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Abstract Researchers have demonstrated that discriminative learning is facilitated when a particular outcome is associated with each relation to be learned. Our primary purpose in the two experiments reported here was to assess whether the differential outcomes procedure (DOP) would enhance 7-year-old children's learning of symbolic discriminations using three different forms of consequences in which (1) reinforcers are given when correct choices are made ("+"), (2) reinforcers are withdrawn when errors are made ("−"), or (3) children receive a reinforcer following a correct choice and lose one following an incorrect choice ("+/−"), as well as different types of reinforcers (secondary and primary reinforcers, Experiment 1; primary reinforcers alone, Experiment 2). Participants learned the task faster and showed significantly better performance whenever differential outcomes were arranged independently of (1) the way of providing consequences (+, −, or +/−) and (2) the type of reinforcers being used. Interestingly, as in a previous study with 5-year-old children (Martínez, Estévez, Fuentes, & Overmier, The Quarterly Journal of Experimental Psychology 62(8):1617–1630, 2009), the use of the DOP also enhanced long-term persistence of learning.

Keywords Differential outcomes procedure · Types of consequential stimuli · Discriminative learning · 7-year-old children

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Introduction

The differential outcomes effect (DOE) refers specifically to the increase in speed of acquisition or terminal accuracy that occurs in a conditional discrimination training when each discriminative stimulus–response sequence is always followed by a particular outcome. In 1970, Trapold provided an early demonstration of this phenomenon. He exposed a group of rats to a discrimination problem that required a response to one lever (e.g., the right lever) in the presence of one stimulus (e.g., a tone), and a response to a second lever (e.g., the left lever) in the presence of another stimulus (e.g., a click). 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, pellets.

The DOE has been widely demostrated with animals, especially with rats and pigeons, and with different types of reinforcers (for reviews, see Goeters, Blakely, & Poling, 1992; Urcuioli, 2005). By contrast, the number of studies exploring the differential outcomes procedure (DOP) in humans is still relatively limited. Shepp (1962, 1964) was one of the first authors to suggest a possible positive effect of the DOP on human learning. Subsequently, four studies that explored the acquisition of two-choice conditional discriminations found the DOE in children with autism (Litt & Schreibman, 1981) and in children and adults with developmental disabilities (Malanga & Poling, 1992; Saunders & Sailor, 1979; Shepp, 1962). Since these early studies, research has developed in two major directions: one focusing on the usefulness of the differential outcomes methodology in improving discriminative learning, another focusing on the role of this procedure in human memory. Although the DOP has been shown to improve memory-based performance in animals (e.g., Brodigan

& Peterson, 1976; DeMarse & Urcuioli, 1994; Savage & Langlais, 1995; Savage, Pitkin, & Careri, 1999), very few studies have explored this issue in humans. Hochhalter, Sweeney, Bakke, Holub, and Overmier (2000) demonstrated, for the first time, that specific outcomes improved recognition memory in people with memory problems. In fact, they found that three patients with alcohol-induced amnesia showed significantly better delayed face recognition when differential outcomes were arranged. Later on, the potential of the DOP for aiding human memory has also been evident in four studies conducted with young people (Martella, Plaza, Estévez, & Fuentes, 2012; Plaza, Estévez, López-Crespo, & Fuentes, 2011), with older adults (López-Crespo, Plaza, Fuentes, & Estévez, 2009), and with Alzheimer's disease patients (Plaza, López-Crespo, Antúnez, Fuentes, & Estévez, 2012). In these studies, delayed face recognition performance of participants was improved by pairing each correct response with a specific outcome.

Regarding discriminative learning, several studies have demonstrated the effectiveness of the DOP in facilitating the acquisition of conditional symbolic discriminations across different populations, such as children and adults without developmental disabilities (e.g., Estévez & Fuentes, 2003; Estévez, Fuentes, Marí-Beffa, Gónzalez, & Álvarez, 2001; Estévez et al., 2007; Maki, Overmier, Delos, & Gutman, 1995; Miller, Waugh, & Chambers, 2002; Mok & Overmier, 2007; Mok, Thomas, Lungu, & Overmier, 2009), adults with Prader–Willi syndrome (Joseph, Overmier, & Thompson, 1997), and children and adults with Down's syndrome (Estévez, Fuentes, Overmier, & González, 2003).

It is worth noting that in all the aforementioned studies, the differential outcomes condition always involved particular consequences that followed the correct responses. That is, participants were always rewarded for correct choices (positive reinforcement). However, very often, in our daily life, the consequence of a particular choice implies the withdrawal of a reinforcer (response cost). Recently, Martínez, Estévez, Fuentes, and Overmier (2009) explicitly addressed the issue of whether these two types of consequential stimuli (the gain of rewards and the loss of things of value) would have an effect on discriminative performance when differential outcomes are arranged. The results showed a robust DOE that was independent of the consequential training conditions. That is, 5-year-old children performed the task better in the differential outcomes condition for the three different forms of consequences (differential gain, loss, or combination; reinforcers are given following correct responses, and they are withdrawn when errors are made). The DOE was also independent of whether secondary and primary reinforcers versus primary reinforcers alone were used. Surprisingly, participants showed higher discriminative performance when they lost a reinforcer following an incorrect choice, and more important, a greater persistence of learning was observed when differential outcomes were arranged. It might be that this pattern of results was specific to this early stage of development and that the advantage of the response cost training or the memory benefits observed under differential outcomes conditions disappeared in older children. To further explore this issue, in the present study, our aim was to assess whether the differential outcomes procedure would produce an enhancement in 7-year-old children's learning and memory of a symbolic delayed matching-to-sample task when different types of consequences and reinforcers were used.

Experiment 1

In this experiment, we explored the potential advantage of the DOP in 7-year-old children's learning and memory using different types of consequential stimuli and secondary and primary reinforcers. Given that, as we have already shown, the DOE is not observed when the task is very simple (e.g., Estévez et al., 2001, 2007; Plaza et al., 2011), we decided to increase the difficulty of the discriminative learning task used by Martínez et al. (2009) by presenting four comparison stimuli instead of two (for a similar task, see Estévez et al., 2001, Experiment 2).

Method

Participants

Fifty-two typically developing children (28 boys and 24 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. The participants ranged in age from 7 years to 7 years and 11 months.

Setting and materials

Each participant sat next to the experimenter in a quiet room. The stimuli (two samples and four comparison choice stimuli; see Table 1), drawings measuring approximately 5 × 5 cm, were presented in black on a white background on a tactile screen (15-in. Active Matrix TFT-LCD monitor) located on a child-sized table. The experimental task was created using the E-Prime program (Psychology Software Tools, 1999). The stimulus display consisted of a sample stimulus centered on the top half of the screen and four comparison stimuli positioned equidistant from one another in the corners of a virtual square with its center on the center of the screen. The position of these stimuli on the virtual square was randomly arranged. Blue and green tokens (animated colored circles that appeared on the screen) were used as immediate secondary reinforcers. Children were told

Table 1 Conditions used in Experiment 1

		Differential Outcomes		
Sample stimuli	**Comparison stimuli**	**+ (D+)**	**- (D-)**	**+/- (D+/-)**
		Win a blue token	None	Win a blue token
		None	Lose a blue token	Lose a blue token
		None	Lose a green token	Lose a green token
		Win a green token	None	Win a green token
		Non-differential Outcomes		
Sample stimuli	**Comparison stimuli**	**+ (ND+)**	**- (ND-)**	**+/- (ND+/-)**
		Win a blue or a green token	None	Win a blue or a green token
		None	Lose a blue or a green token	Lose a blue or a green token
		None	Lose a blue or a green token	Lose a blue or a green token
		Win a blue or a green token	None	Win a blue or a green token

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. Once the experiment was completed, children exchanged blue tokens for food (cookies, vegetable chips, and sweet candies) and green tokens for toys (crayons, pens, and stickers). They could choose their most preferred items from a group of popular food and toys in this age group.

Procedure

The procedure was identical to that used by Martinez et al. (2009). There were six groups according to type of consequential stimuli ("+", "−," or "+/−") and outcomes (differential or nondifferential). The six groups are referred to as D+ ($n = 9$), ND+ ($n = 8$), D− ($n = 10$), ND− ($n = 7$), D+/− ($n = 9$), and ND+/− ($n = 9$). Participants were assigned randomly to one of these experimental treatments. For three groups, the task involved differential outcomes; that is, children received (or lost) a specific outcome associated with a particular conditional (sample stimulus–choice) relation. Participants in the nondifferential outcomes (ND) groups received and/or lost rewards randomly of either blue or green tokens for correct and/or incorrect choices (see Table 1).

Each child participated in a single training session lasting approximately 20 min. They were tested individually in a quiet room free from distraction at their schools. In this phase, participants performed a delayed matching-to-sample task that consisted of 52 trials. The task began with 12 practice trials (4 identity matching trials and 8 conditional discrimination trials) that familiarized participants with the matching game. On the first identity trial, the child saw a picture of a pencil centered on the top half of the screen and two alternative comparison pictures, one of a pencil and the other of a pair of scissors, that appeared on the bottom half of the screen. The experimenter explained that they were to play a memory game in which they had to guess which picture was associated with the sample stimulus. Then participants were instructed to point to the sample stimulus (the pencil) and to the choice alternative that "went with" the sample (the pencil). As a function of experimental treatment, children were told that they would (1) win a blue or a green token following a correct response (it was not explained how the rewards were assigned), (2) lose a blue or a green token following an incorrect choice, or (3) both (they would receive a token following a correct choice and lose one following an incorrect choice). To better understand the consequential procedure, in addition to the animated colored circles that appeared on the screen, children received and lost colored plastic tokens on the trials of this practice phase. 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). On the first conditional discrimination trial, the participants were told that the game would change a little. The sample stimulus (a flower) would not look like either of the two comparison stimuli (a pencil and a scissor). They had to guess which picture (the pencil) was associated with the sample stimulus (the flower) and then remember which picture went with each sample stimulus. The third and fourth identity trials and the third through fifth conditional discrimination trials incorporated a delay of approximately a second between the sample and the comparison stimuli (this delay increased until 2 s for the last three conditional discrimination practice trials). All participants met the criterion of at least 75 % on the pretraining phase to participate in the experiment showing a similar overall performance in this phase.

Forty conditional discrimination trials, randomized in blocks of four trials, followed the practice phase. In this phase, there were two sample stimuli and four choice alternatives, of which two were distractors; these stimuli were novel and different from those used in the pretraining phase. The correct choice was an arbitrary, symbolic match to the particular sample stimulus presented. On each trial, a sample stimulus appeared on the top center of the screen until a response was made (the child had to point to it) (see Fig. 1). Following a delay of 2 s during which the screen was blank, four comparison stimuli appeared on each corner of the screen. Participants were instructed to choose the drawing that they thought went with the sample stimulus they had seen previously. They had to guess which one was associated with the sample stimulus and then remember which comparison went with each sample stimulus. Children were also informed that a memory test would be administered later. The feedback screens were displayed for 2 s, and after an interval of 200 ms, the next trial started. At the end of this session, children exchanged blue tokens for food and green tokens for toys. Although the better they performed the task, the more primary reinforcers they obtained, each child received at least two hedonic outcomes (one food and one toy).

All participants completed a memory task at three different time points: 1 day, 1 week, and 1 month after completing the discrimination-training phase (or learning phase). This task was also conducted in the schools, in the same room as that used during the training session. As in the previous study (Martínez et al., 2009), the memory task consisted of four trials (two with each sample stimulus) similar to those used in the conditional discrimination task, except that no response outcomes were administered. Participants were asked to remember the relations that had been learned recently.

Results

Percentages of correct responses from the discrimination-training phase were calculated every four trials (10 blocks of four trials each) for each participant. The resulting data 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. Where necessary, post hoc comparisons were calculated by Fisher's LSD tests. The significance level was set at $p \leq .05$.

Acquisition

Figure 2 shows the mean percentage of correct choices as a function of outcomes, type of training, and blocks of trials. The analyses revealed significant main effects of outcomes and block of trials, $F(1, 46) = 14.46$, $p < .001$, $\eta_p^2 = .24$, and $F(9, 414) = 10.85$, $p < .001$, $\eta_p^2 = .19$, respectively. Children performed the task better in the differential than in the nondifferential outcomes condition (73 % vs. 54 %, respectively), and accuracy typically increased with blocks of trials (40 %, 51 %, 58 %, 63 %, 65 %, 69 %, 72 %, 70 %, 73 %, and 73 % in B1, B2, B3, B4, B5, B6, B7, B8, B9, and B10, respectively). It is also worth noting that although the difference between both conditions (differential vs. nondifferential) was significant in the first block of trials, $F(1, 46) = 15.26$, $p < .001$, $\eta_p^2 = .25$, no differences between children were found in the first two trials or the first trial (Fs < 1). No other effects or interactions reached statistical significance (ps > .05).

To explore whether the DOE was evident in all types of training ("+," "−," and "+/−"), data from each training group were also analyzed separately. In general, children from the three types of training showed higher accuracy when

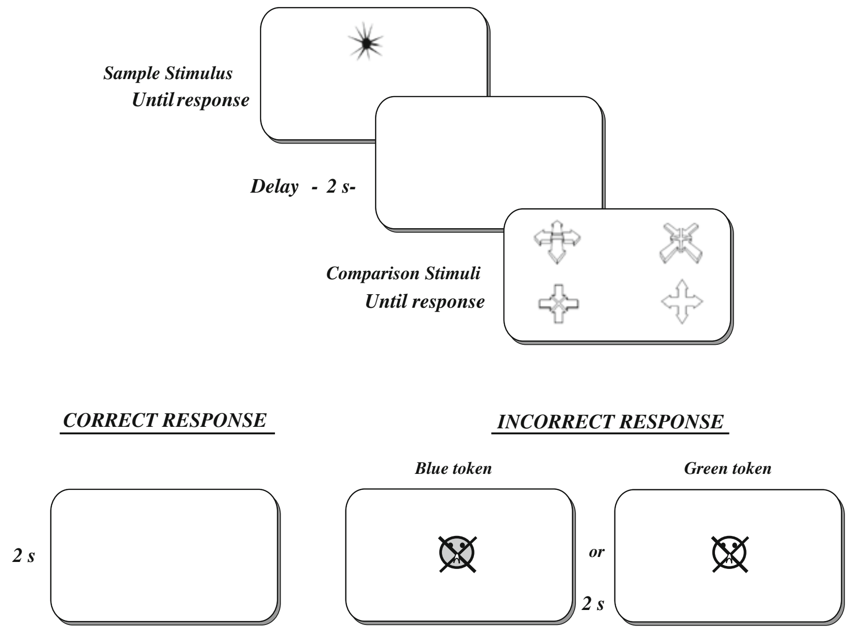

Fig. 1 Stimuli sequence (from left to right) used in Experiment 1 in the "–" condition

differential outcomes were arranged (78 % vs. 58 %, 72 % vs. 53 %, and 68 % vs. 56 % accuracy for groups "+," "–," and "+/–" in the differential and nondifferential outcomes conditions, respectively). This DOE was statistically significant for group "+," $F(1, 15) = 5.02$, $p < .05$, $\eta_p^2 = .25$, and group "–," $F(1, 15) = 5.87$, $p < .05$, $\eta_p^2 = .28$, and approached significance for group "+/–," $F(1, 16) = 3.91$, $p = .065$, $\eta_p^2 = .20$.

Memory test

Nine participants did not complete all three memory tests, and thus they were excluded from the memory analyses. Percentages of correct responses during the last four acquisition trials and those observed in the memory tests as a function of the outcomes procedure are presented in Fig. 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 test (last four discrimination trials, 1 day, 1 week, and 1 month) as the within-subjects factor.

There was a significant main effect of test, $F(3, 111) = 2.90$, $p < .05$, $\eta_p^2 = .07$. Performance decreased from the last four acquisition trials (76 %) to the different delays of testing (75 %, 71 %, and 60 %, for 1 day, 1 week, and 1 month, respectively), although differences were significant only between 1-month delay and both four last trials and 1-day delay (*p*s < .05). Importantly, there was also a significant effect of outcomes, $F(1, 37) = 14.87$, $p < .001$, $\eta_p^2 = .29$, indicating that participants in the study typically performed better on the memory tests when differential outcomes had been arranged during the acquisition phase (85 % vs. 56 % accuracy in the differential and nondifferential outcomes condition, respectively). Although the outcomes × test interaction was not significant

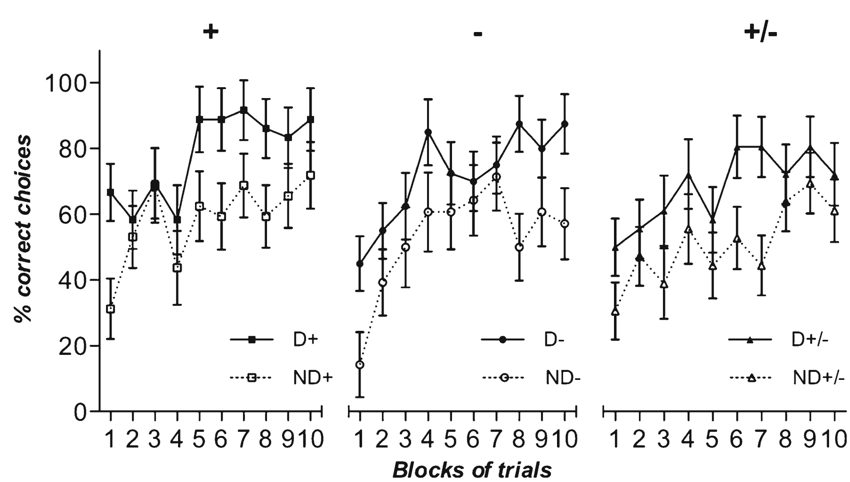

Fig. 2 Mean percentages of correct choice responses as a function of type of training ("+," "–," and "+/–"), outcomes (differential, –straight lines; nondifferential, dotted lines) and blocks of trials (10 blocks of four trials each) in Experiment 1. Error bars represent the standard errors of the means

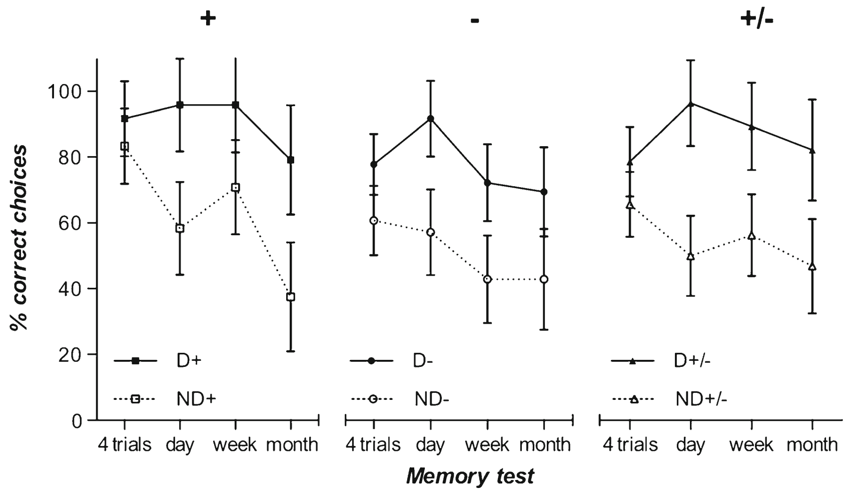

Fig. 3 Mean percentages of correct choice responses as a function of outcomes (differential, D; nondifferential, ND) and memory tests (last four trials, day, week, and month) in Experiment 1. Error bars represent the standard errors of the means

($p > .05$) a trend analysis for the two outcomes conditions revealed a significant linear trend for the nondifferential outcomes treatment, $F(1, 20) = 5.92$, $p < .05$, $\eta_p^2 = .23$, but not for the differential outcomes condition ($F < 1$). In fact, children showed significant lower performance only in the 1-month memory test, as compared with the last four acquisition trials, when nondifferential outcomes were arranged ($p < .05$). No other effects, nor their interactions, reached statistical significance (ps > .05).

Finally, the DOE was evident in all groups ("+," "−," and "+/−") when percentages of correct responses from each training group were analyzed separately, $F(1, 10) = 6.94$, $p < .05$, $\eta_p^2 = .41$, $F(1, 14) = 4.66$, $p < .05$, $\eta_p^2 = .25$, and $F(1, 13) = 4.94$, $p < .05$, $\eta_p^2 = .28$, respectively. That is, participants showed better long-term memory performance when trained with differential outcomes (90 % vs. 62 %, 78 % vs. 51 %, and 86 % vs. 54 % 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 analyzed for each group (ps > .05); the same result was found when data were pooled across groups ($F < 1$).

Discussion

The main aim of this experiment was to explore whether different forms of consequences might modulate the effect that the differential outcomes procedure was expected to have on discriminative learning in 7-year-old children. Results showed that the use of differential outcomes after correct responses improved the task performance regardless of the type of training used ("+," "−," "+/−"). In addition, the DOP affected, similar to previous research with 5-year-old children (Martínez et al., 2009), not only learning, but also the retention of what had been learned. That is, the recall of symbolic relationships was better when differential outcomes were arranged during training, although participants showed a similar learning level on the last four training trials. It is worth noting that while a decline in memory performance was evident in 5-year-old children from the first memory test, participants in the present study showed a significant impairment only when performing the memory test 1 month after the training under nondifferential outcomes. Another difference found with regard to the results reported by Martínez et al. (2009) indicates that the type of training used did not influence the 7-year-old children's discriminative performance. In other words, children learned equally in the three following conditions: when they lost reinforcers, following incorrect responses; when they earned reinforcers, following correct responses; or when both contingencies were arranged (they could earn or lose reinforcers on the basis of their responses).

As Martínez et al. (2009) indicated, the type of reinforcer used (primary and secondary vs. only primary) might have an influence on the efficacy of the DOP as a tool to improve discriminative learning. A second experiment was carried out to explore this issue. A procedure similar to that used in Experiment 1 was employed, except that, in this case, children could only earn or lose primary reinforcers following their responses.

Experiment 2

Method

Participants

Forty-six typically developing children (21 boys and 25 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 7 years to 7 years and 11 months, and none had experience with conditioning experiments. The apparatus and materials were the same as those in Experiment 1.

Procedure

The procedure was identical to that used in Experiment 1, except that in the present experiment, 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 (group + or +/−), the experimenter gave a sticker or a piece of chocolate to the child, which they then placed in the corresponding yellow (for stickers) or red (for chocolates) bowl. As in the previous experiment, children were also randomly assigned to the six groups: D+ (n = 7), ND+ (n = 9), D− (n = 7), ND− (n = 8), D+/− (n = 7), and ND+/− (n = 8).

Results

Acquisition

Figure 4 shows the mean percentage of correct responses in this phase as a function of outcomes, type of training, and blocks of trials.

As in Experiment 1, the main effects of outcomes and blocks of trials were significant, $F(1, 40) = 17.70$, $p < .001$, $\eta_p^2 = .31$. These data indicate that children's discriminative performance was better when differential outcomes were arranged (83 % vs. 63 % accuracy, respectively) and that percentage of correct responses increased with blocks of trials (44 %, 60 %, 65 %, 75 %, 78 %, 75 %, 84 %, 85 %, 83 %, and 82 % accuracy in B1, B2, B3, B4, B5, B6, B7, B8, B9, and B10, respectively). Importantly, the performance of children in the first block of trials, as well as on the first trial, was not different (Fs < 1). No other effects, nor their interactions, reached statistical significance (ps > .05).

Data from each training group were also analyzed separately. The DOE was evident in all the three types of training (81 % vs. 51 %, 84 % vs. 69 %, and 84 % vs. 70 % accuracy for groups "+," "−," and "+/−" in the differential and nondifferential outcomes conditions, respectively), $F(1, 14) = 9.30$, $p < .01$, $\eta_p^2 = .40$, $F(1, 13) = 4.32$, $p = .058$, $\eta_p^2 = .25$, and $F(1, 13) = 4.63$, $p = .051$, $\eta_p^2 = .26$, respectively.

Memory test

Eleven participants did not complete all three 4-trial memory tests, and they were excluded from the analyses. Figure 5 shows the mean percentage of correct responses during the last four acquisition trials and the memory tests as a function of outcomes.

The main effect of outcomes was significant, $F(1, 29) = 18.68$, $p < .001$, $\eta_p^2 = .39$. That is, participants showed a better retention of conditional discriminations learned when trained with differential outcomes (94 % vs. 69 % accuracy in the differential and nondifferential outcomes conditions, respectively). The results also revealed a significant main effect of test, $F(3, 87) = 4.48$, $p < .01$, $\eta_p^2 = .13$. Performance significantly decreased from the last four acquisition trials (76 %) and delays of 1 day (90 %) and 1 week (81 %) to 1 month (69 %)(all ps < .05). Although the outcomes × test interaction only approached significance, $F(3, 87) = 2.25$, $p = .088$, $\eta_p^2 = .07$, a trend analysis showed a significant interaction of both factors in the linear component, $F(1, 29) = 6.89$, $p < .05$, $\eta_p^2 = .19$. The analyses of the interaction revealed a declining trend for the nondifferential outcomes treatment, $F(1, 16) = 13.16$, $p < .01$, $\eta_p^2 = .45$, but not for the differential outcomes (F < 1). Performance was similar in all the memory tests under differential outcomes (ps > .05). By contrast, children showed a lower accuracy in the 1-month delay as compared with the last four acquisition trials and the 1-day delay memory test when nondifferential outcomes were arranged (all ps < .05). Thus, the differential outcomes training enhanced memory persistence. No other effects or interactions reached significance (ps > .05).

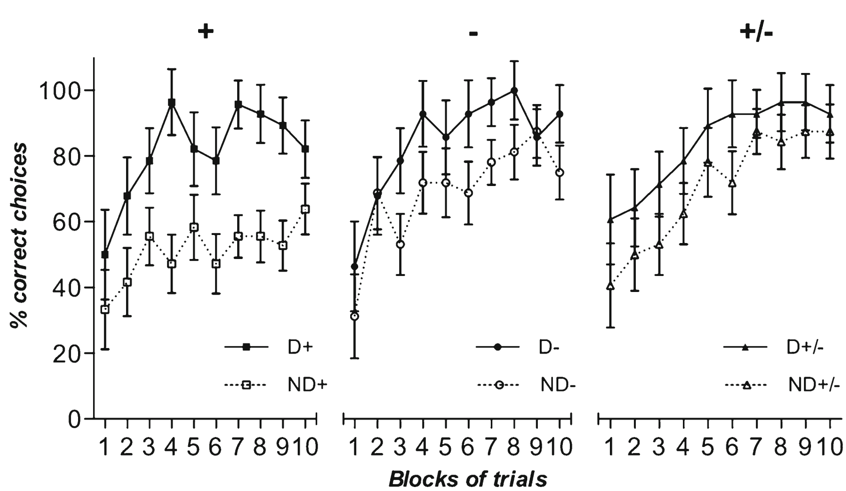

Fig. 4 Mean percentages of correct choice responses as a function of type of training ("+," "−," and "+/−"), outcomes (differential, straight lines; nondifferential, dotted lines) and blocks of trials (10 blocks of four trials each) in Experiment 2. Error bars represent the standard errors of the means

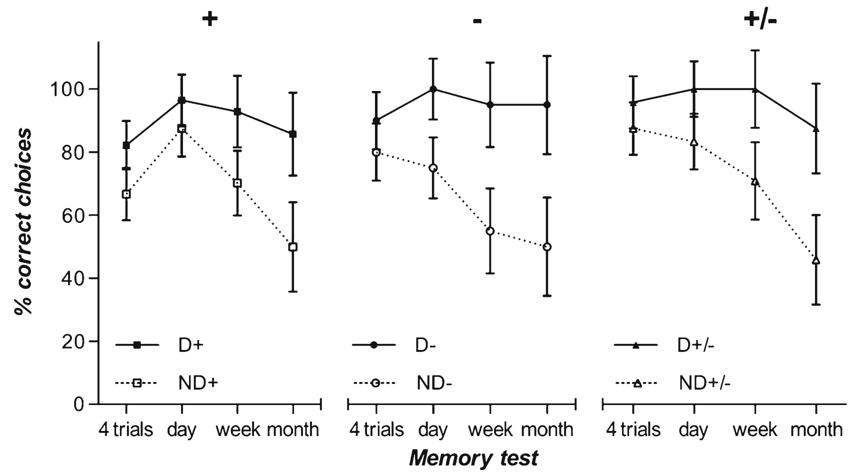

Fig. 5 Mean percentages of correct choice responses as a function of outcomes (differential, D; nondifferential, ND) and memory tests (last four trials, day, week, and month) in Experiment 2. Error bars represent the standard errors of the means

As in Experiment 1, percentages of correct responses from each training group ("+," "−," and "+/−") were also analyzed separately. The analysis showed that children performed significantly better on the memory tests under differential outcomes conditions in groups "−" and "+/−," $F(1, 8) = 8.28$, $p < .05$, $\eta_p^2 = .51$, and $F(1, 10) = 6.22$, $p < .05$, $\eta_p^2 = .38$, respectively, and marginally so in group "+," $F(1, 11) = 4.39$, $p = .060$, $\eta_p^2 = .29$ (89 % vs. 69 %, 96 % vs. 65 %, and 96 % vs. 72 % accuracy for groups "+," "−," and "+/−" in the differential and nondifferential outcomes conditions, respectively). Also, there was no effect of outcomes when the last four acquisition trials were analyzed for each group ($ps > .05$), as well as when data were pooled across groups ($F < 1$).

Discussion

The results obtained are similar to those from the previous experiment: (1) Participants showed better discriminative performance under the differential outcomes conditions; (2) the type of training did not affect the DOE, while an effect of similar magnitude was observed in the three consequential conditions (+, −, and +/−); and (3) children exhibited a similar overall performance under the three types of training used. Thus, these findings, along with those from Experiment 1, indicate that the use of primary reinforcers alone have no influence on the efficacy of the DOP as a tool to improve 7-year-old children's learning and memory. However, it is also worth noting that results showed a slight advantage of primary reinforcers alone (Experiment 2) over primary and secondary reinforcers conditions (Experiment 1) for both acquisition and memory performance (63 % vs. 73 % and 70 % vs. 81 % overall accuracy for both experiments in each phase).[1] This finding might be accounted for in terms of increased participants' motivation to correctly accomplish the task when only primary reinforcers are used.

[1] These differences were statistically significant, $F(1, 86) = 8.16$, $p < .01$, $\eta_p^2 = .087$, and $F(1, 66) = 4.65$, $p < .05$, $\eta_p^2 = .066$, for the acquisition and memory test phases, respectively.

General discussion

In a previous study, Martínez et al. (2009) found that 5-year-old children learned a symbolic discrimination task faster and showed a higher persistence of learning whenever differential outcomes were used, regardless of the type of reinforcers used (secondary plus primary or primary alone), or the different forms of consequences (children receive a reinforcer following a correct choice; a reinforcer was removed after an incorrect choice; or the combination of both). It was also observed that children who received the "−" treatment type obtained a higher percentage of correct responses than did those in the other two consequential training conditions. Maybe this pattern of results could be different in older children. The present study was conducted to investigate that issue and to continue exploring in which conditions the DOP is effective. The results of both experiments replicate and extend those found in the previous study: The differential outcomes training improved discriminative learning and long-term memory performance in 7-year-old children. This significant DOE was observed under the three consequential-training conditions and with all the different types of reinforcers used.

In contrast to the study of Martínez et al. (2009), in the present study, the three types of training were equally effective. The finding that 5-year-old children have a better performance when a *response cost* procedure is used (the contingent withdrawal of reinforcers; for similar results, see Conyers et al., 2004) may result from children at this age being more sensitive to a reinforcement withdrawal than are 7-year-old children, because they probably have not developed strategies and skills to handle the frustration generated by the loss of something they already possess—the secondary or primary reinforcer, in this case. We may hypothesize that the withdrawal of reinforcers and, subsequently, the anticipation of frustration, which they are unable to regulate (maybe due to a lower maturation of the frontal lobes observed at this age; e.g., Lewis, Lamm, Segalowith, Stieben, & Zelazo, 2006; Posner & Rothbart, 2009), increased arousal, improving the overall accuracy of 5-year-old children in both conditions (differential and nondifferential). Accordingly, previous studies have demonstrated that higher arousal levels are correlated with a better performance of different tasks (e.g., Walters & Parke, 1964). By contrast, the more effective regulation of emotions reached at age 7 (maybe due to a higher maturation of the frontal lobes, a process that continues throughout adolescence) might make it unnecessary to activate other processes to cope with the anticipated negative emotions triggered by the withdrawals of reinforcers. It also might be that the withdrawal of reinforcers did not function as a response cost procedure for the 7-year-old children. More research is needed to explore this issue.

Importantly, the DOP was also effective in enhancing long-term memory of what had been learned during the training phase. To our knowledge, this is the first time that such an effect has been reported in 7-year-old children. Some recent studies have shown that the DOP is effective in improving memory-based performance after short delays in normal aging, in young people, and in patients with alcohol-related amnesia and Alzheimer's disease (Hochhalter et al., 2000; López-Crespo et al., 2009; Martella et al., 2012; Plaza et al., 2011, 2012). All these results can be explained according to the model suggested by Savage and colleagues (e.g., Overmier, Savage, & Sweeney, 1999; Ramirez, Buzzetti, & Savage, 2005; Savage, 2001; Savage & Parsons, 1997), who proposed that there are two different memory systems that are activated by differential and nondifferential outcomes. When nondifferential outcomes are used, there is only one source of information that can guide correct choice behavior: the retrospective recall of the particular discriminative stimulus (a cholinergic-dependent memory system). By contrast, there is an additional memory process that can help to solve the task when training under the differential outcomes procedure, related to the prospective memory for the upcoming reward (a glutaminergic-dependent memory system). Such prospective memory—elicited by the discriminative stimulus—seems to be more persistent than the retrospective memory and is critical to the enhancement of performance observed under differential outcomes conditions. This model has been supported by research with both animals and humans (e.g., Mok et al., 2009; Savage & Langlais, 1995; Savage et al., 1999; Savage & Ramos, 2009).

It is also worth noting that results from previous research suggest that even in the absence of an observable effect in performance, different neural systems (and, probably, different cognitive processes) are activated when differential outcomes are used, as compared with nondifferential outcomes (e.g., Easton, 2004; Easton & Gaffan, 2002). If this is the case, it follows that in those circumstances in which the effect is not obtained (for example, when a task is too easy to perform; e.g., Estévez et al., 2001, 2007; Plaza et al., 2011), this would not need to signify that the DOP is not working. By contrast, it might be that the expectancies of reward or prospective memory of what the upcoming reward will be were activated when differential outcomes are arranged but that a ceiling effect was masking the discriminative learning benefits usually observed under this condition. Given the scarce number of studies demonstrating the activation of different neural systems under differential and nondifferential outcomes treatments even in the absence of differences in performance (e.g., Easton & Gaffan, 2002, with monkeys), we consider that more research, maybe using neuroimaging techniques, is needed to further explore this issue in humans.

Finally, our study adds to a growing number of studies that have demonstrated the usefulness of the DOP in improving discriminative learning in typically developing children (e.g., Estévez et al., 2001; Maki et al., 1995; Martínez et al., 2009), as well as in some populations with learning or developmental problems, such as premature children (Martínez et al., 2012) or those with Prader–Willi syndrome (Joseph et al., 1997), with autism (Litt & Schreibman, 1981), or with Down´s syndrome (Estévez et al., 2003). On the basis of these findings and the previously described two-memory systems model proposed by Savage and colleagues, it could be expected that the present results would generalize to children with discriminative learning problems but with a preserved prospective memory system. Although more clinical studies are required, we hypothesize that better performance will be observed when differential outcomes are arranged, irrespective of the type of deficit underlying the discriminative learning problems of these children. Thus, for example, individuals with autistic spectrum disorder might equally benefit from the DOP even though some of their simultaneous discriminative problems are due only to a retrieval failure (higher-functioning children) or to both a retrieval failure and an attentional deficit (severely impaired children) (Reed, Broomfield, McHugh, McCausland, & Leader, 2009).

Conclusions

In summary, the DOP seems to be a useful technique for enhancing symbolic learning in children. The DOP has proved its usefulness not only in the acquisition of discriminative stimulus–response sequences, but also in the long-term retention of such learning. These findings have important implications for educational settings, because they indicate that this simple procedure could be used to effectively teach (in a shorter time and producing a greater recall) symbolic learning in several traditional school subject areas (such as, e.g., mathematics, music, geography, or languages).

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