

Subjects and Apparatus

Apparatus was identical to that of Experiment 1. One subject from the DO-LF group was dropped from the study prior to Experiment 2 due to illness.

Procedure

Return to Baseline: This phase was identical to that described in the training phase of Experiment 1, and it began 21 days after Experiment 1 concluded. It was carried out for 7 days. The mean performance levels on the temporal dimension on the last three days of this phase were 92.0, and 92.9 for DO and NDO respectively. On the nontemporal dimension, the performance levels on the last three days were 87.7 and 91.5 for groups DO and NDO, respectively. In order to ensure that the groups did not systematically differ on the last three days of this phase, and ANOVA with dimension (temporal and nontemporal) and group (DO and NDO) as factors was performed revealing no statistical differences between the groups [$F(1,21) = < 1$], and no interactions with dimension [$F(1,21) = < 1$].

Off-baseline training: In these sessions, all subjects were exposed to sample stimuli (vertical and horizontal lines, 2s and 8s houselight durations) that were immediately followed by either food (3s access to mixed grain in an illuminated hopper) or no-food (a lit hopper light only) on a random half of all trials. This phase continued for 12 sessions, each involving 80 trials. Urcuioli (1990a) found that 3-12 sessions were required to ensure that the birds were responding nondifferentially to the stimuli. No data were recorded for these sessions.

Reintroduction of 0-delay matching with nondifferential outcomes: In this phase, subjects were returned to the matching situation with the same stimuli. Vertical and horizontal lines (presented for 4s and preceded by a warning light identical to Experiment 1) and 2s and 8s houselight durations were presented as samples. Again, durations were matched to red and green comparison stimuli, while linetilt was matched to linetilt comparison stimuli, both of which followed the sample immediately. Food/no food outcomes were presented nondifferentially in that each outcome followed a correct response equally often and randomly. Also, a correction procedure was in place that was identical to that used in Experiment 1. Each session included 80 trials. This phase continued for 10 sessions. The mean performance levels on the temporal dimension on the last three days of this phase were 94.0, and 92.2 for group DO and NDO, respectively. On the nontemporal dimension, the mean performance levels for the last three days were 81.4 and 84.6 for groups DO and NDO, respectively. To ensure that the groups did not differ statistically at this point in the study an ANOVA with dimension (temporal and nontemporal) and group

(DO and NDO) as factors was performed, revealing no group differences [$F(1,21) = < 1$], and no interactions with the dimension variable [$F(1,21) = < 1$].

Matching with delays: This phase was identical to the last except randomly presented delay intervals of 5s, 10s, and 15s were introduced on 25% of the trials. That is, of the 96 trials presented, 72 had no delay and each of the three delays were presented on 8 trials. Again, nondifferential outcomes identical to the previous phase were used. Delay testing continued for 20 sessions.

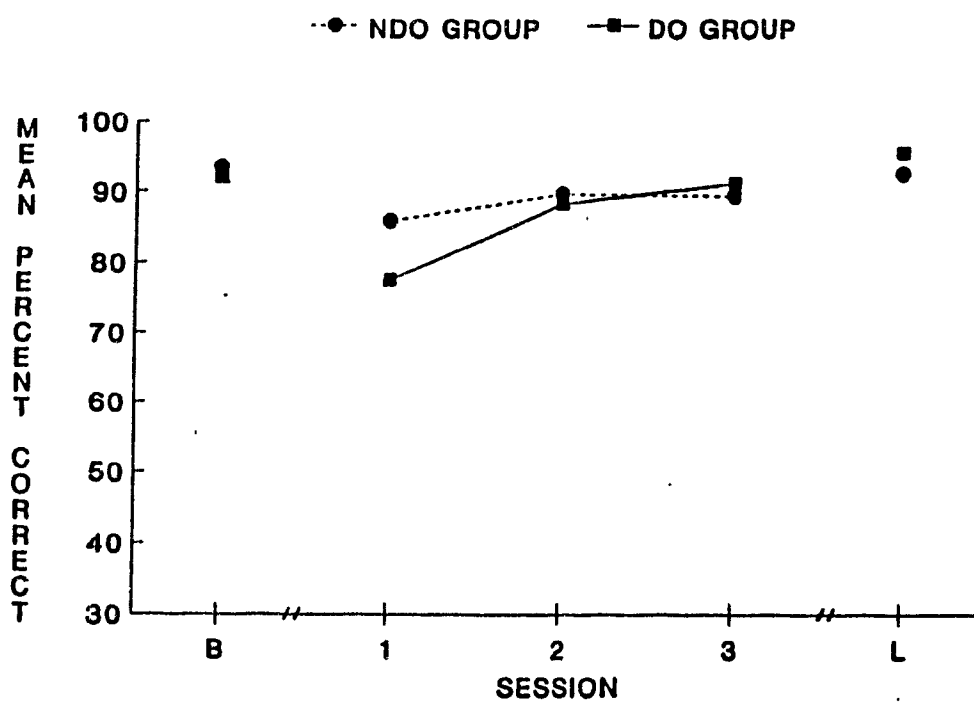
Results

In order to assess the equivalence of the groups during baseline, a sample dimension (temporal and nontemporal) X groups (DO-SF, DO-LF, and NDO) ANOVA was performed data from the last three days of baseline in Experiment 2. No group differences were revealed [$F(1,20) = < 2$], but performance was more accurate on temporal trials [$F(1,20) = 5.85, p < .025$]. The absence of a group difference in accuracy on the last three baseline sessions (B) is visible in both the upper and lower plots in Figure 4. Also, the greater accuracy on temporal sample trials compared to nontemporal sample trials is displayed in Figure 4.

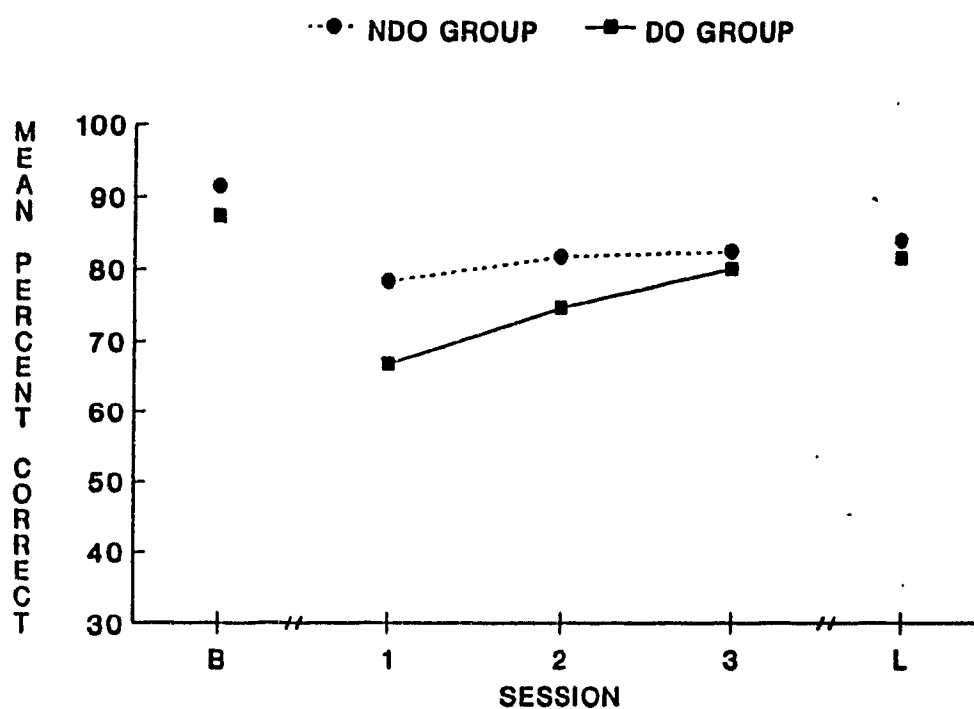
The next phase of Experiment 2, following baseline, involved the presentation of nondifferential outcomes for all groups out of the matching context, or off-baseline. Since there was no matching-to-sample required in this segment of the study, no data were collected. Also, since the DO-SF and DO-LF groups were treated equivalently, most

Figure 4. Mean percent correct matching-to-sample accuracy for both the DO group and the NDO group on the last three sessions of baseline (B), the first three sessions of 0-delay MTS (1,2,3), the last day of 0-delay MTS (L) for temporal sample trials (upper) and nontemporal sample trials (lower) in Experiment 2.

TEMPORAL SAMPLES



NONTEMPORAL SAMPLES



further analyses collapse DO-SF and DO-LF into one "DO" group ($n=15$). The NDO group ($n=8$) remained intact as in Experiment 1.

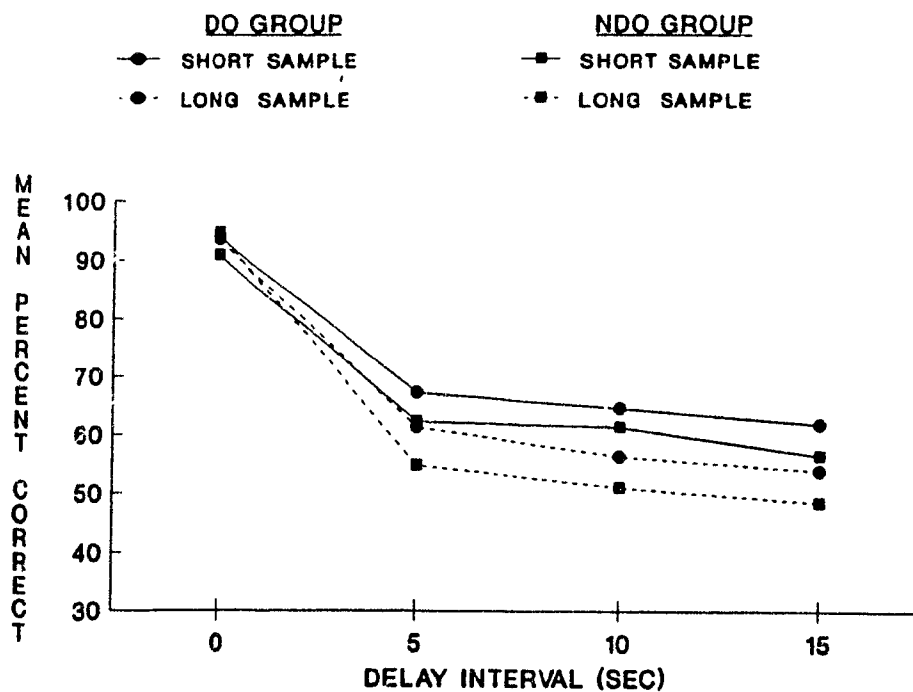
To examine the effects of removing expectancies off-baseline an ANOVA with dimension (temporal and nontemporal), groups (NDO and DO), and session (session 1, 2, and 3 of MTS) as factors was conducted. The results revealed a session X group interaction that was significant [$F(2,42)=4.47, p < .025$]. Also, matching was more accurate on temporal sample trials than on nontemporal sample trials [$F(1,21)=7.90, p < .01$]. Analysis of simple main effects revealed that Group NDO matched more accurately than Group DO on the first session of MTS [$F(1,21)=4.39, p < .05$], but Group DO became more accurate on the second [$F(1,21) = < 1$], and third sessions [$F(1,21) = < 1$]. These effects are visible in Figure 4. An analysis of each of the 10 sessions of 0-delay MTS revealed that the groups did not significantly differ on any session but the first [$F(1,21) = < 1$ for sessions 2-10].

To examine the changes which occurred from baseline to MTS with nondifferential outcomes, an analysis of changes in performance between the last 3 days of baseline and the first day of 0-delay MTS was performed. An ANOVA with group (DO and NDO), session-type (the last three days of baseline and the first day of 0-delay MTS), and dimension (temporal and nontemporal) as factors was conducted. This analysis revealed that the performance of Group NDO was significantly lower than Group DO [$F(1,21)=4.36, p < .05$], and that session-type was significant for both groups [$F(1,21)=34.70, p < .001$]. Also, consistent with baseline trials, performance on temporal sample trials was more accurate than on nontemporal sample trials [$F(1,21)=6.18, p < .025$]. As shown in Figure 4, the performance of both groups declines from baseline to session 1 of MTS.

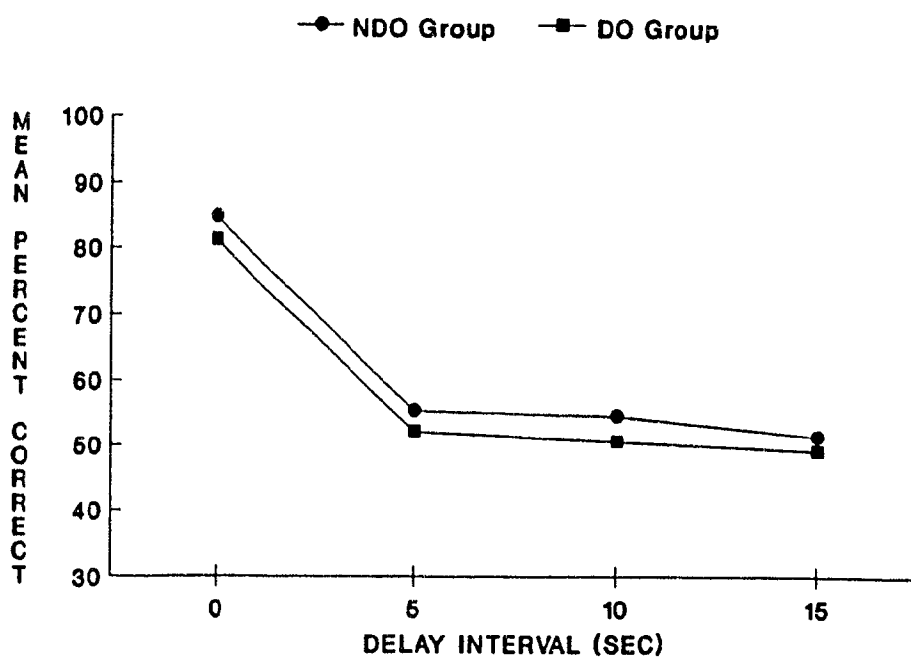
In order to assess group differences during delay testing, an analysis of variance performed on the subsequent 20 sessions of DMTS included dimension (temporal and nontemporal), group (DO and NDO) and delay interval (0s, 5s, 10s, and 15s) as factors. Performance accuracy significantly decreased with increasing delay for both groups [$F(3,63)=236.87, p<.001$]. Also, a significant dimension X group interaction occurred [$F(1,21)=5.64, p<.05$]. An analysis of simple main effects revealed that the DO group performed more accurately on temporal sample trials than on nontemporal, however, the NDO group performed equivalently on both types of trials. It is also worth noting that there were no significant differences between the groups on short [$F(1,21)=<3$], or long [$F(1,21)=<2$] sample trials. In order to investigate the occurrence of a choose-short effect in the DMTS data, an analysis was performed on the temporal data separately. An ANOVA with sample duration (short and long), delay interval (0s, 5s, 10s, and 15s), and group (DO and NDO) was performed, which revealed a sample duration by delay interval interaction [$F(3,63)=4.68, p<.01$]. Analysis of simple main effects revealed that a significant choose-short bias occurred for both groups at the 5s [$F(1,21)=5.01, p<.05$], 10s [$F(1,21)=7.71, p<.025$], and 15s [$F(1,21)=5.07, p<.05$] delay intervals, but not at the 0s delay interval [$F(1,21)=<3$]. Similar choose-short biases for both groups on the temporal dimension is illustrated in the upper portion of Figure 5, while the lower portion demonstrates the similarity of the groups on the nontemporal dimension. The ANOVA summary tables for the analyses carried out in Experiment 2 are found in Appendix A.

Figure 5. Mean percent correct delayed matching-to-sample accuracy of both DO and NDO groups on temporal sample trials (upper) and nontemporal sample trials (lower) in Experiment 2.

TEMPORAL SAMPLES



NONTEMPORAL SAMPLES



Discussion

The findings of Experiment 2 confirm that expectancies of food and no-food have overshadowed control of the sample stimulus. On session one of 0-delay MTS, the DO group showed a decrease in matching accuracy compared to the NDO group, as well as relative to their baseline performance. This finding suggests that the DO group had been ignoring stimulus information while their choice behaviour was mediated by expectancies of differential outcomes. When expectancies no longer aided in their choice, subjects in the DO group had less information with which to respond, therefore causing a drop in accuracy. A point of interest is the rapid increase in matching accuracy displayed by the DO group. By session 2 of 0-delay MTS, their accuracy equalled that of the NDO group. Also, while the accuracy displayed by the DO group on session 1 is significantly less accurate than the NDO group, it is still well above chance levels of responding.

The fact that the DO group improved in matching accuracy so rapidly, and that the DO group maintains performance well above chance levels of matching, suggests that one of two possible events is occurring. First, it is possible that while subjects' matching choices are guided by expectancies, the sample maintains a low level of residual direct control. Therefore, when expectancies are removed performance is only moderately and transiently effected. Another more likely possibility is that a change in performance levels occurred within the first session of 0-delay MTS that the procedure of the present study was not sensitive to. That is, perhaps during the first half of the 80 trials of session 1 the DO group performed very poorly, but then began to obtain information from the sample which increased matching accuracy quickly.

An event that warrants discussion is the decrease in accuracy from baseline to session 1 of MTS with nondifferential outcomes that is displayed by both groups. Perhaps this effect is due to the fact that subjects were not matching for 12 sessions and were therefore out of practice. This effect is also reported by Urcuioli (1990a) after off-baseline training with differential probabilities of reinforcement.

DMTS data from Experiment 2 clearly demonstrate the equivalence of the NDO and DO groups. Both groups display a choose-short bias on temporal sample trials, and on nontemporal sample trials, both groups show a similar decline in accuracy with increasing delay. While it was predicted that the NDO group would perform more accurately than the DO group during this phase in the study, after examining data from the 0-delay MTS phase, it is clear why no differences occurred. Again, the DO group seemed to begin obtaining information from the sample almost immediately, and therefore, sooner than was predicted.

Therefore, clear evidence for overshadowing of both temporal and nontemporal sample information is certainly present in Experiment 2, however, it appears to be a weaker effect than was predicted. An examination of trial-by-trial performance during the first session of 0-delay MTS would be an interesting direction for further research.

General Discussion

Two important conclusions can be drawn from these experiments. First, the present study provides further evidence that differential outcome expectancies of food and no-food overshadow information from the sample stimulus in a DMTS procedure. Further, salient

outcome expectancies such as food and no-food can precipitate the use of categorical coding of sample durations.

Urcuioli (1990a) contributed evidence for the overshadowing of sample stimulus information by outcome expectancies of food and no-food. The relative salience of differential outcome expectancies of food and no-food was demonstrated by comparing them with outcome expectancies evoked by differential outcomes of nonzero probabilities of food. Overshadowing of sample stimulus information occurred when expectancies of food and no-food were present, however, when expectancies of nonzero probabilities of food were present, sample stimulus information was not overshadowed.

As was previously reviewed, after establishing differential outcome expectancies in MTS for Group Diff in Experiment 2, Urcuioli (1990a) used an off-baseline method of pairing samples with outcomes nondifferentially for both Group Nondiff as well as Group Diff. This method was intended to extinguish outcome expectancies for Group Diff. Following this, matching-to-sample was reintroduced with nondifferential outcomes for both groups. Group Nondiff performed more accurately than did Group Diff. Clearly, the choice behaviour of Group Diff had been guided by expectancies during MTS with differential outcomes. While this was occurring, subjects in this group ignored sample stimulus information. Sample information was not useful to Group Diff because salient outcome expectancies were available to aid correct choosing. When the expectancies were later extinguished off-baseline and MTS with nondifferential outcomes was introduced, the only information available to aid in choice behaviour for both groups was from the sample, which Group Diff had learned to ignore, and group Nondiff had been accustomed to. Therefore,

Group Nondiff's performance did not change, but Group Diff's performance accuracy decreased and was less accurate than Group Nondiff. On the food/no-food segment of the study, Urcuioli found strong group differences on the first three days of MTS with nondifferential outcomes, as well as during the subsequent delay tests. Further, when this experiment was performed with nonzero probabilities of reinforcement as outcomes, no overshadowing occurred, suggesting that food and no-food outcomes evoke more salient expectancies than do nonzero probabilities of reinforcement.

The present study, which utilized a design similar to Urcuioli's Experiment 2, replicated Urcuioli (1990a) in that evidence of overshadowing was found on session 1 of MTS with nondifferential outcomes. However, it is interesting to note the effects of overshadowing that existed in the present study did not endure beyond session 1 of nondifferential MTS, or for any session of DMTS, whereas Urcuioli reported strong effects for 3 days of nondifferential MTS, as well as during the subsequent delay testing. It is possible that the DMTS-experienced animals of the present study were better at reacquiring the matching task through the use of sample information than Urcuioli's naive pigeon sample. However, regardless of previous experience, the effects of overshadowing reported by Urcuioli were replicated in the present study.

In order to more closely examine the effects of removing expectancies, a trial-by-trial analysis of matching accuracy is needed. Perhaps the initial performance of subjects in the group receiving differential outcomes during Session 1 of the initial MTS training (in both Urcuioli's and the present study) was very low, but recovered quickly. Further, perhaps if such a trial-by-trial analysis was undertaken in a study re-examining differential nonzero

probabilities of food, a small degree of overshadowing would be found. Indeed, Santi, Ducharme and Bridson (in press) found that differential nonzero probabilities of food altered coding of temporal samples in a DMTS procedure. Therefore, perhaps some overshadowing is occurring in this situation, but the methods of Urcuioli (1990a) were not sensitive enough to detect it.

Peterson, Linwick, and Overmier (1987) suggested that comparing memories for neutral sample stimuli, such as line orientations or colors, with expectancies for survival-relevant outcomes such as food and no-food is biased. As was previously discussed, they compared samples that were associated with prechoice food or no-food with differential outcomes of food and no-food. Briefly, subjects were presented with either memories of prechoice food, expectancies, neither, or both. The results revealed that subjects that developed expectancies only performed as well as subjects that were presented with both expectancies and memories which were consistent. Subjects that received prechoice food or no-food that was not consistent with outcome expectancies performed less accurately, but better than a group that was presented with memories of prechoice food and no-food alone. These results suggest that even when sample stimuli are associated with food and no-food, expectancies exert greater control over choice behaviour than do memories of the sample. Therefore, the established saliency of outcome expectancies that was demonstrated in the present study was not due simply to the possibility that next to neutral stimuli such as durations and line orientations, outcome expectancies of food and no-food controlled matching performance because of their relevance to survival.

An integral and distinctive characteristic of the present study pertains to the two types of sample stimuli utilized. The use of sample durations of light as well as line orientations provided the opportunity to explore the effects of outcome expectancies on memory for event duration and compare it to memory for more conventional sample stimuli: line orientations.

As was previously discussed, Santi *et al.* (in press) provided evidence that when differential nonzero probabilities of food were used as outcomes in a DMTS with event duration and line orientations as samples, both expectancy cues and information from the sample guide behaviour. Since a choose-short bias occurs when subjects are analogically coding sample durations, its presence was taken as evidence that subjects were obtaining some information from the sample. However, since the effects of a choose-favourable bias were also present in this study, expectancy cues were therefore also guiding behaviour.

The present study uses the choose-short bias as evidence of analogical coding, and effects associated with differential outcomes, such as the choose-favourable bias as evidence of the presence of outcome expectancies. Therefore, since in Experiment 1, an equivalent choose-favourable bias occurs in both the DO groups, hence relinquishing any evidence of a choose-short bias, it appears that overshadowing of sample stimulus information has occurred. Other than at the 0s delay interval on no-food trials, as has been discussed, the DO groups perform equivalently. Consequently, in this situation, subjects must be coding sample duration in a nonanalogical or categorical manner.

Experiment 2 provided further evidence of the occurrence of overshadowing, as well as an indication of the level to which it has occurred. As in Urcuioli's study (1990a), the initial MTS training with differential outcomes for the DO group established outcome

expectancies which guided the behaviour of the DO group. The performance of the subjects in the DO group was presumably being guided by outcome expectancies, therefore, they were ignoring stimulus information, whereas the NDO group, not having outcome expectancies to aid their responding, more closely attended information from the samples. During the off-baseline sessions of nondifferential outcomes paired with each type of sample stimulus for both groups, the expectancies of the DO group were extinguished. Therefore, when MTS was reintroduced without differential outcomes for either group, the DO group's performance accuracy declined and was less accurate than the NDO group. This is because the DO group was accustomed to responding with the help of outcome expectancies, which were no longer present. For the NDO group however, no information had been removed, so their performance remained accurate.

In order to strengthen the conclusions of the present study, a possibility for further investigation would be to examine the positive transfer that should occur if nontemporal samples were substituted for the temporal samples. For example, in the present study durations of 2s and 8s are mapped onto red and green comparison stimuli. If subjects are coding duration in a nonanalogical manner, little or no disruption should occur if red and green stimuli were paired off-baseline with consistent food and no-food outcomes and then substituted for the sample durations in the matching situation, mapped onto red and green comparison stimuli.

The purpose of the present study was to examine the flexibility with which pigeons encode event duration. These experiments present a situation in which pigeons abandon the typical analogical coding process of event duration. Evidence from this study and others

leads to the conclusion that while analogical coding usually occurs when subjects are confronted with sample durations, a nonanalogical or categorical form of coding can occur in particular situations. Perhaps when other cues are available that are either more salient, or less difficult to use, subjects will abandon the analogical coding strategy. The present study provides the most apparent instance of this event, but other studies in the area have elements that would support this conclusion. Santi, Bridson, & Ducharme (1991) examined the possibility of nontemporal and temporal sample stimuli being coded commonly in a many-to-one procedure. Indeed, Experiment 1 revealed that the retention functions of the two types of samples were similar, and no choose-short effect occurred. However, Experiment 2 which involved the examination of transfer effects between temporal and color samples showed asymmetrical transfer. During the transfer phase, some subjects received sample stimuli that were consistent with a possible common code (Group Consistent), while others received sample stimuli that were inconsistent with a possible common code (Group Inconsistent). The results revealed that Group Consistent performed more accurately than Group Inconsistent when color samples were matched to shape comparisons. When temporal samples were matched to shape comparisons, however, Group Consistent and Group Inconsistent performed similarly. If subjects were commonly coding the samples, positive transfer would occur in Group Consistent, while negative transfer would occur in Group Inconsistent. Therefore, it was concluded that neither a strictly analogical or a strictly categorical form of coding was taking place. A similar conclusion was drawn by Santi, *et al.* (in press). As was pointed out previously, this study established that both outcome expectancy codes and analogical coding were being used in a DMTS with both temporal and

nontemporal sample stimuli, followed by differential outcomes of nonzero probabilities of food. Therefore, the present study offers clear evidence of a situation in which nonanalogical coding of event duration occurs.

Several conclusions can be drawn from the present study. Further support for the finding that differential food and no-food outcomes overshadow control of the sample stimulus is presented. Also, evidence from the present study in conjunction with the findings of Santi *et al.* (in press) provide further evidence that differential outcomes of food and no-food are more salient than are differential nonzero probabilities of food. Most importantly, the present study presents a situation in which nonanalogical coding of event duration occurs.

Appendix A
ANOVA Summary Tables

Summary Table for the Group (DO-SF and DO-LF), Dimension (temporal and nontemporal), Outcome (food and no-food), and Delay (0s, 5s, 10s, and 15s) ANOVA in Experiment 1.

Source	Sum of Squares	df	Mean Square	F	p
Between Subjects					
Group	7.88	1	7.88	.01	
Error	10037.27	14	716.95		
Within Subjects					
Dimension	463.06	1	463.06	1.46	
Dimension X Group	41.68	1	41.68	.13	
Error	4432.26	14	316.59		
Outcome	50380.61	1	50380.61	87.14	.0001
Outcome X Group	16.35	1	16.35	.03	
Error	8094.03	14	578.14		
Delay	8275.82	3	2758.61	57.29	.0001
Delay X Group	775.78	3	258.60	5.37	.01
Error	2022.24	42	48.15		
Dimension X Outcome	100.13	1	100.13	.74	
Dimension X Outcome X Group	55.22	1	55.22	.41	
Error	1895.73	14	135.41		
Dimension X Delay	64.28	3	21.43	.59	
Dimension X Delay X Group	282.80	3	94.27	2.59	.07
Error	1528.63	42	36.40		
Outcome X Delay	3872.12	3	1290.70	30.13	.0001

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Source	Sum of Squares	df	Mean Square	F	p
Outcome X Delay X Group	790.48	3	263.49	6.15	.01
Error	1798.98	42	42.83		
Dimension X Outcome X Delay	655.66	3	218.55	5.94	.01
Dimension X Outcome X Delay X Group	184.93	3	61.64	1.68	
Error	1545.48	42	36.80		
Total	97321.42	255			

Summary Table for Group (DO-SF, DO-LF, and NDO), Duration (short and long), and Delay (0s, 5s, 10s, and 15s) ANOVA in Experiment 1.

Source	Sum of Squares	Degrees of Freedom	Mean Square	F	p
Between Subjects					
Group	8658.51	2	4329.26	9.95	.001
Error	9141.37	21	435.30		
Within Subjects					
Duration	1652.64	1	1652.64	6.51	.02
Duration X Group	30331.78	2	15165.89	59.88	.0001
Error	5327.19	21	253.68		
Delay	13369.00	3	4456.33	92.34	.0001
Delay X Group	4179.94	6	696.66	14.44	.0001
Error	3040.32	63	48.25		
Duration X Delay	2647.66	3	882.55	15.69	.0001
Duration X Delay X Group	3152.99	6	525.50	9.34	.0001
Error	3544.75	63	56.27		
Total	85046.15	191			

Summary Table for Group (DO-SF, DO-LF and NDO), Dimension (temporal and nontemporal), and Delay (0s, 5s, 10s, and 15s) ANOVA in Experiment 1.

Source	Sum of Squares	Degrees of Freedom	Mean Square	F	p
Between Subjects					
Group	9364.40	2	4682.20	14.40	.0001
Error	6828.18	21	325.15		
Within Subjects					
Dimension	457.26	1	457.26	3.63	
Dimension X Group	35.72	2	17.86	0.14	
Error	2642.13	21	125.82		
Delay	14306.70	3	4768.90	165.87	.0001
Delay X Group	4605.58	6	767.60	26.70	.0001
Error	1811.26	63	28.75		
Dimension X Delay	34.08	3	11.36	0.39	
Dimension X Delay X Group	230.50	6	38.42	1.32	
Error	1838.58	63	29.18		
Total	42154.15	191			

Summary Table for Group (DO-SF, DO-LF and NDO), and Dimension (temporal and nontemporal) ANOVA in Experiment 2.

Source	Sum of Squares	Degrees of Freedom	Mean Square	F	p
Between Subjects					
Group	260.37	2	130.19	1.95	
Error	1334.95	20	66.75		
Within Subjects					
Dimension	154.40	1	154.40	5.85	.05
Dimension X Group	32.19	2	16.09	.61	
Error	527.88	20	26.39		
Total	2309.79	45			

Summary Table for Group (DO and NDO), Session-type (the last three days of baseline and the first day of MTS), and Dimension (temporal and nontemporal) ANOVA in Experiment 2.

Source	Sum of Squares	Degrees of Freedom	Mean Square	F	p
Between Subjects					
Group	856.15	1	856.15	4.36	.05
Error	4128.18	21	196.58		
Within Subjects					
Dimension	799.32	1	799.32	6.18	.025
Dimension X Group	43.95	1	43.95	.34	
Error	2716.63	21	129.36		
Session	4026.89	1	4026.89	34.70	.0001
Session X Group	272.85	1	272.85	2.35	
Error	2436.83	21	116.04		
Dimension X Session	174.86	1	174.86	1.92	
Dimension X Session X Group	.36	1	.36	0.00	
Error	1909.02	21			
Total	17365.04	91			

Summary Table for Group (DO and NDO), Dimension (temporal and nontemporal), and Session (sessions 1, 2 and 3 of MTS) ANOVA in Experiment 2.

Source	Sum of Squares	Degrees of Freedom	Mean Square	F	p
Between Subjects					
Group	680.73	1	680.73	1.44	
Error	9906.05	21	471.72		
Within Subjects					
Dimension	2961.05	1	2961.05	7.90	.05
Dimension X Group	169.93	1	169.93	.45	
Error	7869.38	21	374.73		
Session	1762.77	2	881.39	14.28	.0001
Session X Group	551.54	2	275.78	4.47	.05
Error	2592.93	42	61.74		
Dimension X Session	14.21	2	7.10	.16	
Dimension X Session X Group	9.14	2	4.57	.10	
Error	1840.95	42	43.83		
Total	29358.68	137			

Summary Table for Group (DO and NDO), Dimension (temporal and nontemporal) and Delay (0s, 5s, 10s, and 15s) ANOVA in Experiment 2.

Source	Sum of Squares	Degrees of Freedom	Mean Square	F	p
Between Subjects					
Group	8.54	1	8.54	.05	
Error	3402.68	21	162.03		
Within Subjects					
Dimension	2046.13	1	2046.13	20.77	.001
Dimension X Group	555.59	1	555.59	5.64	.05
Error	2068.91	21	98.52		
Delay	34180.67	3	11393.56	236.87	.0001
Delay X Group	50.81	3	16.94	.35	
Error	3030.27	63	48.10		
Dimension X Delay	181.26	3	60.42	1.29	
Dimension X Delay X Group	31.55	3	10.52	.22	
Error	2955.62	63	46.91		
Total	48512.03	184			

Summary Table for Group (DO and NDO), Sample Duration (short and long), Delay (0s, 5s, 10s, and 15s) ANOVA in Experiment 2.

Source	Sum of Squares	Degrees of Freedom	Mean Square	F	p
Between Subjects					
Group	687.38	1	687.38	2.64	
Error	5468.36	21	260.40		
Within Subjects					
Dimension	1271.71	1	1271.71	6.92	.05
Dimension X Group	.17	1	.17	0.00	
Error	3859.88	21	3859.88		
Delay	38976.94	3	12992.31	202.50	.0001
Delay X Group	147.57	3	49.19	.77	
Error	4042.01	63	64.16		
Dimension X Delay	771.12	3	257.04	4.68	.01
Dimension X Delay X Group	63.48	3	21.16	.39	
Error	3461.27	63	54.94		
Total	58749.89	183			

References

- BMDP User's Digest. (1984). Berkeley: University of California Press.
- Carlson, J. G., & Wielkiewicz, R. M. (1972). Delay of reinforcement in instrumental discrimination learning in rats. *Journal of Comparative and Physiological Psychology*, 81, 365-370.
- Carlson, J. G., & Wielkiewicz, R. M. (1976). Mediators of the effects of magnitude of reinforcement. *Learning and Motivation*, 7, 184-196.
- Carter, D. E. & Eckerman, D. A. (1975). Symbolic matching by pigeons: Rate of learning complex discriminations predicted from simple discriminations. *Science*, 187, 662-664.
- Church, R. M. (1980). Short-term memory for time intervals. *Learning and Motivation*, 11, 208-219.
- Cohen, J. S., Galgan, R., & Fuerst, D. (1986). Retrospective and prospective short-term memory in delayed response tasks in rats. *Animal Learning & Behavior*, 14, 38-50.
- Cook, R. G. (1980). Retroactive interference in pigeon short-term memory by a reduction in ambient illumination. *Journal of Experimental Psychology: Animal Behavior Processes*, 6, 26-338.
- Darwin, C. (1859). *On the origin of the species by means of natural selection*. Cambridge, Mass.: Harvard University Press.
- DeLong, R. E., & Wasserman, E. A. (1981). Effects of differential reinforcement expectancies on successive matching-to-sample performance in pigeons. *Journal of Experimental Psychology: Animal Behavior Processes*, 7, 394-412.
- Edwards, C. A., Jagielo, J. A., Zentall, T. R., & Hogan, D. E. (1982). Acquired equivalence and distinctiveness in matching to sample by pigeons: Mediation by reinforcer-specific expectancies. *Journal of Experimental Psychology: Animal Behavior Processes*, 8, 244-259.
- Fedorchak, P. M., & Bolles, R. C. (1986). Differential outcome effect using a biologically neutral outcome difference. *Journal of Experimental Psychology: Animal Behavior Processes*, 12, 125-130.

- Gibbon, J., & Church, R. M. (1984). Sources of variance in an information processing theory of timing. In H. L. Roitblat, T. G. Bever, H. S. Terrace (Eds.), *Animal cognition*. (465-488). Hillsdale, N.J.: Laurence Earlbaum Associates.
- Grant, D. S. (1976). Effect of sample presentation time on long-delay matching in the pigeon. *Learning and Motivation*, 7, 580-590.
- 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, N.J.: Laurence Erlbaum Associates.
- Grant, D. S. (1981b). Stimulus control of information processing in pigeon short-term memory. *Learning and Motivation*, 12, 19-39.
- Grant, D. S. (1982). Prospective versus retrospective coding of samples of stimuli, responses, and reinforcers in delayed matching with pigeons. *Learning and Motivation*, 13, 265-280.
- Grant, D. S. (1984). Directed forgetting and intratrial interference in pigeon delayed matching. *Canadian Journal of Experimental Psychology*, 38, 166-177.
- Grant, D. S. (1988). Sources of visual interference in delayed matching-to-sample with pigeons. *Journal of Experimental Psychology: Animal Behavior Processes*, 14, 368-375.
- Grant, D. S. Brewster, R. G. & Stierhoff, K. A. (1983). "Suprisingness" and short-term retention in pigeons. *Journal of Experimental Psychology: Animal Behavior Processes*, 9, 63-79.
- Honig, W. K. (1978). Studies of working memory in the pigeon. In S. H. Hulse, H. Fowler & W. K. Honig (Eds), *Cognitive processes in animal behavior*, (pp. 211-248). Hillsdale, N.J.: Laurence Erlbaum Associates.
- Honig, W. K., & Dodd, P. W. D. (1983). Delayed discriminations in the pigeon: The role of within-trial location of conditional cues. *Animal Learning & Behavior*, 11, 1-9.
- Honig, W. K., & Thompson, R. K. R. (1982). Retrospective and prospective processing in animal working memory. In G. H. Bower (Ed.), *Psychology of learning and motivation: Advances in research and theory*, (Vol. 16, 239-283). New York: Academic Press.
- Honig, W. K., & Wasserman, E. A. (1981). Performance of pigeons delayed simple and conditional discriminations under equivalent training procedures. *Learning and Motivation*, 12, 149-170.

- Kazdin, A. E. (1976). The Rich Rewards of Rewards. *Psychology Today*, November, 98-106.
- Keeton, W. T. (1974). The orientational and navigational basis of homing in birds. *Advances in the Study of Behavior*, 5, 47-132.
- Kraemer, P. J., Mazmanian, D. S., & Roberts, W. A. (1985). The choose-short effect in pigeon memory for stimulus duration: Subjective shortening versus coding models. *Animal Learning & Behavior*, 13, 349-354.
- Maki, W. S. (1979). Pigeons' short-term memories for surprising vs. expected reinforcement and nonreinforcement. *Animal Learning & Behavior*, 7, 31-37.
- Overmier, J. B., Bull III, J. A., & Trapold, M. A. (1971). Discriminative cue properties of different fears and their role in response selection in dogs. *Journal of Comparative and Physiological Psychology*, 76, 478-482.
- Parker, B. K., & Glover, R. L. (1987). Event duration memory: The effects of delay-interval illumination and instructional cuing. *Animal Learning & Behavior*, 15, 241-248.
- Pavlov, I. P. (1927). *Conditioned Reflexes*. London: Oxford University Press.
- Peterson, G. B. (1984). How expectancies guide behavior. In H. L. Roitblat, T. G. Bever, H. S. Terrace (Eds.). *Animal cognition*. (135-148). Hillsdale, N.J.: Laurence Earlbaum Associates.
- Peterson, G. B., Linwick, D., & Overmier, J.B. (1987). On the comparative efficacy of memories and expectancies as cues for choice behavior in pigeons. *Learning and Motivation*, 18, 1-20.
- Peterson, G. B., & Trapold, M. A. (1980). Effects of altering outcome expectancies on pigeons' delayed conditional discrimination performance. *Learning and Motivation*, 11, 267-288.
- Peterson, G. B., Wheeler, R. L., & Armstrong, G. D. (1978). Expectancies as mediators in the differential-reward conditional discrimination performance of pigeons. *Animal Learning & Behavior*, 6, 279-285.
- Peterson, G. B., Wheeler, R. L., & Trapold, M. A. (1980). Enhancement of pigeons' conditional discrimination performance by expectancies of reinforcement and nonreinforcement. *Animal Learning & Behavior*, 8, 22-30.

- Pontecorvo, M. J. (1985). Memory for a stimulus versus anticipation of a response: Contrasting effects of proactive interference in two delayed comparison tasks. *Animal Learning & Behavior*, 13, 355-364.
- Rescorla, R. A., & Solomon, R. L. (1967). Two-process learning theory: relationships between Pavlovian conditioning and instrumental learning. *Psychological Review*, 74, 291-303.
- Roberts, S., & Church, R. M. (1978). Control of an internal clock. *Journal of Experimental Psychology: Animal Behavior Processes*, 4, 318-337.
- Roberts, W. A. (1972). Short-term memory in the pigeon: Effects of repetition and spacing. *Journal of Experimental Psychology*, 94, 74-83.
- Roberts, W. A. (1979) Spatial memory in the rat on a hierarchical maze. *Learning and Motivation*, 10, 117-140.
- Roberts, W. A., Cheng, K., & Cohen, J. S. (1989). Timing light and tone signals in pigeons. *Journal of Experimental Psychology: Animal Behavior Processes*, 15, 23-35.
- Roberts, W. A., & Grant, D. S. (1974). Short-term memory in the pigeon with presentation time precisely controlled. *Learning and Motivation*, 5, 393-408.
- Roberts, W. A., & Grant, D. S. (1976). Studies of short-term memory in the pigeon using the delayed matching-to-sample procedure. In D. L. Medin, W. A. Roberts, & R. T. Davis (Eds), *Processes of animal memory* (pp. 79-112). Hillsdale, New Jersey: Laurence Erlbaum Associates.
- Roberts, W. A., & Grant, D. S. (1978). An analysis of light-induced retroactive inhibition in pigeon short-term memory. *Journal of Experimental Psychology: Animal Behavior Processes*, 4, 219-236.
- Roitblat, H. L. (1980). Codes and coding processes in pigeon short term memory. *Animal Learning & Behavior*, 8, 341-351.
- Roitblat, H. L. (1987). *Introduction to comparative cognition*. New York: Freedman.
- Santi, A., Bridson, S., & Ducharme, M. J. (1991, June). Memory codes for temporal and nontemporal samples in many-to-one matching by pigeons. Paper presented at the Canadian Society for Brain, Behavior, & Cognitive Science, University of Calgary, Alberta.

- Santi, A., Ducharme, M. J., & Bridson, S. (In press). Differential outcome expectancies and memory for temporal and nontemporal stimuli in pigeons. *Learning and Motivation*.
- Santi, A., Musgrave, S., & Bradford, S. A. (1988). Utilization of cues signalling different test stimulus dimensions in delayed matching to sample by pigeons. *Learning and Motivation*, 19, 87-98.
- Santi, A., & Roberts, W. A. (1985a). Prospective representation: The effects of varied mapping of sample stimuli to comparison stimuli and differential trial outcomes on pigeons' working memory. *Animal Learning & Behavior*, 13, 103-108.
- Santi, A., & Roberts, W. A. (1985b). Reinforcement expectancy and trial spacing effects in delayed matching-to-sample by pigeons. *Animal Learning & Behavior*, 13, 274-284.
- Schwartz, B. (1984). *Psychology of learning and behavior*. New York: Norton Press.
- Skinner, B. F. (1938). *The behavior of organisms*. New York: Appleton-Century Crofts.
- Skinner, B. F. (1953). *Science and human behavior*. New York: Macmillan.
- Smith, L. (1967). Delayed discrimination and delayed matching in pigeons. *Journal of the Experimental Analysis of Behavior*, 10, 529-533.
- Spetch, M. L., & Rusak, B. (1989). Pigeons' memory for event duration: Intertrial interval and delay effects. *Animal Learning & Behavior*, 17, 147-156.
- Spetch, M. L., & Sinha, S. S. (1989). Proactive effects in pigeons' memory for event duration: Evidence for analogical retention. *Journal of Experimental Psychology: Animal Behavior Processes*, 15, 347-357.
- Spetch, M. L., & Wilkie, D. M. (1983). Subjective shortening: A model of pigeons' memory for event duration. *Journal of Experimental Psychology: Animal Behavior Processes*, 9, 14-30.
- Stonebraker, T. B., & Rilling, M. (1984). Retrospective versus prospective processes in delayed matching to sample. *Bulletin of the Psychonomic Society*, 22, 372-375.
- Tranberg, D. K., & Rilling, M. (1980). Delay-interval illumination changes interfere with pigeon short-term memory. *Journal of the Experimental Analysis of Behavior*, 33, 33-49.

- Trapold, M. A. (1970). Are expectancies based upon different positive reinforcing events discriminably different? *Learning and Motivation*, 1, 129-140.
- Urcuioli, P. J. (1990a). Some relationships between outcome expectancies and sample stimuli in pigeons' delayed matching. *Animal Learning & Behavior*, 18, 302-314.
- Urcuioli, P. J. (1990b). Differential outcomes and many-to-one matching: Effects of correlation with correct choice. *Animal Learning and Behavior*, 18, 410-422.
- Urcuioli, P. J. (1991). Retardation and facilitation of matching acquisition by differential outcomes. *Animal Learning & Behavior*, 19, 29-36.
- Urcuioli, P. J., & Zentall, T. R. (1986). Retrospective coding in pigeons' delayed matching-to-sample. *Journal of Experimental Psychology: Animal Behavior Processes*, 12, 69-77.
- Urcuioli, P. J., & Zentall, T. R. (1990). On the role of trial outcomes in delayed discriminations. *Animal Learning & Behavior*, 18, 141-150.
- Urcuioli, P. J., Zentall, T. R., Jackson-Smith, P., & Steirn, J. N. (1989). Evidence for common coding in many-to-one matching: Retention, intertrial interference, and transfer. *Journal of Experimental Psychology: Animal Behavior Processes*, 15, 264-273.
- Wilkie, D. M. (1988). Proactive effects in pigeons' timing behavior: Implication for an internal-clock model. *Animal Learning & Behavior*, 16, 132-136.
- Wilkie, D. M., & Willson, R. J. (1990). Discriminal distance analysis supports the hypothesis that pigeons retrospectively encode event duration. *Animal Learning & Behavior*, 18, 124-132.
- Wright, A. A., & Watkins, M. J. (1987). Animal learning and memory and their relation to human learning and memory. *Learning and Motivation*, 18, 131-146.
- Zentall, T. R., Urcuioli, P. J., Jagielo, J. A., & Jackson-Smith, P. (1989). Interaction of sample dimension and sample-comparison mapping on pigeons' performance of delayed conditional discrimination. *Animal Learning & Behavior*, 17, 172-178.