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Training with differential outcomes enhances discriminative learning and visuospatial recognition memory in children born prematurely

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ABSTRACT

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 outcome procedure; DOP), learning is faster and more accurate than when the more common non-differential outcome procedure is used. This enhancement of accuracy and acquisition has been called the differential outcome effect (DOE). Our primary purpose in the present study was to explore the DOE in children born with great prematurity performing a discriminative learning task (Experiment 1) or a delayed visuospatial recognition task (Experiment 2). In Experiment 1, participants showed a faster learning and a better performance when differential outcomes were used. In Experiment 2, a significant DOE was also observed. That is, premature children performed the visuospatial recognition task better when they received differential outcomes following their correct responses. By contrast, the overall performance of full-term children was similar in both differential and non-differential conditions. These results are first to show that the DOP can enhance learning of conditional discriminations and recognition memory in children born prematurely with very low birth-weight.

1. Introduction

In daily life, human beings learn both how to discriminate between the different events occurring around them and how to act in consequence. For example, let us imagine that we have ordered soup and we want to eat it up. The soup is for us a discriminative signal that indicates what decision we should make: to take a spoon to eat it or not. However, in Japan soup is usually eaten holding the bowl to one's mouth, never with a spoon. This type of learning, called discriminative learning (in Japan drink the soup from the bowl, in a Western country use a spoon), is common and important for our success in everyday life. However, there are people who have discriminative learning deficits, becoming necessary to use techniques to aid them. The differential outcome training procedure is one such technique.

The differential outcome effect (DOE) refers specifically to the increase in speed of acquisition or terminal accuracy that occurs in conditional discrimination learning, when each discriminative stimulus–response sequence is always followed by a particular outcome (for example, a different type of reinforcer). In an early demonstration of this phenomenon, Trapold

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(1970) exposed rats to a discrimination test in which they were given pellets if they pressed a lever at the sound of a click, or a sucrose solution if they pressed another lever at the sound of a tone. The control (or non-differential) group received either food or sucrose for pressing the correct lever following either stimulus. Trapold observed that rats of the differential outcome group learned the task faster than those in the control group. Since then, it has been widely demonstrated with animal subjects that the differential outcome procedure (hereafter DOP) facilitates both (a) initial learning of conditional relationships (e.g., Carlson & Wielkiewicz, 1976; Trapold, 1970) and (b) memory for the conditional stimuli in delayed matching to sample tasks (e.g., Brodigan & Peterson, 1976). The DOP has become the focus of an expanding series of experiments, and it has been demonstrated with a considerable range of subjects (e.g., pigeons, rats, or dogs) and with a variety of qualitatively and quantitatively different consequences (e.g., food versus water, or different delays to food delivery) (for a review, see Goeters, Blakely, & Poling, 1992; Urcuioli, 2005).

In recent years, there have been a growing number of studies exploring the DOP in humans. Some researchers have investigated the effectiveness of this procedure to improve conditional discrimination learning in clinically normal adults. Miller, Waugh, and Chambers (2002) found that university students (from 18 to 38 years) learned the meanings of Japanese kanji characters more quickly when differential outcomes were arranged. Furthermore, Estévez et al. (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 "$<$", improved when each correct response was consistently followed by a specific outcome as compared with when the outcomes were randomly presented. Finally, Mok and Overmier (2007) observed also the DOE using (1) different sensory outcomes rather than primary hedonic reinforcers, and (2) a unique test involving a concurrent differential versus common outcomes task in a within-subjects design. Similar results have been obtained in several studies assessing the value of the DOP to improve the learning of symbolic relations in children aged from four to eight and a half years old (Estévez & Fuentes, 2003; Estévez, Fuentes, Marí-Beffa, González, & Alvarez, 2001; Maki, Overmier, Delos, & Gutman, 1995; Martínez, Estévez, Fuentes, & Overmier, 2009).

The benefits of the DOP extended also to different clinical populations. Joseph, Overmier, and Thompson (1997) observed facilitative effects of the differential outcome methodology in a study including adults with Prader-Willi syndrome. On the other hand, Estévez, Fuentes, Overmier, and Gonzalez (2003) found this effect with children and adults with Down's syndrome while performing a conditional symbolic discrimination task. It is also worth noting that three recent studies have demonstrated that the DOP is useful for alleviating memory deficits in some populations. Hochhalter, Sweeney, Bakke, Holub, and Overmier (2000) found that the differential outcome methodology improved face recognition after a 5 s delay in three patients with alcohol-induced anterograde amnesia (or Korsakoff-type amnesia). More recently, it has been shown that the DOP can enhance short-term memory in normally functioning younger and older adults (López-Crespo, Plaza, Fuentes, & Estévez, 2009; Plaza, Estévez, López-Crespo, & Fuentes, 2011).

The results obtained in the aforementioned studies strongly suggest the potential of the differential outcome training as a therapeutic technique for facilitating conditional discrimination learning and short-term memory performance in humans, particularly those with learning or memory disabilities. One population that presents such a deficit is premature children. According to the Spanish Society of Neonatology, Spain has seen a significant increase in low birth weight and preterm infants. For example, in 2003, 4267 children were born with a birth weight lower than 1500 g (Portellano, 2007). The survival rate of these children has considerably increased in the last two decades, as it does the risk for physical and neurodevelopmental disorders (e.g., Aylward, 2005; Taylor, Minich, Klein, & Hack, 2004). Although all premature children are at risk of medical and psychological problems, the earlier a child is born, the greater the risk for serious complications. Some of the clinical consequences related to prematurity are neuromotor disorders, visual and sensory problems, difficulties in learning, psychological disturbances, and social disabilities (Colvin, Maguire, & Fowlie, 2004). Furthermore, although children born with prematurity and low birth weight may have a normal intelligence quotient (IQ), it tends to be generally lower than that of full-term children (Portellano, 2000). In a recent study involving a group of five-year-old premature children, it has also been observed that the psychological consequences of being born too early include impairments in neurocognitive functions such as language, visual perception, perceptual motor skills and memory (Portellano, 2007). Accordingly, several studies have consistently found that preterm children are cognitively and academically disadvantaged compared with their full-term counterparts (e.g., Anderson, Doyle, & the Victorian Infant Collaborative Group, 2003; Bhutta, Cleves, Casey, Cradock, & Anand, 2002; Curtis, Lindeke, Georgieff, & Nelson, 2002; Pasman, Rotteveel, & Maassen, 1998; Rose, Feldman, Jankowski, & Van Rossem, 2005).

In the present study we specifically addressed the symbolic learning and spatial recognition deficit widely related to premature children. Given that, in other populations, the use of the DOP has led to better accuracy and faster symbolic discriminative learning and recognition memory than the traditional non-differential outcome procedure, we suggested that it would prove useful for children born with great prematurity. Following previous research, we expected that, contrary to full-term children, premature ones would present deficits on symbolic discrimination and delayed spatial recognition tasks; although the application of the DOP will make possible to ameliorate its impact.

2. Experiment 1

In this experiment, we aimed to evaluate the usefulness of the DOP to improve learning of symbolic relationships in premature children. For this purpose we used a symbolic matching-to-sample task similar to that used by Estévez et al. (2001, see also Martínez et al., 2009).

2.1. Method

2.1.1. Participants

Fourteen premature and 14 full-term children participated in the study. Participants included in the Premature group were born at 32 weeks of gestation or earlier with a birth weight equal or less than 1500 g. The Control group included children who were born at full-term (from 37 to 42 weeks of gestation) with a mean birth weight of 3200 g. Both groups were matched for age and gender. Table 1 presents demographic characteristics of the two study groups. All the premature children were recruited from the Complejo Hospitalario de Torrecárdenas (Torrecárdenas Hospital, Almería, Spain). Participants in the control group were recruited from local schools in Almería (Spain).

All these children participated in a previous study, where a full neuropsychological assessment was conducted (see Roldán-Tapia, Sánchez-Joya, Cánovas, Bembribe, & Ramos-Lizana, submitted). The cognitive domains studied were: executive functions, language, attention, visuoconstruction, visuoperception, learning and memory. The neuropsychological test included the Peabody picture vocabulary test (PPVT), the Kaufman assessment battery for children (KABC; subtests: hand movements; triangles; number recall; word order; spatial memory; faces and places; riddles; arithmetic; photo series; matrix analogies; gestalt closure; reading-decoding; and, reading-understanding), the Wechsler intelligence scale for children (WISC-IV; subtests: letter-number sequencing; symbol search; and, cancellation), the McCarthy scales of children's abilities (MSCA; draw-a-child subtest), the "A" Cancellation test, the Color trail making test (part A and B), the Stroop test, the Controlled oral word association test (COWAT), and the Rey-Osterrieth complex figure test (ROCF, copy trial) (see Roldán-Tapia et al., submitted, for further details about the sample and the neuropsychological assessment; see also Sánchez-Joya, Martínez-Cazorla, Ramos-Lizana, Garrido-Fernández, & Roldán-Tapia, in press).

2.1.2. Setting and materials

Each participant sat next to the experimenter in a quiet room. The stimuli (four samples and eight comparison choice stimuli) were line drawings measuring approximately 5 cm × 5 cm (7 d.v.a. approximately) presented in black on a white background on a 15″ colour monitor laptop with a Pentium processor located on a child-sized table. They were selected from the groups of symbols available in Microsoft Word 2008. Sample stimuli always appeared alone centred on the top half of the screen. Four comparisons or choice stimuli were positioned equidistant from one another in the corners of a virtual square with its centre on the centre of the screen. The position of these stimuli on the virtual square was randomly arranged. The E-prime program (Psychology Software Tools, 1999) controlled the presentation of the stimuli as well as collection of the data.

Red and yellow tokens (smiling animated coloured circles that appeared on the screen) were used as immediate secondary 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 and stickers 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.

2.1.3. Design and procedure

Each session began with a period of approximately 10 min of free play to familiarize children with the experimental setting and with the experimenter. Two experimental sessions lasting approximately 20 min each followed this habituation phase. In each session, participants performed the same matching-to-sample task, but the stimuli, and therefore the to-be-learned associations between the sample and the choice comparison stimuli, were different. In the first session, participants were assigned randomly to one of two experimental treatments in a way such that half of them served in the differential outcome condition and the other half in the non-differential outcome one. For the second session, all participants received the remaining experimental treatment. The assignation of each stimulus set to a particular outcomes condition was also counterbalanced across the children. The interval between the two experimental conditions was 30 min, during which they engaged in free play with the experimenter. The free play session involved a choice of games including drawing, colouring games, board games, soft toys and interactive games.

Table 1
Demographic variables for participants in Experiment 1.

Variables	Premature group ($n = 14$)	Control group ($n = 14$)
Age (years)		
Mean	7.8	7.8
S.D.	2.95	2.95
Range	7–8	7–8
Boys % (n)	71% (10)	71% (10)
Girls % (n)	29% (4)	29% (4)
Birth weight[a] (mean)	1.460	3.200
S.D.	0.360	0.410
Weeks of gestation	29.9	39.4
S.D.	1.82	1.22

[a] Two-sample t-test; all < 0.001.

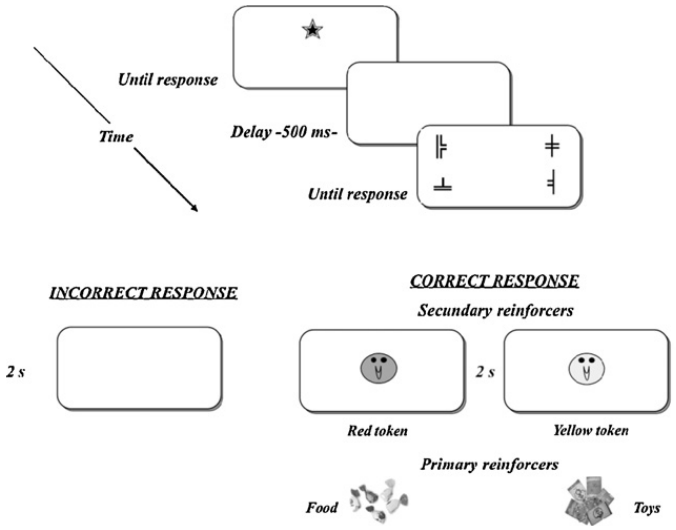

Fig. 1. Stimuli sequence (from left to right) used in Experiment 1.

The conditional discrimination task consisted of two phases: a pretest and a test. The pretest phase consisted of 4 identity matching trials and 8 conditional discrimination trials. This phase familiarized children with the matching-to-sample task. On the first identity trial, the experimenter explained that they were going to play a memory game, and when they responded correctly they would win a token that they could exchange later for a prize. Then, the experimenter showed the participant the association between red tokens and food and yellow tokens and toys. On the first identity trial, children were instructed to click on the sample stimulus centred on the top half on the screen and then on the comparison stimulus that he thought that went with the sample. Two choice stimuli were used in each trial.

On the first conditional discrimination trial, the participants received additional instructions. They were informed that the game would change a little. The picture on the top of the page (the sample stimulus) would not look like either of the two pictures that now appeared on the bottom of the screen 500 ms after they responded to the sample stimulus. Thus, they had to guess first which picture was associated with the sample stimulus and then remember which picture went with each sample stimulus.

The test phase consisted on 40 trials. The trial sequence (see Fig. 1) began with the sample stimulus presented on the top half of the screen until the participant clicked on it with the left button of the mouse. Following a delay of 500 ms during which the screen was blank, four comparison stimuli appeared on each corner of the screen. Two of the four comparison stimuli served always as distracters and neither sample stimuli nor reinforcers were associated with them. The other two comparison stimuli served always as correct choices with associated sample stimuli and reinforcers. The comparison stimuli were on until the participant responded. Following a correct response, participants received a secondary reinforcer. In the differential outcome condition, each sample stimulus was always associated with a specific outcome and correct responses to a particular stimulus led only to its associate outcome. For the non-differential condition, either a red or a yellow token randomly followed correct responses. At the end of the second experimental session, participants exchanged red tokens for food and yellow tokens for toys along with plenty of positive verbal appraisal.

2.2. Results

Correct responses on each of the 40 test trials were registered for each participant. The last 4 trials were removed from the analyses to avoid contamination due to fatigue effects. This correction was carried out after verifying that learning had already reached asymptotic levels. Percentages of correct responses for each participant were calculated for each block (3) of 12 trials according to each type of outcome (differential and non-differential). The resulting values, displayed in Fig. 2,were submitted to a mixed analysis of variance (ANOVA), with Group (Premature, Control) as the between-subjects factor and Outcomes (Differential, Non-Differential) and Block (Block 1, Block 2, Block 3) as within-subjects factors.

There was no overall difference in performance between the two groups, although the controls produced 7% more accurate responses than the premature ones (73% vs. 66%, respectively). Overall performance improved with practice along the 3 blocks of trials [$F(2,52) = 27.11$, $p < 0.001$, $\eta_p^2 = 0.51$], although the shape of the learning curve changed depending on the group [$F(2,52) = 2.57$, $p < 0.087$, $\eta_p^2 = 0.09$]. While the controls increased levels of performance by Block 2 (they had learned mostly the task after 24 trials approximately), the premature group continued learning until Block 3. This pattern was confirmed by a significant change in the quadratic component between the groups [$F(1,26) = 4.20$, $p = 0.051$, $\eta_p^2 = 0.14$]. In addition, and replicating previous results, the differential outcome procedure increased the overall accuracy as compared to the non-differential type [$F(1,26) = 4.24$, $p < 0.05$, $\eta_p^2 = 0.14$]. Although the three-way interaction did not reach significance, the impact of the differential outcomes on the rate of learning seemed to change depending on the group (see Fig. 2) [$F(2,52) = 1.78$, $p < 0.17$, $\eta_p^2 = 0.07$]. As it is shown in Fig. 2, while the control participants had learned the task at Block

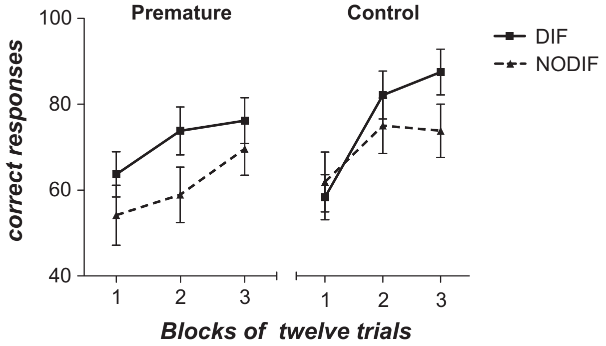

Fig. 2. Mean percentages of correct choice responses on test phase in Experiment 1 as a function of Outcomes (DO vs. NDO) and block of 12 trials.

2 for both types of outcomes, the premature ones accelerated the rate of learning with the differential outcomes, reaching the asymptote at Block 2 with a shape resembling that of the control group (there was a significant difference between the percentage of correct responses obtained in the first two block of trials similar to that found in the controls under differential and non-differential outcome condition, $ps < 0.05$). By contrast, premature children had not learned the task at Block 2 when they received non-differential outcomes following their correct responses. In fact, their performance remained close to chance level in the first two blocks of twelve trials (54% and 59%, respectively). They needed additional practice (another 12 trials) to show a similar accuracy than that obtained under differential outcome conditions. It is also worth noting that performance of pre-term and full-term children were not different in Block 1 ($p > .05$). Finally, full-term children showed a better performance at Block 3 under differential conditions than when they received non-differential outcomes and than those of premature children under non-differential outcome conditions ($ps < 0.05$). No other effects, nor their interactions, reached statistical significance ($ps > 0.05$).

2.3. Discussion

This first experiment was designed to explore whether the differential outcome methodology might be useful in the learning of symbolic relations in premature children. Learning was faster when differential outcomes were arranged. Although children born with great prematurity were able to learn the conditional discrimination task under the more usual condition of non-differential outcomes, they needed more practice than when a differential outcome procedure was used. In fact, in the latter condition, participants showed a similar rate of learning than the control group reaching the asymptote following 24 trials.

Differential outcomes affected also to full-term children but, in this case, the effect was not observed in learning but in final accuracy (after 3 blocks). That is, although these children learned the discrimination task in a similar way under both conditions, they exhibited a higher performance at the last block of twelve trials when receiving differential outcomes.

Once we have shown that DOE generally improves discriminative learning in premature children, our next step was to extend the findings to a new discriminative task in which premature children are likely to be affected the most: a visuospatial recognition task. It has been observed that some of the psychological consequences related to prematurity include deficit in spatial processing and visuospatial short-term memory (Caravale, Tozzi, Albino, & Vicari, 2005; Goyen, Lui, & Woods, 1998; Isaacs et al., 2000; Olsén et al., 1998).

3. Experiment 2

To explore this issue, in the present experiment we used an identity matching task involving the recognition of two-dimensional geometrical figures (sample stimuli were similar to those used in Tetris-like games) that appeared rotated following a brief delay as comparison stimuli. Given that this may be considered a simple task, it was expected that only the preterm children would show the DOE.

3.1. Method

3.1.1. Participants

Sixteen premature and 16 full-term children participated in this experiment. As in Experiment 1, (1) both groups were matched on age and gender (see Table 2 for further details) and (2) all participants had been assessed using a neuropsychological screening protocol (see Roldán-Tapia et al., submitted; Sánchez-Joya et al., in press).

3.1.2. Setting and materials

The settings and materials used in this experiment were very similar to those in Experiment 1 with the exception that now two-dimensional geometric figures measuring 5 cm × 5 cm (7 d.v.a. approximately) were used. These coloured shapes

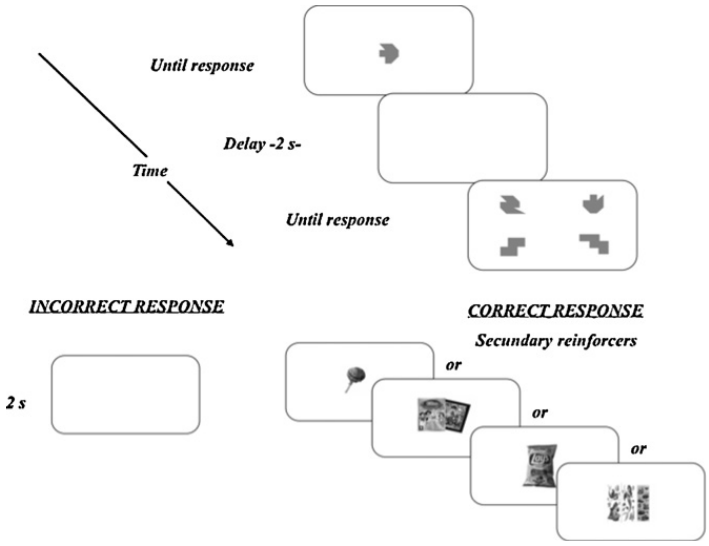

Fig. 3. Stimuli sequence (from left to right) used in Experiment 2.

Table 2
Demographic variables for participants in Experiment 2.

Variables	Premature group ($n = 16$)	Control group ($n = 16$)
Age (years)		
Mean	7.1	7.1
S.D.	6.67	6.67
Range	7–8	7–8
Boys % (n)	56% (9)	56% (9)
Girls % (n)	44% (7)	44% (7)
Birth weight[a] (mean)	1.340	3.400
S.D.	0.340	0.540
Weeks of gestation[a]	29.9	39.3
S.D.	1.16	1.67

[a] Two-sample t-test; all < 0.001.

and their rotated images were computer-designed by LM and AFE. Upright sample stimuli were rotated clockwise by 90, 180, and 240 degrees. The rotated figures served as comparison stimuli. Because a within-subject design was employed in the present study, two versions of the spatial recognition task were designed with two different sets of geometric figures including 4 sample and 12 comparison stimuli each.[1] In both sets the sample and the comparison stimuli were blue. Half of the participants received one set in the differential outcome condition and the other in the non-differential one. The opposite was true for the other half.

As in the previous experiment, primary and secondary reinforcers were used. But now the secondary reinforcers consisted in four pictures of the primary reinforcers (a lollipop, a corn chips bag, a sticker, and a collectable card). One of these pictures appeared on the middle on the screen following a correct response. At the end of the study, as in Experiment 1, all the participants received the prizes along with verbal appraisal.

3.1.3. *Design and procedure*

Following the familiarization phase, children participated in two experimental sessions lasting approximately 15 min with a rest period of 30 min between them. Each recognition task consisted of one practice trial and 48 test trials. Participants were first instructed to choose which of the four alternative figures (comparison stimuli) matched the geometric shape previously seen (sample stimulus), and they were then required to emit a correct response during a first practice trial, to ensure correct understanding of the instructions. If participant made an incorrect response, instructions were repeated and more practice trials were given until a correct response was made.

On each test trial, the sample stimuli were presented until a response was made (see Fig. 3). Participants responded by clicking the left mouse button when the cursor was on the sample. This response was followed by a constant delay of 2 s during which the screen remained blank. Then, the four comparison stimuli were presented until participant made a response. One comparison stimulus (the correct choice) represented the rotated image of the previously shown sample,

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[1] Results from a pilot study confirmed that these two sets of stimuli had the same difficulty level and were equally well discriminated.

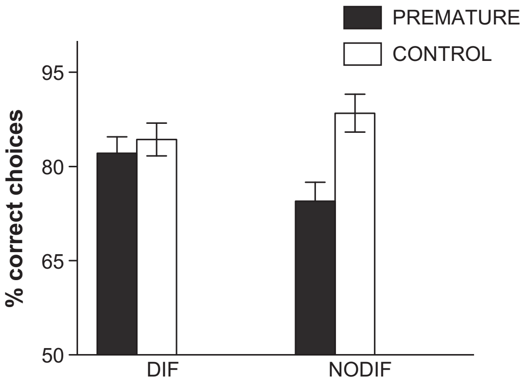

Fig. 4. Mean percentages of correct choice responses on test phase in Experiment 2 as a function of Outcomes (DO vs. NDO).

while the others were rotated images of the others sample stimulus not presented in the current trial. Participants had to decide which one of the four figures was the correct choice. If the response was incorrect, the following trial began after an interval of 2000 ms. Following a correct response, a secondary reinforcer appeared in the middle of the screen during 2000 ms. As in Experiment 1, in the differential outcome condition each sample stimulus was paired with its own outcome. By contrast, in the non-differential condition outcomes were randomly arranged.

3.2. Results

Percentages of correct responses and median correct response times were submitted to a 2 × 2 mixed ANOVA with Group (Premature, Control) as between-groups factor and Outcomes (Differential, Non-Differential) as the within-subjects factor.

The analysis revealed a significant main effect of Group when accuracy data were analyzed [$F(1,30) = 6.74$, $p = 0.014$, $\eta_p^2 = 0.18$]. That is, participants in the control group were more accurate than those in the premature group (86% and 78%, respectively). More important, the results showed a significant Outcomes × Group interaction [$F(1,30) = 5.66$, $p = 0.024$, $\eta_p^2 = 0.16$]. This interaction was mainly due to a significant DOE (a significant differential outcome effect) for the premature children [$F(1,15) = 6.49$, $p < 0.02$, $\eta_p^2 = 0.31$], whereas this effect did not reach statistical significance for the control group ($F < 1$) (see Fig. 4).

Correct response times were also analyzed. The analysis revealed only a significant main effect of Group [$F(1,30) = 50.23$, $p < 0.001$, $\eta_p^2 = 0.63$]. Overall reaction times were longer for premature children (3.304 ms) than for full-term children (2.115 ms).

3.3. Discussion

In this second experiment we aimed to test the DOE in premature children performing a visuospatial recognition task. The present results are the first to demonstrate, that visuospatial recognition of children born prematurely is improved (higher accuracy) when differential outcomes are employed, as compared to non-differential outcomes.

As expected, the overall performance of full-term children was unaffected by the DOP suggesting that the task used was very easy for them to perform. This finding is consistent with previous studies that have found no benefit of using specific outcomes when a task is simple and subjects can easily solve it (Estévez et al., 2001, 2007; Plaza et al., 2011).

4. General discussion

Several studies have shown that the use of differential outcomes enhances the symbolic discriminative learning and recognition memory in children and/or in adults with and without mental handicaps. Very low-birth-weight children are one of the populations that have problems with both processes (e.g., Colvin et al., 2004; Vicari, Caravale, Carlesimo, Casadei, & Allemand, 2004). Actually, learning problems are generally more frequent in this population and reach a prevalence of 30% versus 5–10% of the general school population (Portellano, 2007; in other studies a higher cognitive damage is also observed together with a worse school performance in premature children; see Aylward, 2005; Johnson et al., 2009; Luu et al., 2009). Furthermore, these children tend to show different cognitive deficits that include difficulties associated with spatial processing (Clark & Woodward, 2010; Olsén et al., 1998; Vicari et al., 2004) and visual spatial short-term memory (Clark & Woodward, 2010; Olsén et al., 1998) processes that are central in the formation of key academic abilities, such as reading and writing. Here we have established the DOP as an efficient technique to work against these deficits. To do so, we designed two experiments using a complex symbolic discrimination task (Experiment 1), and a spatial recognition task (Experiment 2).

Findings from the first experiment showed that although premature children learned the task in the usual reinforcement conditions (non-differential) they did it more slowly than full term children. Importantly, learning was similar for both groups when premature children received the DOP requiring the same number of trials to learn the task. A similar pattern of results was obtained for the visual spatial recognition. The difficulty that this population has with regard to spatial recognition tasks was confirmed in the second experiment (by contrast, the control group found this task very easy). This deficit vanished when differential outcomes were arranged. Thus, it was possible to prove that with a technique as simple as associating a specific outcome with each stimulus ameliorated visual spatial recognition problems in premature children.

But, how can the procedure of administering outcomes affect execution in discriminative learning and spatial recognition? The two-memory system model proposed by Savage and colleagues (e.g., Overmier, Savage, & Sweeney, 1999; Ramirez, Buzzetti, & Savage, 2005; Savage, 2001; Savage & Parsons, 1997) can explain the present findings. There are, according to this model, two distinct memory systems that become differentially activated on the basis of how outcomes are administered. Thus, under non-differential outcome conditions the only chance the participant has for correctly solving the task involves to explicitly remember the sample stimulus that was introduced in the first place. So in such cases, a retrospective memory system would therefore become activated (or explicit memory; a cholinergic-dependent memory system). By contrast, there is a different memory process that can be used to solve the task when training under differential outcome procedures: the prospective memory of what the upcoming reward will be (or reward expectancy; a glutaminergic-dependent memory system). Basic research with laboratory animals supports this model by showing not only the existence of different neuro-chemical systems but also different brain regions that are recruited when both differential and non-differential outcomes are employed (for a review, see Savage & Ramos, 2009). The results obtain up to now suggest that the basolateral amygdala and the orbitofrontal cortex, respectively, are critical for the development and maintenance of reward expectancies produced by the DOP, while as to the hippocampus, it would be essential to solve the task when training under non-differential outcome procedures (Ramirez & Savage, 2007; Savage, Buzzetti, & Ramirez, 2004). Similar results have been found in humans (see Mok, Kathleen, Lungu, & Overmier, 2009) although sensory-specific areas are activated instead of the reward system (the basolateral amygdala and the orbitofrontal cortex) when differential outcomes are employed. This model has also been supported by some human research exploring the DOP in delayed face recognition memory. These studies show, as the model predicts, that the use of specific outcomes help to overcome memory deficits that are usually observed in populations whose cholinergic system becomes deteriorated, as in normal aging (López-Crespo et al., 2009) or in Alzheimer's disease (Plaza, López-Crespo, Antúnez, Fuentes, & Estévez, submitted).

5. Conclusions

In summary, these findings demonstrate for the first time, the value of the DOP to improve conditional discrimination learning and spatial recognition memory in premature children. The results therefore suggest the potential of the specific outcomes training as a therapeutic training tool aimed at facilitating discriminative learning and memory (visual spatial short-term memory included) in this population as well as in those people who have deficits related to both processes.

Acknowledgements

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