

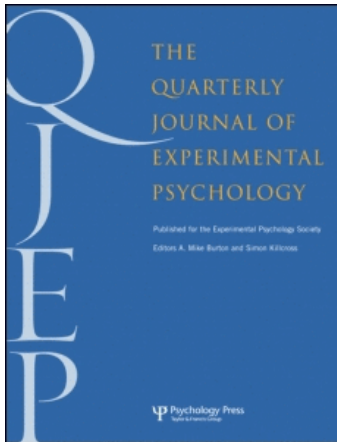
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### Improving conditional discrimination learning and memory in five-year-old children: Differential outcomes effect using different types of reinforcement

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# Improving conditional discrimination learning and memory in five-year-old children: Differential outcomes effect using different types of reinforcement

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Previous studies have demonstrated that discriminative learning is facilitated when a particular outcome is associated with each relation to be learned. When this training procedure is applied (the differential outcomes procedure; DOP), learning is faster and better than when the typical common outcomes procedure or nondifferential outcomes (NDO) is used. Our primary purpose in the two experiments reported here was to assess the potential advantage of DOP in 5-year-old children using three different strategies of reinforcement in which (a) children received a reinforcer following a correct choice (“+”), (b) children lost a reinforcer following an incorrect choice (“−”), or (c) children received a reinforcer following a correct choice and lost one following an incorrect choice (“+/-”). In Experiment 1, we evaluated the effects of the presence of DOP and different types of reinforcement on learning and memory of a symbolic delayed matching-to-sample task using secondary and primary reinforcers. Experiment 2 was similar to the previous one except that only primary reinforcers were used. The results from these experiments indicated that, in general, children learned the task faster and showed higher performance and persistence of learning whenever differential outcomes were arranged independent of whether it was differential gain, loss, or combinations. A novel finding was that they performed the task better when they lost a reinforcer following an incorrect choice (type of training “−”) in both experiments. A further novel finding was that the advantage of the DOP over the nondifferential outcomes training increased in a retention test.

**Keywords:** Differential outcomes procedure; Types of reinforcement; Discriminative learning; Children.

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One of the key challenges of real life is that we are constantly bombarded with decisions to make, and, almost without exception, every choice comes with a consequence. To model such real-life choice behaviours that are conditional on the presenting problems and where successful behaviours are rewarded, psychologists have devised the conditional discriminative choice task. This task takes the general form of a choice environment with two contrasting discriminative stimuli, S1 and S2, and two or more choice alternatives. In the presence of S1, the correct choice is R1, and in the presence of S2, the correct choice is R2. Traditionally in the laboratory, the two correct choices have been rewarded with a single common outcome. However, modern research has shown that the technique of presenting rewards unique to each specific action/choice (that is, correct responses to the conditional relation S1–R1 are rewarded by the unique outcome O1, while correct responses to the conditional relation S2–R2 are rewarded by the unique outcome O2, which better models real-world choices) makes such learning better and faster. In fact, this enhancement of discriminative performance by differential outcomes is one of the more robust and reliable learning phenomena documented in the animal learning literature (see Goeters, Blakely, & Poling, 1992, for a review), and it is generally termed the differential outcomes effect (hereafter DOE).

In an early demonstration of this phenomenon, Trapold (1970) exposed rats to a discrimination problem involving two levers: At the sound of a tone a response to the right-hand lever was rewarded, and at the sound of a click a response to the left-hand lever was rewarded. Trapold observed an increased rate of acquisition and a greater accuracy when the correct choice of the right lever was followed by pellets, and the correct choice of the left lever was followed by sucrose than when both correct responses produced the same reinforcer—for instance, pellet. Later on, it has been widely demonstrated that the differential outcomes procedure (hereafter DOP) facilitates both (a) initial learning of conditional relationships (Carlson & Wielkiewicz,

1976; Trapold, 1970) and (b) memory for the conditional stimuli in delayed matching-to-sample tasks (Brodigan & Peterson, 1976) in animal subjects.

Regarding conditional discriminations in humans, the DOP also produces an increase in speed of acquisition and/or improvement in final accuracy suggesting that this procedure has great potential to be developed into a training tool in applied contexts to help people better learn complex discrimination problems (see Estévez, 2005, for a review). To explore whether DOP might be useful with children, Maki, Overmier, Delos, and Gutman (1995) conducted a study using a delayed matching-to-sample task. The results indicated that children ranging in age from 4 years and 6 months to 5 years and 5 months learned the task more readily when differential outcomes were arranged. Using the classic transfer of control procedure, it was additionally shown that the children could form expectancies for outcomes on which they could later rely for solving new discriminative choice problems involving the same outcomes. In addition, Estévez, Fuentes, Marí-Beffa, González, and Alvarez (2001) found that the DOE could also be obtained in older children (from 7 years and 6 months to 8 years and 6 months), but only when the task used was relatively challenging to them.

The DOE has been also observed in three recent studies involving normal adults without mental handicaps. Miller, Waugh, and Chambers (2002) found that college students (from 18 to 38 years) learned the meanings of kanji characters more quickly when differential outcomes were arranged. More recently, Estévez, Vivas, Alonso, Marí-Beffa, Fuentes, and Overmier (2007) demonstrated that the performance of a group of university students who initially did not discriminate well the correct use of the mathematical symbols “>” and “<” was improved when each relational correct response was always followed by a specific outcome compared to when the outcomes as to correctness of choice were randomly presented across correct choices. Finally, Mok and Overmier (2007) observed the DOE in college students using (a)

different sensory outcomes rather than primary hedonic reinforcers and (b) a unique test using a concurrent differential versus common outcomes task in a within-subjects design.

Finally, the DOP has been shown effective in improving deficits presented by different types of clinical patients. Estévez, Fuentes, Overmier, and González (2003) found facilitative effects of the differential outcomes methodology in a study with children and adults with Down's syndrome. In fact, participants learned the conditional discrimination task only when the correct choices that follow each discriminating stimulus obtained different rewards. Joseph, Overmier, and Thompson (1997) also observed the DOE in adults with Prader-Willi syndrome—a congenital disorder that is accompanied by learning difficulties. They found that when distinct reinforcers were associated with the stimuli being discriminated, there was superior performance, and concepts and difficult equivalence relations were learned better. Later on, an effect was evident in a study that examined delayed face recognition in adults with alcohol-induced amnesias such as Korsakoff's disease (Hochhalter, Sweeney, Bakke, Holub, & Overmier, 2000).

Taken together, these studies with animals, normal children and adults, and learning- and/or memory-challenged children and adults indicate that the DOP acts to facilitate both learning and final accuracy in a conditional discrimination—sometimes very modestly, sometimes dramatically—as well as to improve short-term memory-based performance in humans.

It is worth noting that all the aforementioned studies employed positive reinforcement, a type of reinforcement in which participants received outcomes following their correct responses, to teach the discriminative relationships. However, in daily life reinforcers are also taken away following our incorrect choices. So far, to our knowledge, no study has yet investigated whether the loss of things of value has an effect on differential outcomes discrimination performance.

The present experiments explore this issue of DOE based on loss of value as compared to the usual DOE procedure of gain of rewards. In the

present study children were trained on a conditional discrimination task with two samples and two comparison stimuli using different types of training. The procedure wherein children receive a reinforcer following a correct choice (“+”) was contrasted with the procedure wherein there was the removal of a reinforcer following an incorrect response (“−”) and with a procedure that was a combination of the first two treatments where reinforcers are provided for correct choices and they also are removed for incorrect choices (“+ / −”). These three different types of training were implemented using both the differential (DO) and the common nondifferential (NDO) outcomes methods. It might be that one or more of these types of training better contribute to enhance the effectiveness of the DOP as a technique for facilitating the learning of conditional symbolic relationships.

Until recently, no one had explicitly addressed the issue of whether the DOP might improve memory performance in humans. Hochhalter et al. (2000) observed that patients with alcohol-related amnesia, who had impaired short-term working memory, showed markedly improved face recognition memory at delays of up to 25 seconds between the discriminative stimulus and the choice alternative, when differential outcomes were arranged. This suggests the related possibility that the DOP may well have effects in the execution tasks based on long-term memory. To explore whether the use of this DO procedure may enhance retention and later recall of what has been learned, all participants were also tested after 1 day, 1 week, and 1 month from the discrimination training phase (or learning phase).

## EXPERIMENT 1

In this experiment, we aimed to test the role of different types of reinforcement in the differential outcomes discrimination performances of 5-year-old children using a symbolic delayed matching-to-sample task similar to that used by Maki et al. (1995) and by Estévez et al. (2001, 2003).

## Method

### *Participants*

A total of 91 capable children (38 boys and 53 girls) were recruited from three schools in Almería, Spain: C.E.I.P. Lope de Vega, C.E.I.P. Joaquín Visiedo, and C.E.I.P. José Díaz Díaz. The participants ranged in age from 4 years to 5 years 11 months. Spanish was their native language. A total of 8 of the participants were excluded from the study because of their special educational needs (e.g., a child who had difficulties understanding information).

### *Setting and materials*

Each participant sat next to the experimenter in a quiet room. The stimuli (two samples and two comparison choice stimuli), drawings measuring approximately 5 cm × 5 cm, were presented in black on a white background on a tactile screen (15" Active Matrix TFT-LCD monitor) located on a child-sized table. They were selected from the groups of symbols included in Microsoft Word 95 (see Table 1). Sample stimuli always appeared alone centred on the top half of the screen, and choice alternatives appeared alone on the bottom half of the screen. The two comparisons or choice stimuli were centred equidistant from one another. The E-prime program (Psychology Software Tools, 1999) controlled the presentation of the stimuli as well as collection of the accuracy data. Red and yellow tokens (animated coloured circles that appeared on the screen) were used as immediate secondary reinforcers/feedback. Children were told that when the circle was smiling they had won a token and that they had lost one when the circle was sad (in the last condition an "X" was also superimposed on the circle). Two hedonic outcomes (toys and foods) served as primary reinforcers. Foods consisting of cookies, two kinds of vegetable chips ("triskis" and "gublins balls"), and sweet candies were located in a red bin. Small toy reinforcers including crayons, stickers, masks, and globes were located in a yellow bin. Once the experiment was completed, children exchanged red tokens for food and yellow tokens for toys.

During the training, the bins were located behind the children and out of their immediate sight.

### *Procedure*

Participants were randomly assigned to six groups. Reinforcers were administered following correct responses (type of training "+"), were taken away following incorrect responses (type of training "-"), or both (type of training "+/-"), depending upon the group. In the "-" condition, children were initially provided with a series of reinforcers equal to a number a little larger (28 red tokens and 28 yellow tokens) than the average number of reinforcers they could get if all their responses were correct (24 red tokens and 24 yellow tokens). For three groups, the matching task involved differential outcomes (DO). That is, children received (or lost) a red token following the correct (or incorrect) choice of one comparison stimulus in response to the presentation of one designated sample stimulus and a yellow token following the correct (or incorrect) choice of the other comparison stimulus in response to the presentation of the other sample stimulus. Participants in the nondifferential outcomes (NDO) groups received and/or lost rewards randomly of either red or yellow tokens for correct and/or incorrect choices (see Table 1). The six groups are referred to as D+ ( $N=15$ ), ND+ ( $N=14$ ), D- ( $N=13$ ), ND- ( $N=14$ ), D+/- ( $N=13$ ), and ND+/- ( $N=14$ ).

The experiment consisted of two phases—an initial practice phase and a discrimination training phase—which lasted approximately 5 and 15 minutes, respectively. The initial practice phase ensured the participant's ability to discriminate the to-be-used stimuli. To better understand the reinforcement procedure, in addition to the animated coloured circles that appear on the screen, children received and lost coloured plastic tokens in the trials of this practice phase.

The initial practice phase included four identity trials and eight conditional discriminations trials. On the first identity trial, it was explained that they were going to play a memory game in which they could win and/or lose tokens that could be exchanged later for prizes such as

Table 1. Conditions used in Experiment 1

Outcomes	Stimuli		+ (D+)	- (D-)	+/- (D+/-)	
	Sample	Comparison				
Differential	$\Gamma$	☆	Win a red token	None	Win a red token	
		○	None	Lose a red token	Lose a red token	
	+	☆	None	Lose a yellow token	Lose a yellow token	
		○	Win a yellow token	None	Win a yellow token	
				+ (ND+)	- (ND-)	+/- (ND+/-)
	Nondifferential	$\Gamma$	☆	Win a red or a yellow token	None	Win a red or a yellow token
○			None	Lose a red or a yellow token	Lose a red or a yellow token	
+		☆	None	Lose a red or a yellow token	Lose a red or a yellow token	
		○	Win a red or a yellow token	None	Win a red or a yellow token	

candies (the actual instructions were presented in Spanish). Then, the experimenter showed the child the association between red tokens and food (located in the red bin) and yellow tokens and toys (located in the yellow bin). The child saw a picture of a pencil centred above the midline and two alternative comparison pictures, one of a pencil and the other of a scissors below the midline. Children were instructed to point the sample stimulus (the pencil) and then to the comparison stimuli that went with it (the pencil).

On the first conditional discrimination trial, the participants were told that the game would change a little. The picture on the top on the screen (the sample stimuli; a flower) would not look like either of the two pictures on the bottom of screen (the comparison stimuli; a pencil and a scissors). The experimenter explained that they had to guess which picture (the pencil) was associated with the sample stimulus (the flower) and then to remember which picture went with each

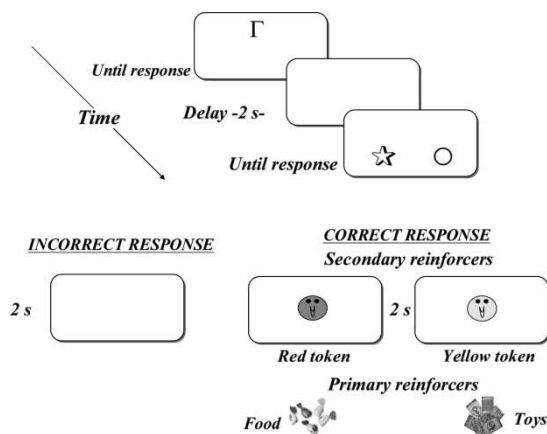
sample. All the participants met the criterion of at least 75% on the pretraining to participate in the experiment.

Delays 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 appeared at the same time. The third and fourth identity trials and the third through fifth conditional discrimination trials incorporated a delay of approximately a second. The last three conditional discrimination practice trials incorporated a delay of approximately 2 s from sample stimulus offset to choice comparison stimuli onset. Thus, for these trials, the sample stimulus was followed by a 2-s blank screen.

Following the initial practice phase, there were 40 conditional discrimination phase trials, randomized in blocks of four trials. There was only

one matching problem; children had to learn that the Greek letter gamma went with the star and that the cross went with the circle (see Table 1). Each sample stimulus appeared twice per block, and correct choice stimuli appeared an equal number of times on the right and left sides. On each trial, the sample stimulus was followed, after an interval of 2 s, by the comparison stimuli, which were presented until a response was made. The participants responded by pointing to the drawing that they thought went with the sample stimulus. The feedback screens were displayed for 2 s, and after an interval of 200 ms the next trial started. Figure 1 shows the sequence of events and the time intervals used in this phase for the “+” condition.

Children were not told in advance that memory for stimulus–response sequences would be tested later. In the memory test phase, three retention intervals were used: For all participants association memory was tested after 1 day, 1 week, and 1 month from the discrimination training phase. The retention test task consisted in four trials (two with each sample stimulus) similar to those used in the conditional discrimination task except that no response outcomes were administered. Thus, the memory task was in extinction so that the 1-week and 1-month retention test tapped the combined effects of extinction and forgetting.



**Figure 1.** Stimuli sequence used in Experiment 1 in the “+” condition. Participants were required to point to the comparison stimulus that went with the sample stimulus.

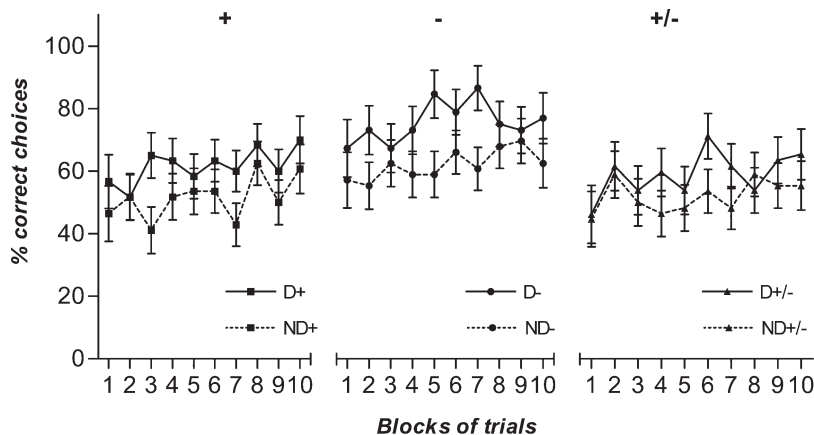
## Results

Percentage of responses to the correct comparison of sample stimuli was calculated every four trials (10 blocks of four trials each) for each participant. Percentages were evaluated with analysis of variance (ANOVA). Rejection criterion was  $p < .05$ .

### Acquisition

Percentages of correct responses from the discrimination training phase were submitted to a mixed ANOVA with type of training (“+”, “−”, and “+/-”) and outcomes (differential and nondifferential) as the between-subjects factors and blocks of trials (1, 2, 3, 4, 5, 6, 7, 8, 9, and 10) as the within-subjects factor. Figure 2 shows the mean percentage of correct choices as a function of outcomes, type of training, and blocks of trials. The main effect of type of training was significant,  $F(2, 77) = 7.20$ ,  $p < .01$ . Fisher’s least significant difference (LSD) comparisons showed significant differences between the “−” (69%) and the other two conditions, “+” and “+/-” (57% and 55% accuracy, respectively;  $p_s < .01$ ). That is, children assigned to the “−” treatment showed better performance than those in the other two conditions (“+” and “+/-”). The results also showed a significant main effect of outcomes,  $F(1, 77) = 10.71$ ,  $p < .01$ , reflecting a clear DOE (65% vs. 55% accuracy in the differential and nondifferential outcomes conditions, respectively). There was also a marginally significant main effect of block of trials,  $F(9, 693) = 1.88$ ,  $p = .051$ . This indicated that performance changed across the different blocks. That is, accuracy typically increased with blocks of trials (53%, 59%, 57%, 59%, 60%, 64%, 60%, 64%, 62%, and 65% accuracy in B1, B2, B3, B4, B5, B6, B7, B8, B9, and B10, respectively). Importantly, the difference between the groups in the first block of trials was not significant (57% vs. 50% accuracy in the differential and non-differential outcomes condition, respectively;  $p_s > .05$ ). There were no significant interactions ( $p_s > .05$ ).

To explore whether the DOE was evident in all the treatments (“+”, “−”, and “+/-”) data from



**Figure 2.** Mean percentages of correct choice responses as a function of type of training (“+”, “-”, and “+/-”), outcomes (differential: D, straight lines; nondifferential: ND, dotted lines), and blocks of trials (10 blocks of four trials each) in Experiment 1. Error bars represent the standard error of the mean.

each group were also analysed separately. Children in groups “+” and “-” showed higher accuracy when differential outcomes were arranged. This effect was statistically significant for group “-”,  $F(1, 25) = 4.43$ ,  $p < .05$ , but marginally significant for group “+”,  $F(1, 27) = 3.64$ ,  $p = .067$ . Although participants in the “+/-” treatment exhibited better overall performance under the differential outcomes condition (59% vs. 52% accuracy, respectively), this difference was not significant ( $p > .05$ ).

### Memory test

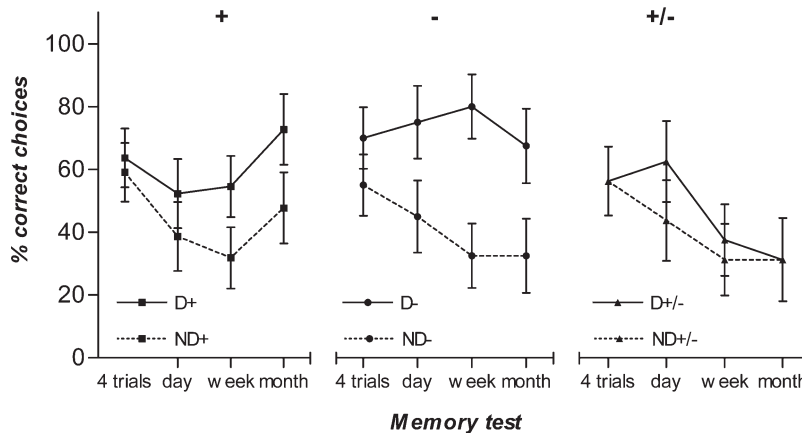
The analysis considered mean percentage of correct responses at the end of the training phase (last four trials). A total of 25 participants did not complete all three memory tests so that they were excluded from the memory analyses. Percentage of correct responses during the last four trials of the training phase and the memory tests as a function of outcomes procedure are presented in Figure 3. These data were submitted to a mixed ANOVA with type of training (“+”, “-”, and “+/-”) and outcomes (differential and nondifferential) as the between-subjects factors and tests (last four discrimination trials, 1 day, 1 week, and 1 month) as the within-subjects factor.

There was a significant main effect of tests,  $F(3, 156) = 2.85$ ,  $p < .05$ . Fisher’s LSD comparisons indicated that children showed a lower performance in the memory tests a week and a month later than in the last four trials (61%, 53%, 45%, and 47%, respectively;  $ps > .05$ ).

With respect to whether memory performance was modulated by training conditions, results across terminal acquisition and the three memory tests revealed significant effect of outcomes,  $F(1, 52) = 12.12$ ,  $p < .001$ . That is, participants in the study typically performed better on the memory tests when differential outcomes had been arranged in acquisition phase (61% vs. 42% accuracy in the differential and nondifferential outcomes condition, respectively). There were no effects of type of reinforcement (“+”, “-”, “+/-”) on memory test or interactions between treatments ( $ps > .05$ ).

Although the Outcomes  $\times$  Type of Reinforcement  $\times$  Block of Trials interaction was not significant ( $p > .05$ ), to determine whether participants in the differential outcomes condition showed higher persistence of learning than those in the nondifferential outcomes condition in all types of training, percentages of correct responses from each group (“+”, “-”, and “+/-”) were also analysed separately. The DOE was evident in groups





**Figure 3.** Mean percentages of correct choice responses as a function of outcomes (differential: D; nondifferential: ND) and memory tests (last four trials, day, week, and month) in Experiment 1. Error bars represent the standard error of the mean.

“+” and “-”,  $F(1, 20) = 5.13$ ,  $p < .05$ , and  $F(1, 18) = 11.85$ ,  $p < .01$ , respectively, but not in group “+/-” ( $F < 1$ ). That is, only participants in the first two groups showed better long-term memory performance when taught with differential outcomes (61% vs. 44% and 74% vs. 41% accuracy for groups “+” and “-” in the differential and nondifferential outcomes conditions, respectively). Children in the group “+/-” performed overall at chance (47% vs. 41% accuracy in the differential and nondifferential outcomes condition, respectively). Finally, there was no effect of outcomes when the last four discrimination trials were analysed for each group ( $p > .05$ ).

## Discussion

This experiment was designated to explore whether different types of reinforcement would have an effect on discriminative performance when differential outcomes are arranged. It was found that the DOE is robust through different types of reinforcement, being found under “+” and “-” types of reinforcement when overall accuracy data were analysed. That is, there were differences among the differential and nondifferential groups in the average number of correct responses obtained in the discrimination phase for these two reinforcement training conditions.

Namely, children showed higher accuracy for the differential outcomes condition than for the nondifferential outcomes condition. However, the effect was not evident when data from the “+/-” group were analysed. We think that the procedure used in this condition was very puzzling for these 5-year-old children. They appeared not to completely understand what the smiling or the sad coloured circles with the “X” superimposed that appeared on the screen following the correct and the incorrect responses meant. It is possible that the DOP may improved the learning and retention of conditional discrimination in this group using a more simple type of training—for example, providing for correct responses and removing for incorrect choices only tangible rewards (primary reinforcers).

When the different types of reinforcement were compared we found significant differences between them. In fact, children performed the discrimination task better in the “-” condition than in the other two conditions (“+” and “+/-”). Thus, participants showed better overall accuracy when they were given a preestablished number of tokens, and that number was reduced following the occurrence of an incorrect response.

Importantly, the results showed that participants in “+” and “-” conditions performed significantly higher on all long-term memory tests

when they were taught with differential outcomes. This finding demonstrates, for the first time, a greater persistence of learning in normal children when differential outcomes are arranged and suggests that the DOP can have an effect not only on the acquisition of learning but also on its long-term retention.

## EXPERIMENT 2

In Experiment 1, as in those from Maki et al. (1995) and from Estévez et al. (2001, 2003; see also Estévez & Fuentes, 2003) children could get or lose coloured tokens (coloured circles that appear on the screen) that they used to “purchase” rewards (primary reinforcers) at the end of the experiment. To date, although primary reinforcers alone have been used in some experiments (e.g., Estévez et al., 2007; Maki et al., 1995), no study has systematically investigated whether the manipulation of the kind of reinforcer used (secondary and primary reinforcers versus primary reinforcers alone) would produce any differences in the discriminative performance observed when the DOP is used.

To explore this issue in Experiment 2 we used primary reinforcers (desired stickers and chocolates) that children could get or lose immediately as a function of the correctness of their choice responses. As in Experiment 1, participants’ learning and memory of the conditional symbolic relationships were tested.

## Method

### *Participants*

A total of 75 capable children (34 boys and 41 girls) were recruited from three schools in Almería, Spain: C.E.I.P. Lope de Vega, C.E.I.P. Joaquín Visedo, and C.E.I.P. José Díaz Díaz. They ranged in age from 4 years to 5 years 11 months, and none had experience with conditioning experiments. A total of 5 of the participants were excluded from the study because of their special educational needs. The apparatus and materials were the same as those in Experiment 1.

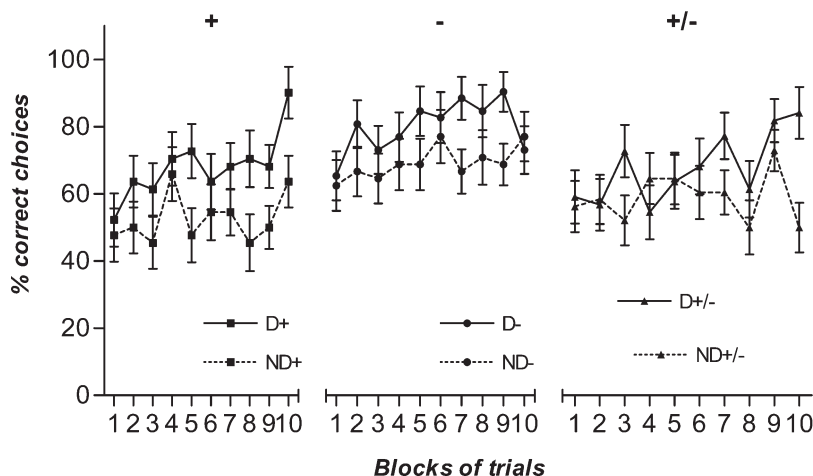
### *Procedure*

Procedure was identical to the one used in Experiment 1, except for what follows. Only primary reinforcers (desired stickers and chocolates) were used as outcomes. Each child had to choose a type of sticker and chocolate before the beginning of the experiment. When correct choices were reinforced (groups D +, ND +, D +/–, and ND +/–), children received either their preferred sticker or their preferred chocolate, which they then placed in the corresponding yellow (for stickers) or red (for chocolates) bowl. The same reinforcers were withdrawn following incorrect responses for groups D –, ND –, D +/–, and ND +/–. As in Experiment 1, participants gave their response touching with a finger within the area of the comparison stimulus. They were also randomly assigned to the six groups: D + ( $N = 11$ ), ND + ( $N = 11$ ), D – ( $N = 13$ ), ND – ( $N = 12$ ), D +/– ( $N = 11$ ), and ND +/– ( $N = 12$ ).

## Results

### *Acquisition*

As in Experiment 1, percentages of correct responses from the discrimination training phase were submitted to a mixed ANOVA with type of training (“+”, “–”, and “+/–”) and outcomes (differential and nondifferential) as the between-subjects factors and blocks of trials (1, 2, 3, 4, 5, 6, 7, 8, 9, and 10) as the within-subjects factor (Figure 4 shows the percentage of correct responses in this phase as a function of outcomes, type of training, and blocks of trials). The main effect of type of training was significant,  $F(2, 64) = 7.24$ ,  $p < .01$ . Fisher’s LSD comparisons showed significant differences between the “–” (75%) and the other two conditions, “+” and “+/–” (60% and 63%, respectively;  $ps < .01$ ). That is, children assigned to the “–” treatment showed better performance than those in the other two conditions (“+” and “+/–”). The results also showed a significant main effects of outcomes,  $F(1, 64) = 13.69$ ,  $p < .00$ , and block of trials,  $F(9, 576) = 3.10$ ,  $p < .01$ . Although performance of the participants in the first block of trials was the same in both outcomes conditions



**Figure 4.** Mean percentages of correct choice responses as a function of type of training (“+”, “-”, and “+/-”), outcomes (differential: D, straight lines; nondifferential: ND, dotted lines), and blocks of trials (10 blocks of four trials each) in Experiment 2. Error bars represent the standard error of the mean.

(59% and 55% accuracy in the differential and nondifferential outcomes conditions, respectively;  $p > .05$ ), average performance was better in the differential outcomes condition (72% vs. 60% accuracy in the differential and nondifferential outcomes conditions, respectively), and overall performances increased with blocks of trials (57%, 63%, 62%, 67%, 67%, 68%, 69%, 64%, 72%, and 73% accuracy in B1, B2, B3, B4, B5, B6, B7, B8, B9, and B10, respectively). There were no significant interactions ( $ps > .05$ ).

Data from groups “+”, “-”, and “+/-” were also analysed separately to explore whether children in the differential outcomes condition exhibited better conditional discrimination performance in each of the three types of training. The DOE was evident in all the treatments. Children in groups “+” and “-” showed higher final accuracy when differential outcomes were arranged,  $F(1, 20) = 11.01$ ,  $p < .01$ , and  $F(1, 23) = 4.86$ ,  $p < .05$ , respectively. The results also showed a significant Outcomes  $\times$  Block of Trials interaction when data from participants in the “+/-” treatment were analysed,  $F(9, 189) = 2.19$ ,  $p < .05$ . Analysis of the interaction revealed a significant main effect of block of trials when the participants in this group received differential outcomes,  $F(9,$

$90) = 2.39$ ,  $p < .05$ , but not when they received nondifferential outcomes ( $p > .05$ ). Data from this group indicated that participants learned the task only when taught with the differential outcomes methodology.

#### Memory test

A total of 24 participants did not complete all three 4-trial memory tests, and they were excluded from the analyses. Data from the final training phase and the memory tests were submitted to a mixed ANOVA with type of training (“+”, “-”, and “+/-”) and outcomes (differential and nondifferential) as the between-subjects factors and tests (last four discrimination trials, and tests at 1 day, 1 week, and 1 month) as the within-subjects factor. Figure 5 shows the mean percentage of correct responses as a function of outcomes.

The main effect of outcomes was significant,  $F(1, 40) = 18.96$ ,  $p < .001$ . That is, the overall performance of children was more accurate in the differential outcomes condition (73% vs. 41% accuracy in the differential and nondifferential outcomes conditions, respectively). The result also revealed a significant main effect of tests,  $F(3, 120) = 5.38$ ,  $p < .01$ . Fisher’s LSD comparisons indicated that children showed poorer

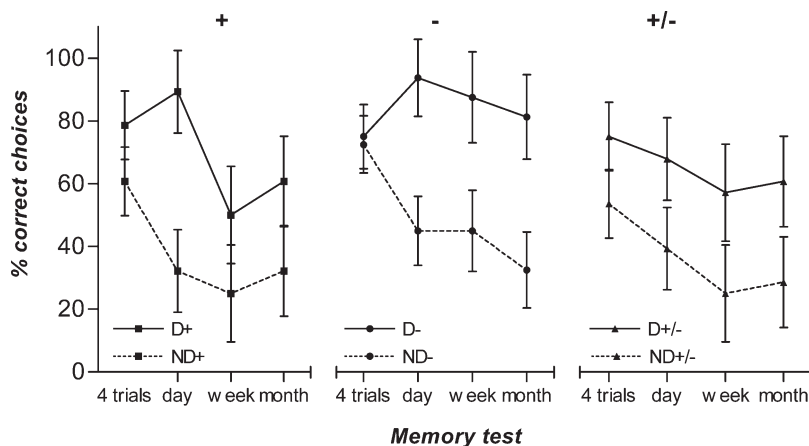


Figure 5. Mean percentages of correct choice responses as a function of outcomes (differential: D; nondifferential: ND) and memory tests (last four trials, day, week, and month) in Experiment 2. Error bars represent the standard error of the mean.

performance in the 1-week and 1-month tests than in the last four acquisition trials (70%, 61%, 48%, and 49%, respectively;  $p_s < .01$ ) and marginally so in the 1-day test ( $p_s = .057$ ). There were no effects of type of reinforcement (“+”, “-”, “+/-”) on memory test or interactions between treatments ( $p_s > .05$ ).

As in Experiment 1 percentages of correct responses from each group (“+”, “-”, and “+/-”) were also analysed separately. The DOE was evident for the three groups,  $F(1, 12) = 5.64$ ,  $p < .05$ ;  $F(1, 16) = 8.20$ ,  $p < .05$ ; and,  $F(1, 12) = 5.74$ ,  $p < .05$ . These data indicated that, in general, participants showed better long-term memory performance when differential outcomes had been arranged in acquisition phase (69% vs. 37%, 80% vs. 69%, and 66% vs. 37% accuracy for groups “+”, “-”, and “+/-” in the differential and nondifferential outcomes conditions, respectively). Importantly, there was no effect of outcomes when the last four discrimination trials were analysed for each group ( $p_s > .05$ ).

## Discussion

The results of Experiment 2 replicate and extend those found in the previous experiment. As in Experiment 1: (a) There was a consistent

advantage in favour of type of training wherein the reinforcers were withdrawn (“-”) over other types wherein reinforcers were given for correct responses (“+”, “+/-”). (b) the DOE was observed under the reinforcement training conditions “+” and “-”. Importantly, unlike Experiment 1, participants in group D+/- performed the discrimination task significantly better than those in the nondifferential outcomes condition. Our interpretation of this results is that the potential confound of using happy and sad coloured circles (secondary reinforcers) that 5-year-old children could get following their correct responses and lose following their incorrect choices and that they used to purchase primary reinforcers rather than the “+/-” strategy of reinforcement per se was responsible for the lack of effect observed in this condition in Experiment 1. (c) Long-term persistence of learning was improved when discriminative training involved differential outcomes. These findings indicate that the DOP acts both to facilitate overall accuracy in a symbolic conditional discrimination and to improve long-term memory performance in children for all types of reinforcers (secondary plus primary or only primary) or the way the reinforcers are administered (“+”, “-”, or “+/-”).

## GENERAL DISCUSSION

The effectiveness of DOP has received considerable empirical support mainly from animal studies (for a review, see Goeters et al., 1992). In comparison with the research available on the DOP in animals, the value of this procedure in human discriminative learning and memory has received relatively limited empirical support. In the present study we separately evaluated the individual effects of DOP (a procedure in which usually the correct choices that follow each discriminating stimulus elicit different rewards) and different types of reinforcement on the discriminative learning and memory of 5-year-old children using secondary and primary reinforcers (Experiment 1) versus primary reinforcers alone (Experiment 2). In both experiments the DOE was observed, replicating the results obtained by Maki et al. (1995) and by Estévez et al. (2001) and providing a clear confirmation that the DOP is useful as a tool to enhance discriminative learning in children. Importantly, the results showed that the DOE was obtained for three different ways of providing reinforcement—when reinforcers are given when correct choices are made (Experiments 1 and 2), when reinforcers are withdrawn when errors are made (Experiments 1 and 2), and when correct response earn reinforcers, and errors lose reinforcers (Experiment 2).

One surprising important observation in this study is that although all the three reinforcement training conditions were effective in 5-year-old children's discriminative learning, the “–” training in which errors lost rewards improved conditional discriminative performance to a significant greater extent than did the other two procedures (“+” and “+/-” conditions), whether or not participants received differential or nondifferential outcomes. In clinical psychology, the contingent withdrawal of potentially reinforcing items such as free time, tokens, points, and so on has been classified as “response cost” (Kazdin, 1972; Kazdin & Bootzin, 1972; McLaughlin & Scott, 1976). This system, free of many of the negative side effects of punishment, has been employed as a procedure to control a variety of inappropriate

behaviours in classroom settings (Iwata & Bailey, 1974; Kazdin, 1972; McCain & Kelley, 1994). Some studies have demonstrated that token reinforcement (positive reinforcement) and response cost is a more effective package to increase academic behaviour than token reinforcement alone (McLaughlin & Malaby, 1977; Truchlicka, McLaughlin, & Swain, 1998). However, in our study children did not show any advantage of condition “+/-” compared to condition “+” (Experiment 2). In addition, Experiment 1 showed that condition “–” produced better performance than both “+” and “+/-” conditions. This latter result might be accounted for in terms of increased participant's motivation to correctly accomplish the task, and, therefore, they paid more attention to it. It also might be that the benefit of using the type of reinforcement “–” was limited to this early stage of development and that such advantage disappeared in older children. This issue is currently a matter of further research in our laboratory. Another interesting question refers to which of these reinforcement training conditions children liked the best. Since in the present experiments data on child preferences were not gathered, studies that examine how well the participants like the various treatments and whether this factor may contribute to the differential outcomes performance are needed.

The results of great theoretical and practical interest here are those from memory tests. Most theoretical considerations of the DOE have invoked expectancy theory (Trapold & Overmier, 1972). 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 expectancies, which are conditioned to the discriminative stimuli, can then, in turn, provide an additional discriminative cue for responding. Recently, in an interesting extension of this theory, Savage (2001) proposed that the DOP results in the utilization of a different type of memory process (implicit like strategies; e.g., expectancies) relative to the standard or nondifferential procedure (related to explicit type events;

e.g., remembrance of the sample). As Savage, Pitkin, and Careri (1999) indicated, the memory processes activated by the DOP is less disrupted by increasing delay interval and appears to be more tolerant of some types of brain dysfunction. The effect of this procedure in the memory tests used in our study can be accounted for by the fact that these implicit (or prospective) memories that are specific to the rewards appear to have also a greater persistence than those explicit (or retrospective) memories (the only source of information afforded by the nondifferential outcomes procedure; Overmier, Savage, & Sweeney, 1999). However, other mechanisms could also underlie or contribute to the DOE observed in the memory tests. For instance, it might be that the differential outcomes procedure enhanced the encoding of the sample–comparison associations involved in the discriminative task during training. This better encoding could, in turn, improve memory performance. Alternatively, the presence of the sample stimuli at the time of the memory tests could act as a cue that would activate the differential outcome expectancies, facilitating memory performance. Further research is needed to investigate the mechanisms involved in the observed memory benefits under differential outcomes conditions.

In summary, we can conclude that the differential outcomes procedure—however implemented—produces an improvement in overall accuracy and persistence of learning in 5-year-old children. The last finding is very important because it is the first time that it has been observed that the DOP improves the execution of a long-term-memory-based task in children. Very recently, Romero, Vila, and Overmier (2008) and Motos, Estévez, Martínez, and Fuentes (2008) have observed a greater learning retention in the presence of a DOP in normally functioning adults (university students). The results from these two studies taken together, with the results from the two experiments in the present article, demonstrate that although the DOP effects appear to occur during acquisition, they have also effects in later processing stages such as in some later memory stage. The present findings strongly

suggest that differential outcomes generally can be a technique to facilitate long-term-memory-based performance in human beings. Further investigation is needed to test the potential applied use of this procedure as aid to memory especially in people with memory impairments.

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