The Psychological Record, 2007, 57, 187-200

# THE DIFFERENTIAL OUTCOMES EFFECT IN NORMAL HUMAN ADULTS USING A CONCURRENT-TASK WITHIN-SUBJECTS DESIGN AND SENSORY OUTCOMES

LEH WOON MOK and J. BRUCE OVERMIER
*University of Minnesota, Twin Cities*

The differential outcomes effect is a phenomenon where use of a choice-unique outcome for each type of correct choice in a conditional discrimination task increases rate of learning and overall accuracy, as compared to the traditional use of a single, common outcome for all types of correct choices. This phenomenon was successfully demonstrated here in college students ($p < .05$) using differing immediate sensory outcomes rather than the usual rewards that have obvious hedonic values. Further, a unique version of a concurrent-task, within-subjects design, rather than the typical between-subjects design, was employed. Applications of this effect using sensory outcomes in education and training are discussed.

That choice behavior can be enhanced through mediation by outcome-specific expectancies has been exemplified by the *differential outcomes effect* (DOE) (e.g., Kruse, Overmier, Konz, & Rokke, 1983; Peterson & Trapold, 1980; Trapold & Overmier, 1972). This effect is now one of the most reliable and robust phenomena documented in the learning literature. However, since its first demonstration by Trapold (1970) with rats, the observation of this effect has been restricted mainly to animals, children with and without handicap (up to the age of 8 years), and mentally challenged adults, receiving hedonically important rewards for choices.

The typical experimental task used to investigate the DOE is the conditional discrimination choice task. Generally, after the presentation of one discriminative/cue stimulus S1, R1 is the correct choice response, and after the presentation of stimulus S2, R2 is the correct response. Under the differential outcomes (DO) training procedure, unique outcomes follow correct responses to S1 and S2, respectively—correct S1-R1 occurrences are consistently followed by the outcome O1, and correct

This research was supported in part by the Overseas Graduate Scholarship, National Institute of Education, Nanyang Technological University, Singapore, made to Leh Woon Mok and in part by the Center for Cognitive Sciences, University of Minnesota.

Correspondence concerning this article should be addressed to Leh Woon Mok, Department of Psychology, University of Minnesota, Twin Cities, N218 Elliott Hall, 75 East River Road, Minneapolis, MN 55455. (E-mail: mokx0002@umn.edu).

S2-R2 occurrences are consistently followed by a second outcome O2; incorrect responses are not followed by any specific outcome and they terminate the experimental trial. This experimental setup provides a good model of choice behaviors in real life (e.g., go to a restaurant vs. a vending machine) that are conditional on the discriminative problems (e.g., dinner date vs. getting a snack) and of how successful choice behaviors are rewarded (e.g., a warm kiss vs. frozen food). The DOE describes the effect where learning under the differential outcomes procedure is faster, more accurate, and/or to a higher asymptote, than under the standard, more traditional procedure where all correct responses are rewarded by either a single common outcome (CO) or two randomly presented outcomes (nondifferential outcomes, NDO).

Since Trapold's (1970) first demonstration of the DOE in rats, this between-groups effect has been extensively demonstrated in other animals such as pigeons (e.g., Brodigan & Peterson, 1976), dogs (Overmier, Bull, & Trapold, 1971), and even horses (Miyashita, Nakajima, & Imada, 2000) (see Goeters, Blakely, & Poling, 1992; Urcuioli, 2005; for a review). Traditionally, learning theories (e.g., Thorndike's Law of Effect, 1914) do not consider the particular reward to be part of what is learned in discrimination learning. The demonstration of the DOE, however, highlights that what is learned is more than just the simple pairing between the presenting stimulus (S) and the rewarded response (R). Trapold and Overmier (1972) suggested that what gets learned is also a conditioned "expectancy" (or, in cognitive terms, a representation[1]) of the reward, that is, an *outcome expectancy* that is independent of the response itself and generated by the predictable stimulus-outcome (S-O) relation. This outcome expectancy (E) is hypothesized to mediate between the initial discriminative stimulus and the rewarded response, resulting in the following relation: S–E–R[O], where the outcome O is contingent on a correct response. Using the techniques of outcome reversal (e.g., Peterson & Trapold, 1980) and transfer-of-control[2] (e.g., Kruse et al., 1983), it has been demonstrated that the specific conditioned outcome expectancies actually do have functional stimulus-like properties that serve as reliable cues to guide subsequent behavior. In fact, the discriminative cues provided by outcome-specific expectancies are *more salient* than those provided by the initial discriminative stimuli themselves in guiding choice behaviors (e.g., Linwick, Overmier, Peterson, & Mertens, 1988; Urcuioli, 1990).

So far, demonstrations of the DOE, especially in animals, have

[1]Although Trapold and Overmier (1972) assumed the "expectancy" could be a central representation, it has been acknowledged that it could be a "conditioned reaction" (see Urcuioli, 2005). Nonetheless, some data challenged this (Overmier, Bull, & Trapold, 1971).

[2]The technique of outcome reversal involves reversing the outcomes that follow correct responses in each type of learning trial; the technique of transfer-of-control involves showing that other stimuli previously paired with the same outcome as the training stimuli, and hence eliciting of the same outcome expectancy, but have no history of controlling discriminative choice behavior can substitute for the discriminative training stimuli in controlling the choice behavior leading to that outcome.

generally employed a 2-cue, 2-choice task. In humans, the establishment of this phenomenon, as it applies to conditional discriminations, in children with and without handicap, has also commonly used a 2-cue, 2-choice task. For example, the DOE has been reported with normal children averaged 5 years (Maki, Overmier, Delos, & Gutmann, 1995), and children (and teenagers) with Down's syndrome, aged 6 to 17 years (Estevez, Fuentes, Overmier, & Gonzalez, 2003). With older normal children (around 8 years), however, the experimental tasks had to be considerably more difficult (e.g., stimuli were more similar to one another, and four instead of two choices were used) before the DOE obtained (Estevez, Fuentes, Mari-Beffa, Gonzalez, & Alvarez, 2001). Several studies also looked at mentally challenged adults using a 2-cue, 2-choice task to obtain the DOE with four mentally retarded adults (Malanga & Poling, 1992) and adults with Korsakoff syndrome, aged 64-86 years (Hochhalter, Sweeney, Bakke, Holub, & Overmier, 2000). Joseph, Overmier, and Thompson (1997), however, used a 2-cue, 4-choice task to obtain the DOE with adults with Prader-Willi syndrome. Only one study, by Dube, Rocco, and McIlvane (1989), did not find a significant DOE among four mentally retarded adult men.

There have been no published studies in normal human adults until very recently when this study was being planned. Recently, Miller, Waugh, and Chambers (2002) investigated in a between-subjects design the ability of university students (18 -38 years) to discriminate among 15 Japanese kanji characters. Nine choices (meanings of characters in English) were provided for the discrimination learning of these 15 characters; in a given trial, other than the correct choice that matched the cue character just presented, the 8 foils were randomly selected from the meanings of the other 14 characters. Participants were randomly assigned to one of three conditions: (a) a differential condition where both immediate (photos) and delayed (lottery prizes) outcomes were uniquely correlated with specific correct responses; (b) a partial differential condition (only photos and not prizes were uniquely correlated with specific correct responses); and (c) a nondifferential condition (both photos and prizes were randomly delivered when a correct response was made). Immediate outcomes were attractive color pictures of natural scenes such as beach, cityscape, and sea creature. For the delayed outcomes, there were 15 independent lotteries to be conducted after the whole study was completed. Each correct choice was followed by one entry into one of the lotteries; each prize averaged $10 and was a practical item such as cash, office supplies, and cookies. Participants were preexposed to the 15 lottery prizes (1 for each lottery) because the prizes were on display in the testing room. Using this method, Miller et al. extended the generality of the DOE to normally functioning human adults.

Participants in the study by Miller et al. (2002) were explicitly told that the experiment aimed to "examine the effects of different types of rewards upon the speed and accuracy of learning." This could well have alerted or biased the participants to expect unique correlations between the various outcomes and the particular discrimination problem to be solved, and that this association might have some bearing on learning speed and accuracy. Furthermore, following each *incorrect* response, participants were told the correct English meaning. This additional error-correcting outcome was probably necessary to promote learning. But such correcting outcome was also stimulus-specific and likely interacted with any of the existing memory, cognitive and/or affective processes, adding another source of confound to the experiment.

Our present study avoided these possible confounds found in the study by Miller et al. (2002) and additionally extended their findings from use of significant rewards and prizes to use of sensory outcomes. First, rewards were immediate sensory outcomes that participants were not preexposed to. Kelly and Grant (2001) have previously shown that immediate blue and yellow lights, respectively, were effective as differential sensory outcomes among pigeons in producing the DOE. Second, we used a unique version of a concurrent-task, within-subjects design. Most demonstrations of the DOE have employed the between-subjects design. Very few have used a within-subjects design. When used, it was usually between-sessions, especially in human participants (e.g., Litt & Schreibman, 1981, with autistic children).

Our experiment provides the first demonstration of a within-sessions, within-subjects comparison between outcome conditions in human participants. The experimental tasks took the form of two difficult and very similar visual perceptual discrimination (2-cue, 4-choice) tasks that were *concurrently* given to participants within a single experimental session. Participants were trained on symbolic matching, where the relation between the initial cue stimulus and correct choice symbol was arbitrary. In the differential outcomes task condition, each conditional relation was followed by a unique outcome: Participants consistently received one outcome following correct responses to one conditional relation and another outcome following correct responses to the other conditional relation. In the common outcome task condition, a single common outcome followed each conditional relation. Trials from each task condition were randomly intermixed. It was expected that learning would be faster and more accurate in the differential outcomes condition than in the common outcome condition.

In addition, herein no suggestion was made in the instructions of the possible correlation between reward type and problem type, and/or that such associations might influence response accuracy and speed. Finally, a more technical aim was to employ a fully computer-operated testing environment—from stimulus generation, outcome delivery to data recording, where there was minimal interaction between the experimenter and the human participants.

## Method

### *Participants*

Eighteen adults aged 18 to 34 years participated in the main study and were paid standard university rate. They were students at the

University of Minnesota, Twin Cities, had normal or corrected-to-normal vision, and no known history of learning difficulties. Ten were females (aged 19 to 32 years) with a mean age of 22.7 ($SE$ = 1.19), and 8 were males (aged 18 to 34 years) with a mean age of 24.38 ($SE$ = 2.21); males were not significantly older than females (equal variances not assumed), $t(10.95) = 0.67$, $p > .50$. They were selected based on the inclusion criteria presented in the section on participant selection.

*Materials*

*Conditional discrimination tasks*. Two difficult delayed conditional discriminative choice tasks were used—one to serve in the differential outcomes condition and the other in the common outcome condition. In each task, there were two discriminative stimuli and four choice alternatives, of which two were distractors. Four choice alternatives were used because results from pilot studies indicated that the two- and three-choice tasks, respectively, were too easy for participants. Following every correct response, a 1.45 sec outcome was presented. Incorrect responses were not rewarded or corrected; instead, silence and a blank screen of the same 1.45 sec duration followed.

To minimize the use of verbal mediators as mnemonics in encoding the stimuli and/or the associations between stimuli, the stimuli were designed to be as nonverbally codeable as possible. Stimuli were complex 3D geometric shapes. They varied along four dimensions: (a) shape (e.g., an irregular star, or arrows overlapping at right angles), (b) color (e.g., different shades of blue, yellow, green, or purple), (c) angle of rotation (e.g., tilted 120° down and 20° to the right, or tilted 50° up and 25° to the left), and (d) depth of geometric shape (e.g., 72 points in depth, or 36 points in depth).

In one of the two concurrent tasks, both discriminative stimuli were yellow; in the other, both were blue. In the yellow task, choice alternatives were in various shades of green; in the blue task, choice alternatives were in various shades of purple. To increase the level of difficulty, the discriminative stimuli in each task were made perceptually very similar to each other along the four stimulus dimensions. The choice alternatives in each task were also similar to one another, although to a lesser degree than within each pair of discriminative stimuli. Figure 1 shows all the experimental stimuli used.

*Pilot study 1: Tasks.* Because a within-subjects design was employed, it was essential that the two discriminative tasks were comparable in difficulty, regardless of which would be used in the differential outcomes or the common outcome condition. Thus, prior to the actual experiment an extensive series of pilot testing, which involved 26 participants, was conducted for the purpose of fine-tuning the stimuli to equate the difficulty level of the two tasks. Pilot participants performed the same 4-choice tasks within a single experimental session in which all correct responses were followed by the same outcome—O3 (forest picture + music).

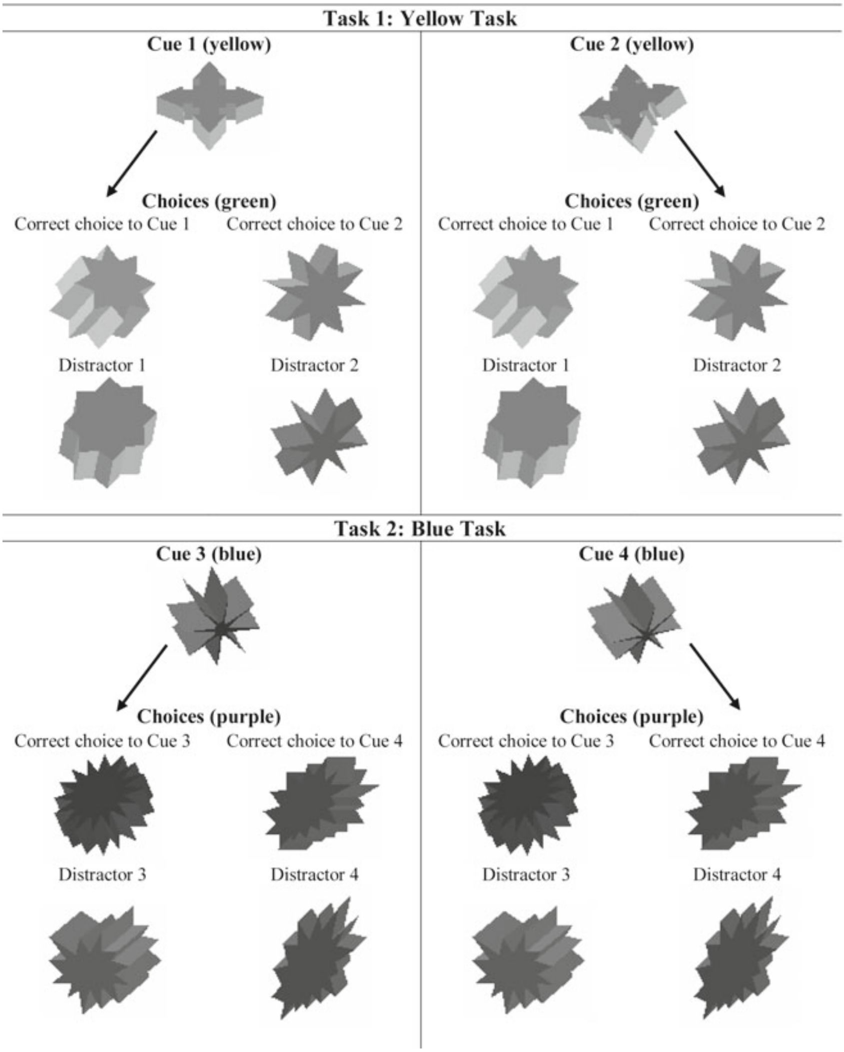


*Figure 1.* Stimuli used in the discrimination tasks. Cues 1 and 2 were in different shades of yellow; Cues 3 and 4 different shades of blue; Choices 1 and 2, and Distractors 1 and 2, different shades of green; and Choices 3 and 4, and Distractors 3 and 4, different shades of purple.

Six University of Minnesota, Twin Cities, students provided data for the final sets of to-be-used stimuli; these individuals did not participate in the main experiment. These individuals were aged 21 to 35 years, with a mean age of 27.5 years. They scored on the average 45% correct out of 48 trials ($SE$ = 9.49) on the yellow task and 41% ($SE$ = 7.29) on the blue task (chance performance was 25%). The tasks were statistically equivalent, $t(5) = 1.01$, $p > .35$.

Also, in terms of reaction time on correct trials, there was no significant difference between the two tasks, $t(5) = 1.55$, $p > .18$ (yellow: $M = 2{,}519$ msec, $SE = 242$; blue: $M = 2{,}344$ msec, $SE = 270$). This established that the two conditional discrimination tasks to be used in the actual experiment were about equally difficult.

*Outcomes*. The rewards or outcomes, when appropriately given for correct choices, were immediate and presented using the same computer on which the experiment was run. The duration of each outcome was 1.45 sec. In the differential outcomes condition, Outcome 1 (O1) was a series of three baby pictures appearing at different spots of the computer screen at unfixed intervals; there were no concurrent auditory signals presented. Outcome 2 (O2) was the first 1.45 sec of the pop song, Macarena (music only without lyrics); a blank computer screen was presented when this music was played. In the common outcome condition, the outcome (O3) was a combination of a still picture of a forest scene and the first 1.45 sec of a flute version of the Chinese violin concerto, The Butterfly Lovers; the picture stayed in the middle of the screen for 1.45 sec. All auditory stimuli were delivered on headphones.

*Pilot study 2: Outcomes.* Another pilot study was conducted to evaluate how rewarding consistently with only one outcome (O3: forest picture + music) compared against rewarding randomly with O1 (baby pictures) or O2 (Macarena), counterbalanced across the yellow and blue tasks. Each participant received both the common outcome and random outcome conditions for the concurrent discriminations within a single experimental session.

Another 6 participants from the same participant pool were recruited. They were aged 19 to 26 years, with a mean age of 22 years. On the average, they scored 45% correct out of 48 trials ($SE = 7.61$) when O1 or O2 outcomes were randomly presented and 45% ($SE = 6.67$) when there was only one single outcome (O3). This difference was obviously not statistically significant, $t(5) = 0.01$, $p > .99$. In addition, participants reacted in about the same time across both outcome procedures on correct trials, $t(5) = 1.46$, $p > .20$ (random: $M = 3{,}919$ msec, $SE = 1309$; common: $M = 3{,}110$ msec, $SE = 850$). Thus, a random combination of a mixture of O1 and O2 did not have a different reward value from a single common outcome O3.

*Identity matching test*. To check if a potential participant was able to discriminate among all the stimuli to be used in this main experiment, an identity matching test was administered prior to the experiment proper. This was a two-choice discrimination task with no outcome provided. The correct choice was the identity match to the discriminative stimulus presented. The foil was a stimulus that differed only slightly from the correct choice stimulus along one of the four stimulus dimensions—color, shape, angle of rotation, and depth; a filler dimension—shading—was included. In four trials, the yellow and blue stimuli to be used as discriminative stimuli in the main experiment were used. There were 24 identity test trials.

*Participant Selection*

Each participant underwent 4 identity matching test practice trials and then the 24 actual identity matching test trials. Only participants who scored perfect on all 4 identity test trials that included the to-be-used discriminative stimuli and scored at least 87.5% correct on all 24 identity test trials were selected. In addition, any individual who had a reaction time that exceeded 10 s (approximately three times the mean found in the preliminary experiments) on any one identity matching test trial was excluded. An unusually long reaction time could indicate the engagement of some unusual response strategy. The visual discriminations were very difficult. Twenty-six potential participants were excluded for failing this preliminary test.

In addition, there were 2 participants who underwent the main conditional discrimination tasks but were excluded because they were not learning the experimental tasks. By the end of the experiment, both performed at or below the 25% chance level across both tasks; 1 performed at about 17% correct on both tasks, and the other performed below 20% on one task and below 30% on the other.

*Design*

Half of the participants received the yellow task in the differential outcomes condition and the blue task in the common outcome condition (Task Condition 1), and the other half received the tasks the other way round (Task Condition 2). Participants were randomly assigned a task condition.

*Setting and Procedure*

The whole experiment was programmed in SuperLab Pro ver 2.0. All stimuli were presented on a 12.1-in LCD monitor driven by an IBM Thinkpad 300 MHz laptop computer and responses were recorded using a touchscreen. Participants indicated their choice by touching the relevant on-screen stimulus. They sat approximately 40 cm away from the computer screen so that they were close enough to make touchscreen responses.

The experiment was conducted in English, in a quiet, well-lit air-conditioned room. Learning the concurrent conditional discrimination choice tasks was preceded by a series of practice trials to assess the visual discriminative capacity of the participants and to accustom them to the dimensions of the stimuli and the trial structures. Stimuli used for practice were different from those used in the actual test or experiment but constructed in the same way.

Each experimental session lasted about 40 minutes. There were eight easy conditional discrimination practice trials. These were followed by 96 actual experimental acquisition trials on the concurrent conditional discrimination. Participants were instructed that "this study requires you to learn and remember the associations between some visual objects through playing a computer game. Your memories of these associations will be tested by requiring you to make touchscreen responses using only the index finger of your dominant hand." They were encouraged to be as accurate and as fast as they could in performing the tasks, and were told that one of three types of outcomes would be delivered whenever they made a correct response: (a) a short piece of music alone, (b) moving pictures of babies, or (c) a combination of both a short piece of music and a stationary picture of a forest scene. But that whenever they answered incorrectly, they would get a blank screen with no music. Refer to Appendix for the exact instructions that were directly relevant to the conditional discrimination task, delivered after the identity matching test.

*A conditional discrimination trial*. Touchscreen responses were recorded. At the start of each trial, the participant touched a red dot in the middle of the computer screen to begin the trial. A red fixation '+' sign followed immediately in the middle of the screen against a black background for 1.5 sec. The participant was instructed to visually attend to this fixation sign. The discriminative stimulus was then presented for 2 sec in the middle of the screen in a white box of dimensions 8.7 cm (width) x 7.4 cm (height) against a black background. The participant was instructed to attend to and remember this stimulus. This was followed by a constant delay of 0.75 sec during which a black screen was presented. Then all four choice alternatives were simultaneously presented, arranged in a diamond fashion, in a white box of dimensions 13 cm (width) x 11 cm (height). The participants were required to respond by touching the choice alternative that corresponded to the discriminative stimulus they had just seen. If no response was detected within 20 sec, the trial self-terminated and the next trial was presented.

The particular correlated outcome followed immediately after each correct response. If the response was incorrect, the participant received a blank screen for an equivalent duration of 1.45 sec. For every trial, irrespective of whether the response was correct, there was a 4 sec intertrial interval (ITI) where a blank screen was presented following each trial outcome. At the end of the experiment, participants were debriefed and paid.

*Order of trials.* The four choice alternatives were arranged in four positions in a diamond fashion—left, right, up, or down, each 4 cm radial from the middle of the computer screen. For each discriminative stimulus, when one corresponding choice alternative was held constant in one particular position, there were 3! = 6 different ways of arranging the other three choice alternatives in the other three positions. This gave (4 x 6 =) 24 different configurations for all four choice alternatives of each discriminative stimulus. Therefore, across all four discriminative stimuli, there were (4 x 24 =) 96 possible configurations, giving 96 different trials. As such, position of correct choice was fully controlled over acquisition.

The 96 trials were divided into three blocks of 32 trials each, equating for type of discriminative stimulus, choice alternatives, and position of correct choice. Within each block, the order of trials was fixed and pseudo-randomized with the constraint that the same discriminative stimulus did not occur more than twice on consecutive trials. The order of presenting these three blocks of trials was counterbalanced using a 3 x 3 Latin square. Participants were randomly assigned one of the three resulting trial sequences.

## Results

Practice trial data and experimental acquisition trials in which no response was recorded were not considered. A significance level of .05 was used in all analyses unless otherwise stated.

### *Percentage Correct Data*

Results from preliminary analyses indicated that all three participant control variables of task condition, trial sequence, and gender had no significant effects, $ps > .33$. Therefore, the outcome effect is reported below collapsing across these control variables.

*Overall percentage correct.* That acquisition performance was better in the differential outcomes condition than the common outcome condition was borne out by a 1-way (Outcome: differential vs. common) repeated-measure ANOVA of overall percentage correct scores. Participants were significantly more accurate in the differential outcomes condition ($M$ = 61%, $SE$ = 5.02) than in the common outcome condition ($M$ = 49%, $SE$ = 4.02), $F(1, 17) = 6.13$, $MSE = 223.88$, $p < .05$.

*Learning curves.* The 48 trials in *each* discrimination task were then grouped into 3 sequential blocks of 16 trials each, equating for both types of discriminative stimulus, for further analyses. Refer to Figure 2. Percentage correct per block of trials was cast as an Outcome (2) x Block (3) repeated-measure ANOVA. As expected, both the outcome and block main effects were significant [outcome: $F(1, 17) = 6.17$, $p < .05$; block: $F(2, 34) = 37.85$, $p < .001$]. However, the interaction between outcome and block was not significant, $F(2, 34) = 1.16$, $p > 0.30$.

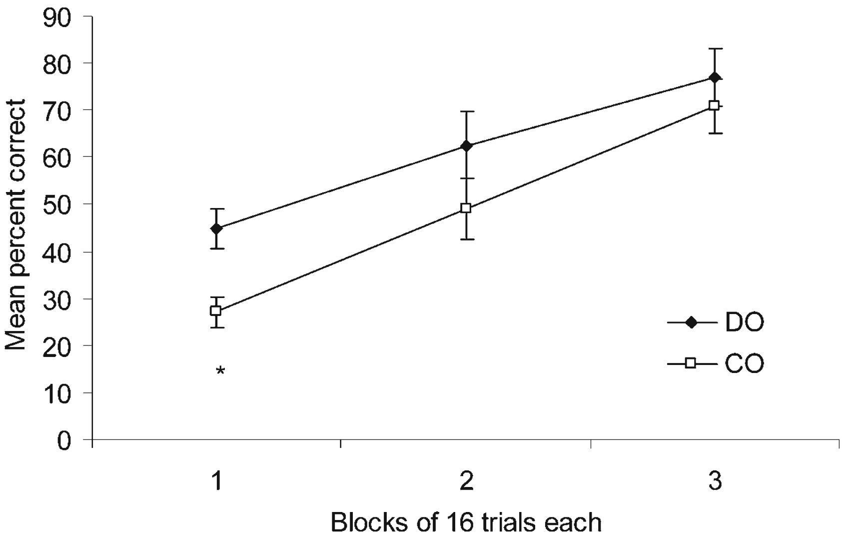


*Figure 2.* Learning curves by participants for the differential outcomes (DO) vs. common outcome (CO) conditions; error bars are standard errors of mean. Note that * denotes $p < .01$ for difference between outcome conditions at that block.

Nonetheless, a paired *t* test at each block indicated that performance difference between the differential outcomes condition (*M* = 45%, *SE* = 4.26) and common outcome condition (*M* = 27%, *SE* = 3.35) was significant only at Block 1, $t(17) = 3.60$, $p < .01$. By Blocks 2 and 3, performance difference between the two outcome conditions while persisting was not statistically significant, *p*s > .10. Incidentally, there was no significant difference in performance across the two outcome conditions at the outset, in the initial four learning trials (equated for type of discriminative stimulus), $t(17) = 0.83$, $p > .40$ (differential: *M* = 31%, *SE* = 4.52; common: *M* = 24%, *SE* = 5.14); these percentage correct scores were not significantly different from chance level of 25%, *t*(17)s < 1.23, *p*s > .20.

## Discussion

This study successfully demonstrated the DOE in normal adult humans (aged 18 to 34 years) in a unique version of a concurrent-task, within-subjects design. In addition, this demonstration was achieved using a 2-cue, 4-choice task analogous to those used in animals, and young or challenged young people. This experiment did so by posing a set of more complex and difficult perceptual challenges than those used previously with nonhumans, children, or mentally challenged individuals. Furthermore, we obtained this positive result using sensory outcomes.

Our results extend in important ways the finding of Miller et al. (2002). Unlike the findings of Miller et al. in their between-subjects procedure, our result did not depend on error-correcting outcome or the use of delayed differential outcomes. Moreover, our instructions did not bias participants to expect that outcome type might be correlated with discrimination problem type and/or that this might have an influence on choice accuracy, as did the instructions of Miller et al. Additionally, when learning trials were grouped into three blocks of 16 trials each per outcome condition that equated for type of discriminative stimulus, it was revealed that the DOE peaked early in training in adult humans, in the first 16 trials or so. Incidentally, there was no performance difference between the two outcome conditions at the outset, in the first four trials, where performance was not significantly different from chance level of 25%.

The sensory outcomes of pictures of babies or forest scene, and short pieces of music, as employed in this study, are distinguished from primary hedonic reinforcers such as food and water. However, at this juncture, it should be acknowledged that it was possible for these sensory outcomes to have acquired the status of conditioned reinforcers for some individuals. Previous studies with nonhuman animals that employed pairs of differential outcomes that were distinguished by biologically neutral features, such as water only vs. water-plus-light (Fedorchak & Bolles, 1986), food only vs. food-plus-light (Friedman & Carlson, 1973), and pairs of light (blue vs. yellow) that predicted the same food reinforcer (Kelly & Grant, 2001, Exp 2), have considered this possibility. Nonetheless, their conclusions were that such an argument was strained because there was no consistent preference for one differential outcome over the other, which would be expected if the differential outcomes have acquired conditioned reinforcing properties.

The employment of the concept of outcome-specific expectancies in explaining the DOE (Trapold & Overmier, 1972) harks back to classic mediation theories of human learning and cognition that were popular in the 1960s, especially in the area of verbal behavior (e.g., Foss & Jenkins, 1966; Jenkins & Bailey, 1964). Such research established that mediators are effective mnemonics in complex human learning. Much as verbal mediators have been found to be effective mnemonics in complex human learning, mediation by outcome-specific expectancies could also be viewed as a mnemonic-engaging strategy that could be employed to enhance learning and memory in both children and adults, with and without handicap. Especially important is the demonstration, as in this study, that the benefits of differential outcomes extend to arbitrary relations between discriminative stimuli and choice alternatives. The learning of such arbitrary relations of symbols is important to many aspects of higher level cognitions such as symbolic relation learning, as in human language (e.g., Staats, Staats, Finley, & Minke, 1963).

The visual discriminations in this study were very difficult. Therefore, robust selection criteria were used to select participants to ensure that they had the visual capacity to effectively learn the concurrent discrimination problems. This might somewhat limit the generalizability of the obtained results. However, the fact that the training procedure worked even with sensory outcomes, such as pictures and short pieces of music, increases the scope of real-life discrimination problems to which the differential outcomes methodology can be applied. Also, the DOE was demonstrated in this study using a fully computer-operated training procedure, making it highly portable and suitable for the modern computerized classroom. This greatly increases the potential of the differential outcomes training procedure to be structured into a fun and sensory-enriching learning experience (Mok, Estevez, & Overmier, in press).

## References

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

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

ESTEVEZ, A. F., FUENTES, L. J., MARI-BEFFA, P., GONZALEZ, C., & ALVAREZ, D. (2001). The differential outcome effect as a useful tool to improve conditional discrimination learning in children. *Learning and Motivation*, 32, 48-64.

ESTEVEZ, A. F., FUENTES, L. J., OVERMIER, J. B., & GONZALEZ, C. (2003). Differential outcomes effect in children and adults with Down syndrome. *American Journal on Mental Retardation,* 108, 108-116.

FEDORCHAK, P. M., & BOLLES, R. C. (1986). Differential outcome effect using a biologically neutral outcome difference. *Journal of Experimental Psychology: Animal Behavior Processes*, 12, 125-130.

FOSS, D. J., & JENKINS, J. J. (1966). Mediated stimulus equivalence as a function of the number of converging stimulus items. *Journal of Experimental Psychology*, 71, 738-745.

FRIEDMAN, G. J., & CARLSON, J. G. (1973). Effects of a stimulus correlated with positive reinforcement upon discrimination learning. *Journal of Experimental Psychology*, 97, 281-286.

GOETERS, S., BLAKELY, E., & POLING, A. (1992). The differential outcomes effect. *The Psychological Record*, 42, 389-411.

HOCHHALTER, A. K., SWEENEY, W. A., BAKKE, B. L., HOLUB, R. J., & OVERMIER, J. B. (2000). Improving face recognition in alcohol dementia. *Clinical Gerontologist*, 22, 3-18.

JENKINS, J. J., & BAILEY, V. B. (1964). Cue selection and mediated transfer in paired-associate learning. *Journal of Experimental Psychology*, 67, 101-102.

JOSEPH, B., OVERMIER, J. B., & THOMPSON, T. (1997). Food-and nonfood-related differential outcomes in equivalence learning by adults with Prader-Willi syndrome. *American Journal on Mental Retardation*, 101, 374-386.

KELLY, R., & GRANT, D. S. (2001). A differential outcomes effect using biologically neutral outcomes in delayed matching-to-sample with pigeons. *The Quarterly Journal of Experimental Psychology*, 54B, 69-79.

KRUSE, J. M., OVERMIER, J. B., KONZ, W. A., & ROKKE, E. (1983). Pavlovian CS effects upon instrumental choice behavior are reinforcer specific. *Learning & Motivation*, 14, 165-181.

LINWICK, D., OVERMIER, J. B., PETERSON, G. B., & MERTENS, M. (1988). The interaction between memories and expectancies as mediators of choice behavior. *American Journal of Psychology,* 101, 313-334.

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

MAKI, P., OVERMIER, J. B., DELOS, S., & GUTMANN, A. J. (1995). Expectancies as factors influencing conditional discrimination performance of children. *The Psychological Record*, 45, 45-71.

MALANGA, P., & POLING, A. (1992). Letter recognition by adults with mental retardation: Improving performance through differential outcomes. *Developmental Disabilities Bulletin*, 20, 39-48.

MILLER, O. T., WAUGH, K. M., & CHAMBERS, K. (2002). Differential outcomes effect: Increased accuracy in adults learning kanji with stimulus specific rewards. *The Psychological Record*, 52, 315-324.

MIYASHITA, Y., NAKAJIMA, S., & IMADA, H. (2000). Differential outcome effect in the horse. *Journal of the Experimental Analysis of Behavior*, 74, 245–253.

MOK, L. W., ESTEVEZ, A. F., & OVERMIER, J. B. (in press). Unique reward expectations as a training tool in an educational setting. In O.-S. Tan, A. S.-H. Seng, & L. K.-H. Pou (Eds.), *Cognitive modification systems: New frontiers in learning and dynamic assessment*. Singapore: McGraw Hill.

OVERMIER, J. B., BULL, J., A., & TRAPOLD, M. A. (1971). Discriminative cue properties of different fears and their role in response selection in dogs. *Journal of Comparative and Physiological Psychology*, 76, 478-482.

PETERSON, G. B., & TRAPOLD, M. A. (1980). Effects of altering outcome expectancies on pigeon's delayed conditional discrimination performance. *Learning and Motivation*, 11, 267-288.
STAATS, A. W., STAATS, C. K., FINLEY, J. R., & MINKE, K. A. (1963). Meaning established by classical conditioning controlling associates to the UCS. *Journal of General Psychology*, 69, 247-252.
TRAPOLD, M. A. (1970). Are expectancies based upon different positive reinforcing events discriminably different? *Learning and Motivation*, 1, 129-140.
TRAPOLD, M. A., & OVERMIER, J. B. (1972). The second learning process in instrumental learning. In A. H. Black & W. F. Prokasy (Eds.), *Classical conditioning II: Current theory and research* (pp. 427-452). New York: Appleton-Century-Crofts.
URCUIOLI, P. J. (1990). Some relationships between outcome expectancies and sample stimuli in pigeons' delayed matching. *Animal Learning & Behavior,* 18, 302-314.
URCUIOLI, P. J. (2005). Behavioral and associative effects of differential outcomes in discrimination learning. *Learning & Behavior*, 33, 1-21.

## Appendix

*Instructions Delivered for the Conditional Discrimination Task after the Identity Matching Test*

Now, I shall explain to you the second section. This section is basically the same as the previous section, except for a few differences. First of all, there will now be four instead of two options. Also, none of the options will look identical to the target object you have just seen. Say, the target object is a blue pen, your task is to find among the four available options, the particular option that matches the blue pen. You do this by first guessing and then remembering both the correct and incorrect choices you have made, so that you would eventually identify the option that matches the blue pen. Once you have identified the correct option to a particular target object, remember it so that every time that target object is presented, you would be able to choose that same option. The next crucial question is, 'How would you know when you've made a correct response?' Whenever you make a correct response, you will receive a message telling you so. This message could be a short piece of music, some moving pictures, or a combination of both a short piece of music and a stationary picture. Whenever you make an incorrect response, you will get a blank screen with no music. Note that the relationship between the target object and the correct option is 1-to-1. For example, if the option that matches the blue pen is a yellow pencil, the yellow pencil is a correct answer only when the blue pen is presented; it will not be a match to any other target object. And when the blue pen is presented, only the yellow pencil will be the correct answer and not any other option. This 1-to-1 relationship remains the same throughout the whole exercise. There is a correct answer to every question. Your task is to find the answer to each question. In this section, some of the target objects may look very similar to each other, or they may look as different as they were in the practice trials. So, please pay attention to each object. Make use of whatever cues there are to remember the relationships between target objects and options. Again, please try to be as accurate and as fast as you can.

We shall now go through a few practice trials. There are two ways of informing you that you have the right answer. One is by playing a short piece of music alone, and the other is by presenting some moving pictures.

[Practice trials]

If you are ready, we will now begin with the actual trials. In these actual trials, there are three ways of informing you that you've got the right answer. You will hear a short piece of music alone, see moving pictures of babies, or get a combination of both a short piece of music and a stationary picture of a forest scene. Please remember to be as accurate and as fast as you can. This section will last for about 15-20 minutes depending on how fast you are.