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Differential outcomes effect in children: Demonstration and mechanisms ☆

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Abstract

The present paper reports three experiments that examine the role of sample stimulus-outcome (S-O) and of comparison or choice response stimulus-outcome (R-O) relations in the differential outcomes discrimination learning of five-year-old children. In these experiments, S-O relations or R-O relations were maintained or removed across two different conditional discrimination tasks. The results indicated that only children who received training in either S-O or R-O relations showed positive transfer between the conditional discriminations. These data support a two-process ('outcome expectancy') account of differential outcomes phenomena in which each sub-problem in a discriminative conditional choice task has its own unique reinforcer, but they also indicate that both unique sample-outcome associations and unique choice-outcome associations are important contributing features to enhanced discriminative learning under differential outcomes procedures in humans. Comparison to a control in Experiments 2 and 3 indicated that merely having had previous experience with the stimuli or having previously discriminated the stimuli did not contribute to cross-discrimination transfer in the absence of prior explicit association between those stimuli and the specific differential outcomes.

Keywords: Differential outcomes effect; Children; S-O and R-O associations

In a differential outcomes procedure, each of two correct S–R sequences is rewarded with its own unique reinforcer. This situation is unlike typical instrumental

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and operant procedures in which all responses produce the same reinforcer. The differential outcomes paradigm has attracted considerable empirical and theoretical interest since Trapold (1970) demonstrated that discrimination learning proceeds more rapidly when different responses produce different outcomes (i.e., reinforcers) than when they produce the same one. An expanding series of experiments have confirmed Trapold's original finding using a considerable range of subjects (e.g., pigeons, rats or dogs) and a variety of qualitatively and quantitatively different consequences (e.g., food vs. water, or different delays to food delivery) (for a review, see Goeters, Blakely, & Poling, 1992). These studies have also provided support for the expectancy theory originally proposed by Trapold and Overmier in 1972 (i.e., Delong & Wasserman, 1981; Edwards, Jagielo, Zentall, & Hogan, 1982; Honig, Matheson, & Dodd, 1984; Peterson, 1984; Peterson & Trapold, 1980; Urcuioli, 1990, 1991; Urcuioli & DeMarse, 1996; Williams, Butler, & Overmier, 1990). This theory states that the subject learns something specific about the qualitative and quantitative properties of the outcomes and develops expectancies of the specific outcomes. The theory argues that the expectancies are classically conditioned to stimuli (the sample stimuli in a conditional discrimination task) that signal which reinforcer is contingent on responding (the choice of the comparison stimuli). However, what makes training with differential outcomes so effective is that it allows for the unique expectancies to become discriminative cues that serve as additional guides for choice behavior. Thus, two important associative relations are emphasized in this theoretical explanation of the differential outcomes effect (DOE): the Pavlovian stimulus-outcome (S-O) associations, which yield the outcome expectancies, and the instrumentally reinforced expectancy-response (E-R) relations. It should be noted that organisms trained with non-differential outcomes are also thought to develop outcome expectancies, but, because the expectancies are common to both choices, they can contribute nothing to enhance accuracy.

Although this theory places emphasis on the differential sample stimulus-outcomes association, other mechanisms could also underlie or contribute to the DOE. Holman and Mackintosh (1981) assessed the claim that discriminative stimuli become classically conditioned stimuli for the instrumental reinforcer and that it is by virtue of their classically conditioned properties that they come to control instrumental responding. Their results suggested that the fundamental relationship learned in instrumental conditioning is that between the response and the reinforcer (R-O association). The associative analyses of instrumental learning have often been explicitly extended to explain effects in the animal differential outcomes literature. For instance, Rescorla and Colwill (1989) and Rescorla (1992, 1994) have proposed an alternative account of differential outcomes performances, known as the backward association theory, that places the emphasis on this R-O association. According with this account, during a given trial, the stimulus gives rise to a unique outcome representation which, in turn, elicits the appropriate response through a backward link between the outcome and the response. Like the expectancy theory, it recognizes the involvement of differential S-O associations in performance. Unlike the expectancy theory, the differential and bidirectional R-O associations are seen as the source of the DOE. Urcuioli and DeMarse (1996, 1997) conducted a series of experiments with animals to assess both theories They found that both associative mechanisms (sample-outcomes, S-O, and comparison response-outcomes, R-O, associations) created by virtue of the differential outcomes procedure may contribute to enhanced performance observed when this procedure is used.

So far, most evidence comes from animal subjects, mainly rats (i.e., Carlson & Wielkiewicz, 1972, 1976; Kruse & Overmier, 1982; Trapold, 1970) and pigeons (Alling, Nickel, & Poling, 1991; Brodigan & Peterson, 1976; Delong & Wasserman, 1981; Urcuioli & DeMarse, 1997; Williams et al., 1990). However, the differential outcomes procedure also appears to be useful for humans, although surprisingly few published studies have explored this possibility (Dube, Rocco, & Mcilvane, 1989; Janssen & Guess, 1978; Joseph, Overmier, & Thompson, 1997; Litt & Schreibman, 1981; Malanga & Poling, 1992; Saunders & Sailor, 1979). Maki, Overmier, Delos, and Gutman (1995) conducted one of these studies, and they demonstrated that children, ranging in age from 4 years and 6 months to 5 years and 5 months, learned conditional symbolic discriminations more readily when taught with the differential outcomes procedure than with the common outcomes procedure. Furthermore, in an effort to understand the mechanism of differential outcomes facilitation, Maki et al. (1995), using a transfer-of-control test, demonstrated that children who received differential outcomes following correct responses had expectances for outcomes, which functioned to guide choice behavior.

To explore whether the differential outcomes procedure is useful in children with a broader range of age, Estévez, Fuentes, Mari-Beffa, González, and Alvarez (2001) conducted a study using a delayed symbolic matching-to-sample task similar to that used by Maki et al. The results indicated that children from 4 years and 6 months to 7 years and 6 months learned the conditional discrimination task faster and showed a higher terminal accuracy when differential outcomes were arranged. Moreover, they found similar results in children from 7 years and 6 months to 8 years and 6 months when a more difficult task was used.

One surprising observation in those experiments was that children trained with the differencial outcomes treatment, and only they, showed better performance in the first four trials of a second conditional discrimination. This might have been because the same correct choice alternatives and reinforcers were used in the second problem as in the first with only the sample stimuli changing. It might be that initial discrimination training on the unique choice alternatives-outcomes associations facilitated the second discrimination learning with new discriminative cues under differential outcomes conditions.

Our primary purpose in the three experiments reported here was to investigate the role of the different possible associations (S-O and R-O) in the differential outcomes discrimination performance of five-year-old children and in the facilitated transfer across discriminations. It is possible that either or both associations created by virtue of the differential outcomes procedure may contributes to enhanced performance. If both, it would also be of interest to compare the magnitude of their contributions.

Experiment 1

To explore this issue in Experiment 1, all children were first trained on a conditional discrimination task with two samples and two pairs of comparison alternatives using differential outcomes. In the second phase of the task, discrimination phase II, the sample stimuli-outcome association, the comparison stimuli-outcome association, or neither of them were the same as those used in discrimination phase I. If the R-O association, as well as the S-O association, contributes to the discriminative performance, children in the same R-O association condition will show higher accuracy in the first trials of discrimination phase II than those in a phase II discrimination in which both the sample and the comparison stimuli are different.

Method

Participants. Thirty-two children (16 boys and 16 girls) were recruited from the school C.P. Lope de Vega in Almería, Spain. The participants ranged in age from 5 years to 5 years and 6 months.

Setting and materials. Each participant sat next to the experimenter in a quiet room. A book containing the stimuli was located on the table between the child and the experimenter. Stimuli measuring approximately 5×5 cm were shown on pages contained in a binder. Each trial consisted of four pages. The first page contained the number of the trial written in the lower right corner. The second page had the discrimination cue stimulus, a sample stimulus centered in the upper half of the page. The third page was blank and served as an approximate 2-s delay. Finally, the fourth page contained two comparison or choice stimuli placed equidistant from each other in the lower half of the page below the midline.

Following pre-training with these materials and the reinforcement process, there were two or three conditional discrimination phases, depending upon the group, which will be referred to as phase I, phase II, and phase III. A separate binder held the stimuli for each phase. Fig. 1 shows the stimuli used in each one.

Two bowls, one red and the other green, were located to the right side of the child. Following a correct choice, children received either a red or a green token which they then placed it in the corresponding red or green bowl. The children used these tokens to 'purchase' rewards. Foods consisting of cookies, two kinds of vegetable chips (triskis and gublins balls) and sweet candies were located in the red bin. Small toy reinforcers including crayons, stickers, masks and globes were located in the green bin. Red tokens purchased items from the red bin; green tokens purchased items from the green bin. The bins were located behind the children and out of their immediate sight. The experimenter controlled stimulus presentations, data collection, and outcome presentations. Reliability checks of the experimenter's scoring and reinforcement procedures were obtained on one fourth of the total sessions of the study (8 sessions) and covered all treatment conditions. This procedure consisted of observations of the experimenter's procedure by an observer present in the experimental setting. The observer independently recorded the child's responses and the reinforcement procedure being used. These reliability assessments revealed no

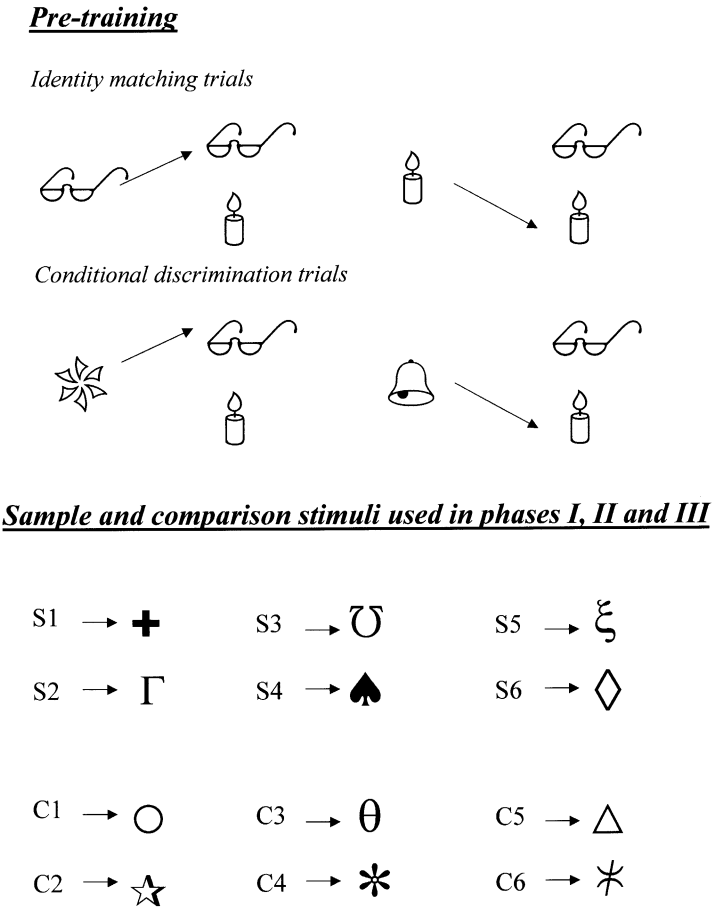

Fig. 1. Stimuli used in each phase of Experiments 1, 2, and 3, where S is sample stimulus and C is the comparison stimulus.

disagreements between experimenter and observer on either response or training condition.

Procedure. Participants were randomly assigned to four groups, such that in each group there were 8 children, 4 girls and 4 boys. For three groups (Different, Same Sample, and Same Comparison), the matching task involved differential outcomes. They received a red token following the correct choice of one comparison stimulus in response to the presentation of one designated sample stimulus and a green token following the correct choice of the other comparison stimulus in response to the presentation of the other sample stimulus (see Fig. 2). Once the experiment was completed, children exchanged green tokens for toys and red tokens for food. In this respect, both the primary and the secondary reinforcers served as differential outcomes. The two tokens (green and red) served as secondary differential reinforcers,

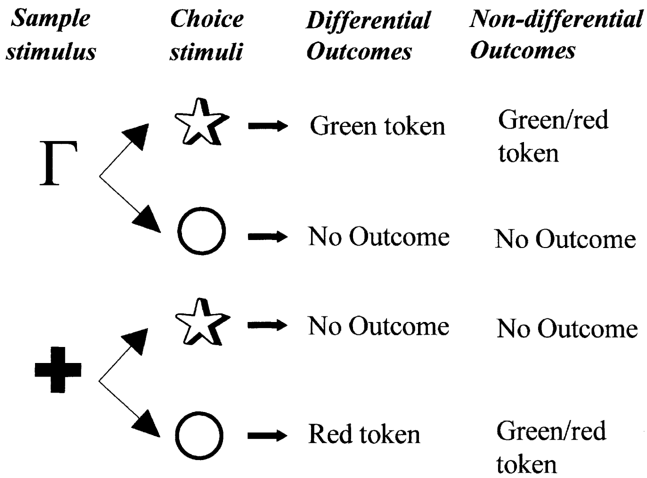

Fig. 2. Conditions used in Experiments 1, 2, and 3 (differential outcomes and non-differential outcomes).

and the two hedonic reinforcers (toys and food) served as primary differential reinforcers. The secondary differential reinforcers in this condition had both different stimulus features (color) and distinct associations (green tokens shared a distinct hedonic association with toys and red tokens shared a distinct hedonic association with food). Participants in the group Non-Differential mixed outcomes, although rewarded for each correct choice, received rewards randomly of either red or green tokens for correct choices (see Fig. 2). Incorrect choices led only to an approximate 3-s intertrial interval for all groups.

Each child participated in a single session lasting approximately 30 min. The task began with a pre-training phase to ensure the participants' ability to discriminate the to-be-used stimuli. That phase consisting of four identity matching trials and eight conditional discrimination trials. On the first identity trial, it was explained that they were going to play a memory game and that if they chose correctly they would win a token that could be exchanged later on for a prize. Then, the experimenter showed the child the association between red tokens and food and between green tokens and toys. The child saw a page with a picture of a pair of glasses centered above the midline and two alternative comparison pictures, one of a pair of glasses and the other of a candle, below the midline. Children were instructed to point to the sample stimulus (the pair of glasses) and then to the comparison stimulus that "goes with" it (the pair of glasses).

On the first conditional discrimination trial, the participants received additional instructions. They saw a page with a bell centered above the midline and two alternative pictures, one of a glasses and the other of a candle, below the midline. They were informed that now the game was going to change a little. The picture on the top of the page (the sample stimulus, the bell) did not look like either of the two pictures on the bottom of the page. They had to guess which picture "goes with" the sample stimulus, and then remember that for each sample stimulus.

Delays between the presentation of the sample stimulus and presentations of the comparison stimuli were introduced gradually to the children in the following manner. The first and second identity trials and the first and second conditional discrimination trials included no delay. For these four trials, the sample stimulus and the two comparison pictures were on the same page. The third and fourth identity trials and the third through fifth conditional discrimination trials incorporated a delay of approximately a second. For these trials, the sample stimulus was on one page and the two comparison stimuli were on the next page. The last three conditional discrimination pre-test trials incorporated a delay of approximately 2 s. For these trials, a blank page inserted between the sample stimulus and the comparison stimuli served as the delay. All the participants had to meet the criterion of at least 75% on pre-training to participate in the experiment. This was followed by discrimination training.

Phase I training consisted of 32 conditional discrimination trials randomized in blocks of eight trials. Each sample stimulus appeared four times per block, and correct choice stimuli appeared an equal number of times on the right and left sides. Table 1 shows this and the following phases (II and III) schematically.

Phase II training consisted of another 32 conditional discrimination trials randomized in blocks of eight trials. For group Different (D), new sample and comparison stimuli were used. For groups Same Sample (SS) and Same Comparison (SC), the sample stimuli or the comparison stimuli from phase I were used, respectively. Group Non-differential (ND) was similar to group Different except that children received non-differential outcomes following their correct responses. These contingencies are depicted in the middle column of Table 1.

After completing phase II, children in groups D and ND performed phase III which consisted of 32 conditional discrimination trials. The sample and comparison stimuli were different from those used in preceding phases. Following completion of phase II (groups SS and SC) or III (groups D and ND), children exchanged the chips they got for reinforcers.

Table 1
Phases used in Experiment 1

Group	Phase I	Phase II	Phase III
Different (D)	S1–C1–O1 S2–C2–O2	S3–C3–O1 S4–C4–O2	S5–C5–O1 S6–C6–O2
Same Sample (SS)	S1–C3–O1 S2–C4–O2	S1–C5–O1 S2–C6–O2	
Same Comparison (SC)	S3–C1–O1 S4–C2–O2	S5–C1–O1 S6–C2–O2	
Non-differential (ND)	S1–C1–O1/O2 S2–C2–O1/O2	S3–C3–O1/O2 S4–C4–O1/O2	S5–C5–O1/O2 S6–C6–O1/O2

Note. S1–S6, sample stimuli; C1–C6, comparison choice responses; O1 and O2 represent the green and red tokens that children exchanged for toys and food, respectively.

Results

Overall accuracy. To first determine whether children in the differential outcomes treatment exhibited greater terminal accuracy than those in the non-differential outcome treatment, data from groups D and ND were analyzed through the different phases I, II, and III. Because the pattern of results was similar for boys and girls, data from this factor were collapsed for the statistical analyses. Correct choices were analyzed through between-subjects ANOVA with Group (D vs. ND) as the between-subjects factor. A rejection criterion of $p \leqslant .05$ was adopted for this and subsequent analyses. Fig. 3 shows the mean percentage of correct choices as a function of group and phase.

The main effect of Group was significant in each phase ($F_{\mathrm{I}}(1,14) = 122.23$; $F_{\mathrm{II}}(1,14) = 80.74$; and $F_{\mathrm{III}}(1,14) = 54.61$). Children in the differential outcomes condition (group D) learned the discrimination and performed better than those in the non-differential outcomes condition (group ND), thus confirming the DOE with children and with our procedures. In fact, children receiving non-differential outcomes performed virtually at chance in all phases (50.39%, 51.95%, and 55.85% accuracy in phases I, II, and III respectively). That is, in the absence of some supplemental associations from embedded S-O or R-O associations, the discrimination tasks were not readily learnable by five-year old children.

Data from the differential outcomes groups D, SS, and SC were analyzed to explore whether children exhibited transfer and different terminal accuracy when we used the same sample stimuli but different comparison stimuli (group SS), different sample stimuli but the same comparison stimuli (group SC), or different sample and different comparison stimuli (group D) across the two conditional discrimination phases (I and II). A between-subjects ANOVA with Group as the between-subject factor was performed on data from these two phases.

The results revealed main effects of Group only in phase II ($F(2,21) = 4.34$). Children's discriminative performance was similar for all groups in phase I ($F < 1$).

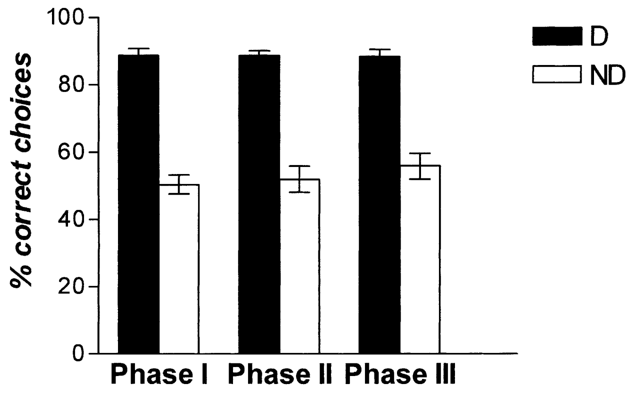

Fig. 3. Mean percentages of correct choice responses as a function of group (D and ND) for phases I, II, and III in Experiment 1. Error bars represent the standard error of the mean.

However, in phase II, the overall performance of children was less accurate for group D compared with the groups SS and SC ($F(1, 21) = 7.76$). This is attributable (see analysis below) to differences in performance on the first trials, where positive transfer from discrimination phase I would be greatest. Critically for the theoretical questions, no differences between groups SS and SC were found even in these first trials where transfer effects should be most evident ($F < 1$).

Learning curves. To explore whether children in the differential outcomes treatments (group D, SS, and SC) learned the discrimination task faster than those in the non-differential outcomes treatment (group ND) and whether the rates of learning were faster if there were common elements across phases (i.e., transfer), we analyzed their performance through the different phases, grouping the trials in eight blocks of four trials each. Fig. 4 shows the percentage of correct choices in all phases as a function of group and block of trials. Visual inspection confirms that all the differential outcomes groups learned faster than the non-differential outcomes group, consistent with Fig. 3. Importantly, a one-way ANOVA on the first block of trials showed no significant differences between groups D and ND in phases I, II, and III ($F\text{s} \leqslant 1$).

Data from groups D, SS, and SC were analyzed through a mixed ANOVA with Group as the between-subjects factor and Block of trials as the within-subjects factor. The results showed a main effect of Block in phases I and II ($F_{\text{I}}(7, 147) = 10.64$ and $F_{\text{II}}(7, 147) = 5.81$). There was also a significant effect of Group in phase II ($F(2, 21) = 4.34$). These data suggest that discriminative learning of the task was similar for the three groups in both phases, although their overall performance was different in phase II.

The analysis of the first block of trials in phase II revealed a marginal main effect of Group ($F(2, 21) = 3.12$, $p = 0.065$). Children in groups SS and SC showed higher accuracy in the first block of trials than children in group D ($F(1, 21) = 6.24$), and there were no differences between the SS and SC groups ($F < 1$). However, these three

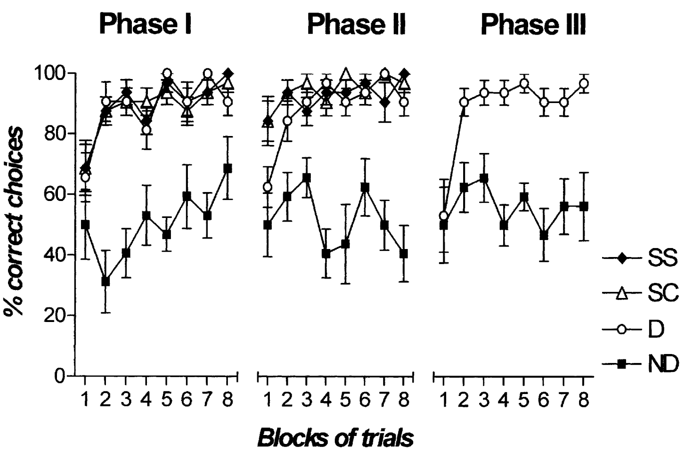

Fig. 4. Mean percentages of correct choice responses as a function of blocks of trials (eight blocks of four trials each) and group (D, SS, SC, and ND) for phases I, II, and III in Experiment 1. Error bars represent the standard error of the mean.

groups had shown similar accuracies in the first block of trials in phase I (65.62%, 68.75% and 68.75% accuracy, respectively). Thus, these results indicated that children showed higher accuracy in the first trials of phase II when we used the same sample stimuli and reinforcers (group SS; 84% accuracy) or the same correct choice alternatives and reinforcers (group SC; 83% accuracy) as had been used in phase I than when none of the elements were common (group D, 62% accuracy), reflecting positive transfer of training in both of the groups with common relations across discrimination tasks.

Discussion

In this experiment, we found the DOE in children ranging in age from 5 years to 5 years and 6 months. The data from groups D and ND showed that participants in the differential outcomes group performed significantly better and learned the discrimination task faster than those who received non-differential outcomes following their correct responses. In fact, performance of the latter group remained at chance during all the discriminative phases. These results replicate and extend the findings of previous studies with children (Estévez et al., 2001; Maki et al., 1995).

More importantly, groups SS and SC showed more accurate performance than group D in the first block of trials of phase II. This implies that having previously established S-O or R-O associations facilitates learning of new conditional choice discrimination tasks that share these elements. Moreover, there were no differences between groups SS and SC. Our interpretation of these results is that *both* S-O and C-O associations are important contributing features to the generally enhanced learning under a differential outcomes procedure.

However, it is possible that the difference between these groups occurred because in shifting from Phase I to Phase II, the control group (group D) had a greater number of stimuli changed in its matching task than did Group SS or Group SC. In other words, while groups SS and SC had only two new stimuli in Phase II, group D had four new stimuli. Because matching to sample acquisition requires both a successive discrimination between the samples and a simultaneous discrimination between the comparison stimuli (Carter & Eckerman, 1975), group D could be at a disadvantage relative to groups SS and SC at the outset of Phase II. Specifically, while one of the two component discriminations was already demonstrably present in Groups SS and SC, neither discrimination was likely present for Group D. Experiments 2 and 3 were designed to address this possible confound. Experiment 2 controlled for number of new stimuli and equates groups on experience with the stimuli, while Experiment 3 controls for the role of discrimination of all stimuli.

Experiment 2

In this experiment, we aimed to test the role of the S-O and R-O associations in the discriminative performance of children using the differential outcomes teaching procedure with a transfer task different from that used in Experiment 1. Experiment 2 consisted of a pre-training phase and three conditional discrimination phases. In conditional discrimination phase III or "test" phase, all children received differential outcomes and they had to learn exactly the same symbolic discrimination. For groups Control (C), Same Sample (SS), and Same Comparison (SC), the sample stimuli or the comparison stimuli from phases I or II were used. That is, these three groups had previously experienced both the sample stimuli and the comparison stimuli prior to their being used in phase III. Moreover, in the last two groups, either the sample stimulus-outcome associations or the comparison stimulus-outcome associations were maintained across phases II and III. In other words, all children in these three groups experienced all the same prior discriminations, had equal experience with all the stimuli used in the test phase, and differed only in whether they had prior associations with the outcomes to carry forward into this final phase. Thus, unlike Experiment 1, it is not possible that any performance differences in transfer between these groups could be due to the different numbers of stimuli experienced in training. Thus, as in Experiment 1, if the R-O association, as well as the S-O association, contributes to the discriminative performance, children in the same R-O association condition (group SC) will show higher accuracy in the first trials of the test phase that those who did not have pre-established outcome relations from phase II (group C). However, although all these groups have equal prior experience with the discriminations, it is possible that this experience contributes to learning the final discrimination. To explore this question, in group None (N), new sample and comparison stimuli were used through each successive discrimination phase. If the prior experience with the stimuli contributes importantly to discriminative learning, group Control will show better performance that group None in phase III. These contingencies are depicted in Table 2.

Method

Participants. Thirty-two children (16 boys and 16 girls) were recruited from the school C.P. Lope de Vega in Almería, Spain. They ranged in age from 5 years to 5 years and 6 months.

Table 2
Phases used in Experiment 2

Group	Phase I	Phase II	Phase III
Same Sample (SS)	S3–C1–O1/O2	S1–C3–O1	S1–C1–O1
	S4–C2–O1/O2	S2–C4–O2	S2–C2–O2
Same Comparison (SC)	S1–C3–O1/O2	S3–C1–O1	S1–C1–O1
	S2–C4–O1/O2	S4–C2–O2	S2–C2–O2
Control (C)	S1–C3–O1/O2	S3–C1–O1/O2	S1–C1–O1
	S2–C4–O1/O2	S4–C2–O1/O2	S2–C2–O2
None (N)	S5–C3–O1/O2	S3–C5–O1/O2	S1–C1–O1
	S6–C4–O1/O2	S4–C6–O1/O2	S2–C2–O2

Note. S1–S6, sample stimuli; C1–C6, comparison choice responses; O1 and O2 represent the green and red tokens that children exchanged for toys and food, respectively.

Setting and materials. The setting and apparatus were similar to those in Experiment 1. Food reinforcers consisting of cookies, two kinds of vegetable chips (triskis and gublins balls), and sweet candies were located in the red bin. Small toy reinforces including crayons, stickers, masks, and globes were located in the green bin. As in Experiment 1, following a correct choice, children received either a red or a green token and then placed it in the corresponding red or green bowl. These red and green tokens were exchangeable for food and toy reinforcers, respectively. Reliability checks of the experimenter's scoring and reinforcement procedures revealed no disagreements between experimenter and observer on either response or training condition.

There were a pre-training phase and three training phases in the experiment. The three conditional discrimination phases will be referred to as phase I, phase II, and phase III or test phase. A separate binder held the stimuli for each phase. The stimuli were similar to those used in Experiment 1 (see Fig. 1).

Procedure. Participants were randomly assigned to four groups, such that in each group there were 8 children, 4 girls and 4 boys. In some phases, according to the group, the matching task involved differential outcomes. A red token followed the correct choices made to one comparison stimulus, whereas a green token followed the correct choices made to the other comparison stimulus. In those phases in which non-differential outcomes were arranged, children received random rewards with either red or green tokens for correct choices.

Each child participated in a single session lasting approximately 40 min. As in Experiment 1, the task began with pre-training consisting of four identity matching trials and eight conditional discrimination trials. The instructions were similar to those described in Experiment 1. Thirty-one participants met the criterion of at least 75% on the pre-training phase and went on to participate in the experiment. One child in group None failed to meet the predetermined inclusion criterion on pre-training and was excluded.

Phase I consisted of 20 conditional discrimination trials randomized in blocks of four trials. Each sample stimulus appeared two times per block, and correct choice stimuli appeared an equal number of times on the right and left sides. In this phase, all groups received non-differential outcomes. Table 2 shows schematically this and the following phases (II and III).

Phase II consisted of 20 different conditional discrimination trials randomized in blocks of four trials. In this phase, only groups SS and SC received differential outcomes. In fact, they were trained in the particular sample stimulus-outcome or comparison stimulus-outcome relation that would be used in the test phase.

After completing phase II, children performed the phase III transfer test consisting of another 20 conditional discrimination trials. In this phase, all children received differential outcomes, and they all had to learn the same discrimination. Following completion of this phase, children exchanged the chips they earned for primary reinforcers.

Results

To explore whether children in the groups SS and SC exhibited different discriminative performance from those in the groups C and N, we analyzed their performance through the different phases, grouping the trials in five blocks of four trials each. Because the pattern of results was similar for boys and girls, data were collapsed across gender for the statistical analyses. Fig. 5 shows the percentage of correct choices in all phases as a function of group and block of trials.

Data from phase I were analyzed through a mixed ANOVA with Group as the between-subjects factor and Block of trials as the within-subjects factor. There were no significant main effects of either Group or Block of trials (Fs < 1). The Outcome $\times$ Block interaction was also not significant ($F < 1$). These data indicate that children's discriminative performance was similar for all groups in this phase. The participants performed overall at chance (53%, 52%, 47%, and 47% accuracy for groups SS, SC, C, and N, respectively).

Data from phases II and III were also analyzed. The main effect of Group was significant in both phases ($F_{\mathrm{II}}(3,27) = 5.47$; $F_{\mathrm{III}}(3,27) = 4.78$). The overall performance of children was less accurate for groups C and N compared with groups SS and SC in both phases ($F_{\mathrm{II}}(1,27) = 13.67$; $F_{\mathrm{III}}(1,27) = 14.39$). Moreover, there were no differences between groups C and N or between groups SS and SC (Fs < 1). In phase II, children in groups SS and SC received differential outcomes following their correct responses. By contrast, non-differential outcomes were arranged for those in the groups C and N. Thus, as in Experiment 1, we found the DOE in children ranging in age from 5 years to 5 years and 6 months. That is, children in the differential outcomes condition (groups SS and SC) performed better than those in the non-differential outcomes condition (groups C and N). However, in phase III, all the participants received differential outcomes following their correct responses. The results obtained in this phase appear to be attributable (see analysis below) to differences in performance on the first trials, where transfer effects should be most evident.

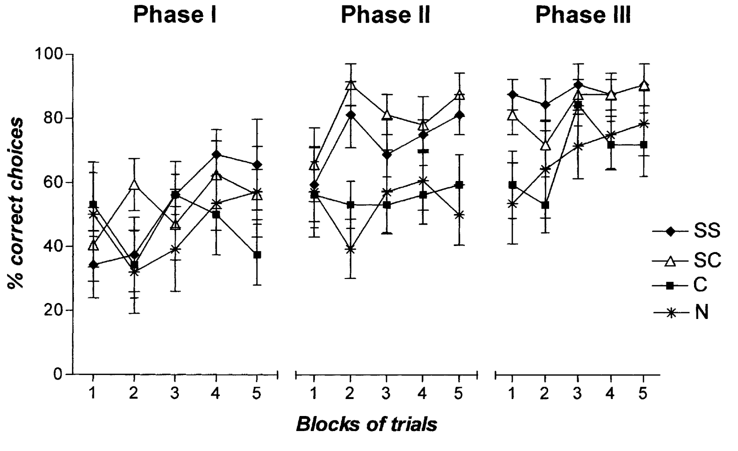

Fig. 5. Mean percentages of correct choice responses as a function of blocks of trials (five blocks of four trials each) and group (SS, SC, C, and N) for phases I, II, and III in Experiments 2. Error bars represent the standard error of the mean.

The results revealed main effects of Blocks of trials only in phase III ($F(4,108) = 3.38$), indicating that performance changed across the different blocks. The Group × Blocks interaction was not significant in any phase (Fs < 1).

Importantly, a one-way ANOVA on the first block of trials in phase III revealed a main effect of Group ($F(3,27) = 3.42$). Children in groups SS and SC showed higher accuracy in these trials than children in groups C and N ($F(1,27) = 9.90$). There were no differences between the SS and SC groups ($F < 1$) or between the C and N groups ($F < 1$). However, these four groups had shown non-differential accuracy in the first block of trials in phase I and in phase II (Fs < 1). Thus, these results indicated that children showed higher accuracy in the first trials of phase III when we used the same sample stimuli and reinforcers relations (group SS) or the same correct choice alternatives and reinforcers relations (group SC) as had been used in phase II, reflecting positive transfer of training in both of these groups.

Discussion

Experiment 2 was originally designed to provide further evidence for the role of S-O and R-O associations in differential outcomes discrimination learning. In the third phase of the task used in the present experiment, discrimination phase III transfer test, the sample-outcome association (group SS), the comparison-outcome association (group SC), or neither of them (groups C and N) were the same as those experienced in the discrimination phase II. Children in groups SS and SC showed better performance in the first trials of the transfer test phase than those in the other two groups. These data nicely confirm the findings of Experiment 1. Both S-O and R-O associations appear to contribute, and equally so, to the positive transfer of training observed in groups SS and SC.

One other point is worth noting. The present results appear not to be subject to the possible alternative interpretations mentioned earlier. Because groups C, SS, and SC had the same previous experience with the stimuli used in phase III, the differences in their performance cannot be attributed to different numbers of new stimuli experienced in training or to different amounts of experience with the stimuli used in the final discrimination. Moreover, there were no differences between groups C and N in phase III, indicating that the hypothesized potential confound of different amounts of prior experience with the stimuli did not appear to contribute to learning the final discrimination. However, the present results are not entirely compelling. The problem of differential discriminability of stimuli between the experimental and control groups remains because the evidence shows that group C had previously only poorly discriminated in phases I and II between the samples and the comparisons appearing in the phase III transfer test. In fact, as seen in Fig. 5, performance in phases I and II by this group with these stimuli remained only marginally better than chance. So, a plausible alternative explanation of the between-group differences seen in phase III is that acquisition of the task was more rapid when subjects had previously *discriminated* between either the sample stimuli (Group SS) or the comparison alternatives (Group SC) than when they had not (Group C) and that this discrimination per se rather than the unique associations with the reinforcers was responsible for the positive transfer.

Experiment 3

Experiment 3 was an attempt at systematic replication of Experiment 2 under conditions that would ensure that, without differential outcome associations, group C actually discriminated all stimuli to be learned in the final test phase. Like Experiment 2, the differential sample stimulus-outcome or the differential comparison stimulus-outcome associations were maintained across phases II and III for groups SS and SC, respectively. Unlike Experiment 2, group C received additional training in phases I and II to ensure that participants in this group had learn to discriminate in these phases between the samples and the comparisons but without unique associations with the reinforcers. If the transfer effects observed in Experiments 1 and 2 were due to differential discrimination of stimuli between the experimental (SS and SC) and control groups, then in this experiment the performance of group C in the first trials of phase III should be similar to or better than that found in groups SS or SC. On the other hand, if prior discrimination per se is not as critical as the associations with the unique reinforcers, then SS and SC should still be better than group C.

Method

Participants. Twelve experimentally naive children (6 boys and 6 girls) were recruited from the school C.P. Lope de Vega in Almería, Spain. The participants ranged in age from 5 years to 5 years and 6 months.

Setting and materials. The setting and materials were the same as those used in Experiment 2. The reliability assessments revealed no disagreements between experimenter and observer on either response or reinforcement condition.

Procedure. Participants were randomly assigned to three groups, such that in each group there were 4 children, 2 girls and 2 boys. The procedure was similar to that used in Experiment 2.

Each child participated in two sessions lasting approximately 15–30 min each. The first session began with the pre-training described in the previous experiments. All the participants met the criterion of at least 75% on this phase required to participate in the experiment. Phase I conditional discrimination trials followed pre-training on the same day. Participants in group C were advanced to the next experimental phase only after meeting a criterion of 10 correct responses in 12 consecutive trials (83% accuracy). For those in groups SS and SC this phase consisted of 20 trials. As in the Experiment 2, in phase I of Experiment 3, non-differential outcomes were arranged for all groups (see Table 2). After completing phase I, children were advanced to phase II. In this phase, groups SS and SC received, as in the prior experiment, differential outcomes throughout 20 conditional discrimination trials. Participants in group C were trained with non-differential outcomes until they met the criterion of 10 correct responses in 12 consecutive trials (83% accuracy).

The second session, one or two days later, was the phase III transfer test. First, all children received 12 pre-training trials using different stimuli (a flower, a pencil, an scissors, and a diamond) from those used in pre-training for session I; this served simply to remind them of the game and rules. Then, 20 conditional discrimination phase III trials followed. As in Experiment 2, all children received differential outcomes, and they all had to learn the same discrimination.

Results

All the participants in group C reached the established criterion in phases I and II. The average number of trials needed to meet the criterion in each phase was 40 and 34, respectively. Participants in group C showed better matching accuracy in phase I than those in groups SS and SC whose discriminative performances were close to chance (70%, 54%, and 55% accuracy, respectively). However, in phase II, the performance of the participants in these three groups did not differ (78%, 74%, and 74% accuracy, respectively). The overall accuracy of group C in phases I and II was similar to that obtained when differential outcomes were arranged for groups SC and SS in phase II. This indicated that all the participants of group C learned the two discriminations. That is, during phases I and II, they learned to discriminate between the different samples and between the different comparison stimuli appearing in phase III. Group C, however, did not learn any specific relations between samples or comparison stimuli and reinforcers. Thus, groups SS, SC, and C differed in whether they had a prior association with the outcome to carry forward into the test phase.

Correct choices from phase III, grouping the trials in five blocks of four trials each, were analyzed through a mixed ANOVA with Group as the between-subjects factor and Block of trials as the within-subjects factor (gender did not produce any significant difference, and data from this factor were collapsed). Fig. 6 shows the percentage of correct choices in this phase as a function of group and block of trials.

The ANOVA revealed only a significant main effect of Group ($F(2,9) = 5.04$). The overall performance of children was less accurate for group C compared with groups SS and SC ($F(1,9) = 10.02$), and there were no differences between these two groups (SS and SC) ($F < 1$).

Importantly, a one-way ANOVA on the first block of trials in this phase revealed a main effect of Group ($F(2,9) = 5.17$). Again, participants in groups SS and SC showed higher accuracy in these first four trials than those in group C ($F(1,9) = 10.02$). There was no difference between groups SS and SC ($F < 1$). Thus, participants showed higher accuracy in the first trials of phase III when the same sample stimuli and reinforcers (group SS) or the same correct choice alternatives and reinforcers (group SC) were used in phases II and III, replicating the transfer results obtained in Experiment 2.

Discussion

In this experiment, as in Experiment 2, we found that the performance of groups SS and SC in the first block of trials of phase III was significantly better than that of group C. For all groups, the sample stimuli or the comparison stimuli from phases I and II were used in the phase III transfer test. To ensure that group C had previously learned to discriminate between these stimuli, participants were trained to a high

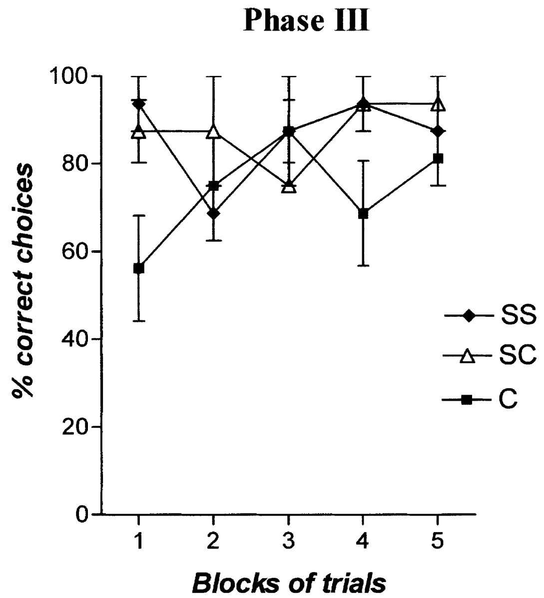

Fig. 6. Mean percentages of correct choice responses as a function of blocks of trials (five blocks of five trials each) and group (SS, SC, and C) for phase III in Experiments 3. Error bars represent the standard error of the mean.

level of accuracy with the samples (phase I) and with the comparison (phase II) stimuli *without* differential outcomes. Thus, the key difference between these three groups was whether the differential sample-outcomes associations (group SS), the differential response-outcomes associations (group SC) or neither of them were maintained across phases II and III. The results obtained in this experiment rule out the possibility that the observed positive transfer in groups SS and SC can be interpreted as a mere prior discrimination effect. In other words, the overall pattern of accuracy in Experiment 3 in the first block of trials clearly confirmed that both S-O and R-O prior associations contribute to the high discriminative performance observed in phase III when differential outcomes were arranged for all groups.

General discussion

The results of the present three experiments are noteworthy for two reason. First, they all confirm that the differential outcomes procedure may be useful as a tool to enhance discriminative learning in humans. Children showed higher accuracy when differential outcomes were arranged. Indeed, when children received differential outcomes following their correct responses (groups D, SS, and SC), they were able to readily learn a conditional discrimination problem that was otherwise very challenging. In fact, when non-differential outcomes were arranged (groups ND, N, and C), the discriminative performance of children was close to chance.

Second, the phase III results of Experiments 2 and 3 clearly confirm the suggestion of Experiment 1 that both the S-O and the R-O associations make an important contribution to learning under a differential outcomes procedure. We expected from the study of Maki et al. (1995) that group SS would show higher transfer accuracy than groups N and C during this phase because embedded S-O associations were pre-established. Thus, the results of greater theoretical interest here are those from group SC. They demonstrate that the unique embedded R-O associations between the choice alternatives and their outcomes that could have been, pre-established in phase II, did in fact contribute to the enhanced performance in phase III under a differential outcomes procedure.

The expectancy theory (Trapold & Overmier, 1972) does not appear to be a sufficient account of the performance observed in group SC in the first block of trials of the transfer phase. According to this theory, the unique associations between the sample stimuli and the outcomes permit subjects to anticipate or expect which outcome is scheduled for that trial. Those differential outcome expectancies, which are conditioned to the discriminative stimuli, can then, in turn, provide an additional discriminative cue for responding. Thus, in order for the expectancy to gain control over the response, expectancy theory requires that there must be previously established differential S-O associations because they are the original source of these crucial expectancies. According to this theory, children in group SS should perform significantly better in the first trials of the test phase than those in group SC because in the latter group, as in group C, differential S-O associations need to be established in order for the participants to anticipate the particular outcome on the basis of the discriminative stimuli. Consequently, the finding that the average level of performance in group SC was in fact comparable to that observed in group SS indicates that other associative processes besides those proposed by expectancy theory are involved in differential outcomes facilitated learning and performance. In fact, the results obtained in the present experiment suggest that the differential response-outcome associations are clearly an additional mechanism that contributes to the differential outcomes effect.

It is also important to note that these results are not fully consistent with the alternative account of differential outcomes performance proposed by Rescorla (1992, 1994) and Rescorla and Colwill (1989). The backward association theory hypothesizes that each sample stimulus gives rise to a unique outcome representation which can then activate the appropriate response through the backward operation of the R-O association. Since the sample stimuli used in the transfer phase for group SC had been associated non-differentially with the outcomes in phase I, they could not generate the outcome representations needed to activate the backward R-O association in the first block of trials of this phase. Although the results obtained in these experiments indicated that the R-O associations are an important factor in differential outcomes performance, further research is needed to assess how these associations exert their influence.

Despite these theoretical issues, however, what is clear is that preestablished S-O and R-O relations, that may give rise to specific associations, are empirically important contributing features of enhanced discriminative learning under differential outcomes procedures. Moreover, the comparable performances of groups SS and SC indicate that the contribution of both relations, and probable associations, is about the same. These results are consistent with a group of studies using pigeons reported by Urcuioli and DeMarse (1996, 1997), who found that sample-outcome and comparison response-outcome relations can be involved in differential outcomes performance. The present experiments provide a clear confirmation of the important contribution of both S-O and R-O associations to discriminative learning in humans.

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References

Alling, K., Nickel, M., & Poling, A. (1991). The effects of differential and non-differential outcomes on response rates and accuracy under a delayed-matching-to-sample procedure. *Psychological Record, 41*, 537–549.

Brodigan, D. A., & Peterson, G. B. (1976). Two-choice conditional discrimination performance of pigeons as a function of reward expectancy, prechoice delay, and domesticity. *Animal Learning & Behavior, 4*, 121–124.

Carlson, J. G., & Wielkiewicz, R. M. (1972). Delay of reinforcement in instrumental discrimination learning of 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.

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.

Dube, W. V., Rocco, F. J., & Mcilvane, W. J. (1989). Delayed matching-to-sample with outcome specific contingencies in mentally retarded humans. *The Psychological Record, 39*, 483–492.

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.

Estévez, A. F., Fuentes, L. J., Mari-Beffa, P., González, C., & Alvarez, D. (2001). The differential outcomes effect as useful tool to improve conditional discrimination learning in children. *Learning and Motivation, 32*, 48–64.

Goeters, S., Blakely, F., & Poling, A. (1992). The differential outcomes effect. *The Psychological Record, 42*, 389–411.

Holman, J. G., & Mackintosh, J. (1981). The control of appetitive instrumental responding does not depend on classical conditioning to the discriminative stimulus. *Quarterly Journal of Experimental Psychology B, 33*, 21–31.

Honig, W. K., Matheson, W. R., & Dodd, P. W. D. (1984). Outcome expectancies as mediators for discriminative responding. *Canadian Journal of Psychology, 38*, 196–217.

Janssen, C., & Guess, D. (1978). Use of function as a consequence in training receptive labeling to severely and profoundly retarded individuals. *AAESPH Review, 3*, 246–258.

Joseph, B., Overmier, J. B., & Thompson, T. (1997). Food and nonfood related differential outcomes in equivalence learning by adults with Prader–Willi syndrome. *American Journal on Mental Retardation, 4*, 374–386.

Kruse, J. M., & Overmier, J. B. (1982). Anticipation of reward omission as a cue for choice behavior. *Learning and Motivation, 13*, 505–525.

Litt, M. D., & Schreibman, L. (1981). Stimulus-specific reinforcement in the acquisition of receptive labels by autistic children. *Analysis and Intervention in Developmental Disabilities, 1*, 171–186.

Maki, P., Overmier, J. B., Delos, S., & Gutman, A. J. (1995). Expectancies as factors influencing conditional discrimination performance of children. *The Psychological Record, 45*, 45–71.

Malanga, P., & Poling, A. (1992). Letter recognition by adults with mental handicaps: Improving performance through differential outcomes. *Developmental Disabilities Bulletin, 20*, 39–48.

Peterson, G. B. (1984). How expectancies guide behavior. In H. L. Roitblat, T. G. Bever, & H. S. Terrace (Eds.), *Animal cognition* (pp. 135–138). Hillsdale, NJ: Erlbaum.

Peterson, G. B., & Trapold, M. A. (1980). Effects of altering outcome expectancies on pigeons' delayed conditional discrimination performance. *Learning and Motivation, 11*, 267–288.

Rescorla, R. R. (1992). Response-outcome versus outcome-response associations in instrumental learning. *Animal Learning & Behavior, 20*, 223–232.

Rescorla, R. R. (1994). Transfer of instrumental control mediated by a devalued outcome. *Animal Learning & Behavior, 22*, 27–33.

Rescorla, R. R., & Colwill, R. M. (1989). Associations with anticipated and obtained outcomes in instrumental training. *Animal Learning & Behavior, 17*, 291–303.

Saunders, R., & Sailor, W. (1979). A comparison of three strategies of reinforcement on two-choice learning problems with severely retarded children. *AAESPH Review, 4*, 323–333.

Trapold, M. A. (1970). Are expectancies based upon different positive reinforcing events discriminably different? *Learning and Motivation, 1*, 129–140.

Trapold, M. A., & Overmier, J. B. (1972). The second learning process in instrumental learning. In A. A. Black & W. F. Prokasy (Eds.), *Classical conditioning: Current research and theory* (pp. 427–452). New York: Appleton-Century-Crofts.

Urcuioli, P. J. (1990). Some relationships between outcome expectancies and sample stimuli in pigeons' delayed matching. *Animal Learning & Behavior, 18*, 302–314.

Urcuioli, P. J. (1991). Retardation and facilitation of matching acquisition by differential outcomes. *Animal Learning & Behavior, 19*, 29–36.

Urcuioli, P. J., & DeMarse, T. B. (1996). Associative processes in differential outcomes discriminations. *Journal of Experimental Psychology: Animal Behavior Processes, 22*, 192–204.

Urcuioli, P. J., & DeMarse, T. B. (1997). Some further tests of response-outcome associations in differential-outcome matching-to-sample. *Journal of Experimental Psychology: Animal Behavior Processes, 23*, 171–182.

Williams, D. A., Butler, M. M., & Overmier, J. B. (1990). Expectancies of reinforcer location and quality as cues for a conditional discrimination in pigeons. *Journal of Experimental Psychology: Animal Behavior Processes, 16*, 172–178.