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DIFFERENTIAL OUTCOMES EFFECT: INCREASED ACCURACY IN ADULTS LEARNING KANJI WITH STIMULUS SPECIFIC REWARDS

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The differential outcomes effect refers to the increase in accuracy obtained in discrimination tasks when rewards provided for correct responses vary according to the stimulus presented. The present research examined this effect in a sample of university students discriminating multiple stimuli. A computer task was used to teach the meanings of 15 Japanese kanji characters, with both immediate (photos) and backup (lottery prizes) rewards following correct responses. Students were randomly allocated to one of three conditions: a differential condition (photos and prizes were uniquely associated with specific kanji), a partial differential condition (photos but not prizes were uniquely associated with specific kanji), and a nondifferential condition (photos and prizes were randomly associated with specific kanji). Participants in the differential condition learned the kanji meanings more quickly than those in the nondifferential condition. Accuracy in the partial differential condition was intermediate to, and not significantly different from, the other two conditions. These results extend the generality of the differential outcomes effect and have important practical implications.

In a standard discrimination procedure, common rewards are provided for correct responses to different stimuli. In a differential outcomes procedure, the rewards provided for correct responses vary according to the stimulus presented. The improvement in accuracy obtained with the latter procedure, compared to that obtained with common or random rewards, is known as the *differential outcomes effect* (DOE).

Trapold (1970) was the first to demonstrate a DOE. His experiment was designed to assess a two-process theory of learning. He suggested that an association is formed not only between the stimulus (S) and response (R), but also between the stimulus and the reinforcer (S^R). The predicted S-S^R association meant that the stimulus would come to elicit a learned representation/expectation of the reinforcer that consistently followed it. If this

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were the case, one would expect higher accuracy when differential outcomes are used, as additional discriminable information is available at the time of responding. Trapold tested this reasoning by teaching rats to discriminate between a clicker and a tone. Responses to the left bar were reinforced after presentation of the clicker. Responses to the right bar were reinforced after presentation of the tone. Rats who experienced differential outcomes received food for one type of correct response and sucrose solution for the other. Rats who experienced nondifferential outcomes received either food or sucrose for both types of correct responses. Rats in the differential outcomes group learned the discrimination more quickly than rats in the latter control group. Support for the two-process theory of learning was obtained and the DOE was discovered.

Since the Trapold (1970) study, many articles have reported a DOE (see Goeters, Blakely, & Poling, 1992, for a review). This well-established effect has been found across a range of different species and with outcomes that differ in type and/or in quantity. However, the literature generalizing this effect to humans, particularly normally functioning humans, is sparse. As Overmier, Savage, and Sweeney (1999) point out, we need “to establish that the principles at hand are, in fact, general ones that apply to humans as well as animals” (p. 238).

A recent study by Maki, Overmier, Delos, & Gutmann (1995) looked at the effects of differential outcomes in humans. Children aged between 4 and 7 years were rewarded for discriminating two simple figures or shades. Differential outcomes consisted of food for one type of correct response and verbal praise for the other. Nondifferential outcomes consisted of food or praise allocated randomly after correct responses. Children who experienced the differential outcomes were significantly more accurate than those who did not. Differential tokens (backed up by nondifferential rewards) were also effective in facilitating performance. Additional testing demonstrated that those in the differential outcomes group formed expectancies for the rewards associated with each stimulus and were able to use these expectancies to solve a new discrimination problem.

The present study extended on previous research in a number of ways. First, it used a sample of normally functioning adults (university students). Second, it used a complex discrimination task; participants had to discriminate between 15 different kanji characters. All previously reported research has examined very simple learning situations where only two stimuli are discriminated. Finally, the current research manipulated the differential nature of both immediate and delayed outcomes.

It was expected that participants who experienced differential outcomes for correct responding would learn the kanji characters more quickly than those who did not.

Method

Participants

Sixty-three students (48 female and 15 male), aged between 18 and

38 years, were recruited from the University of Canberra. Fifty received course credit for their involvement, while the remaining participants took part voluntarily. Participants were randomly assigned to one of three conditions. The group with the *differential condition* consisted of 6 males and 15 females and had a mean age of 20.8 years. The group with the *partial differential condition* consisted of 4 males and 17 females and had a mean age of 22.1 years. The group with the *nondifferential condition* consisted of 5 males and 16 females and had a mean age of 24.4 years. (Age differences were coincidental and were not significant.)

Apparatus and Materials

Discrimination task. All sessions were run in a small quiet room on a PC computer with a 15" monitor and a standard keyboard and mouse. The software was purpose-built using Microsoft Visual Basic (Version 6.0). The discriminative stimuli consisted of 15 Japanese kanji characters. These were presented as black characters in white rectangles, ranging from 7.2 to 7.8 cm in height and 6.4 to 7.9 cm in width, on a gray screen. The kanji were selected to have primarily abstract meanings, making it more difficult to form visual associations between the image and the meaning (i.e., to raise the difficulty level of the task). The kanji meanings were: abbreviation, benefit, degree, drama, length, loss, phrase, politics, price, quality, reason, source, technique, virtue, and wealth. All text was black on a gray background unless otherwise stated.

Pictures. Immediate outcomes consisted of attractive color pictures displayed on the monitor. Fifteen pictures were obtained from Eureka Software's Graphics Explosion Pack and showed the following scenes: Divers, golden gate bridge, dog, sea creature, pond, desert, beach, mountain, cityscape, sunset, waterfall, traffic, canyons, brick wall, and haystack.

Lotteries. Delayed outcomes were provided using 15 independent lotteries. Each lottery had a prize with an average value of $10. The prizes were: cash, blank disks, movie ticket, phone card, jelly lollies, video or game hire, office supplies, cookies, photocopy card, wooden massager, scratch ticket, incense, drinking glasses, voucher for coffee and cake, and chocolates. These prizes were on display in the testing room. The same 15 lotteries were used for all conditions. Each correct response led to one entry into one of the lotteries. A bar displayed continuously at the bottom of the screen showed a running tally of entries received into each prize draw. When the study was completed, a prize winner was randomly selected from each lottery and the student was contacted and asked to collect the appropriate prize.

Procedure

All participants were tested individually and by the same researcher. They were told that the experiment aimed to "examine the effects of different types of rewards upon the speed and accuracy of learning." They were also informed that they would be completing a questionnaire regarding the prizes after completing the task. This questionnaire required participants to rank each of the 15 prizes in order of preference. The purpose of this instruction was to encourage participants to focus on the prizes and thus increase their saliency.

There were three blocks of trials in the discrimination task. Each block took approximately 15 minutes to complete. The following instructions were presented on screen at the start of each block:

> Welcome to the experiment. Your task is to learn the meaning of a set of 15 kanji. We will present you with one kanji at a time. It will be on the screen for 5 seconds before it is removed and replaced with nine different words. One of the words will mean the same as the kanji you just saw. You will need to select the word you think correctly matches the meaning of the kanji. If you get this correct you go into the draw for a prize (each kanji has its own prize). Every time you get that kanji correct you will get another entry into the draw. The more times you enter the better your chances of winning. To start with you will not know any of the kanji characters, therefore you will only get about 1 in 9 correct. But as you learn, you will get more and more entries in the prize draws. WIN WIN WIN. Use the mouse to select the word. Click OK to continue.

Each of the 15 kanji was presented three times in a random order in each block of trials. At the start of each trial, a kanji (sample stimulus) was presented for 5 s after which it was replaced with a screen of nine possible meanings (comparison stimuli). These meanings were presented in a random order within a 3 x 3 grid. Participants were required to indicate, using the mouse, which of the meanings they believed was correct. The eight distracters in each trial were a random selection of the meanings of the remaining 14 kanji. The correct identification of a kanji character resulted in a 4-s presentation of a screen displaying a color photographic picture (this was not related to the meaning of the kanji). After presentation of this image, a screen showed the text, *"Well done!! That is correct. You have another prize entry in the draw for the ———. You now have —- entries in this draw."* An incorrect response was followed by a screen showing the text, *"No that's wrong! The correct answer is ———. You have missed out on a prize entry in the draw for ———."* The prize descriptions were highlighted in red. These feedback screens were displayed for 7 s, after which the next trial started. Participants were given a 2-min break between each block of 45 trials.

For participants in the *differential condition*, each kanji was associated with a specific photographic picture and prize. Correct responses to a particular kanji always led to its associated picture and prize entry. Incorrect kanji identification resulted in no picture and a failure to receive an entry to win a specific prize. For participants in the *partial differential condition*, each kanji was associated with a specific photographic picture but not a specific prize. Correct responses to a particular kanji led to its associated picture but a random prize entry. Correct responses by participants in the *nondifferential condition* led to a random picture and a random prize entry.

When participants had completed the three blocks of trials, they completed the prize index and were then debriefed on the purpose of the study. Data collected included: the correct response for each trial, the participant's actual response on each trial, the identity of the distracter stimuli, and the number of entries for each prize in each block of trials.

Results

Figure 1 shows the mean percentage of kanji correctly identified in each block of trials for each experimental condition. A two-way analysis of variance (ANOVA) revealed a significant improvement in performance with experience on the task [$F(2, 120) = 490.6$, $p < .001$], a significant effect of experimental condition [$F(2, 60) = 4.7$, $p = .013$, *partial* $\eta^2 = 0.14$], and no interaction between experience and condition [$F(4, 120) = 1.6$, $p = .191$]. Post hoc analyses (Fisher's LSD) showed participants in the differential condition were significantly more accurate than those in the nondifferential condition ($p = .004$). There was a trend towards a difference in accuracy between the differential and partial differential conditions ($p = .054$), but no such trend in the partial differential-nondifferential comparison ($p = .299$). Given the probable floor and ceiling effects present in Blocks 1 and 3 (which would reduce any difference between the groups), pairwise comparisons (Fisher's LSD) were made on group means in Block 2. These revealed that accuracy was

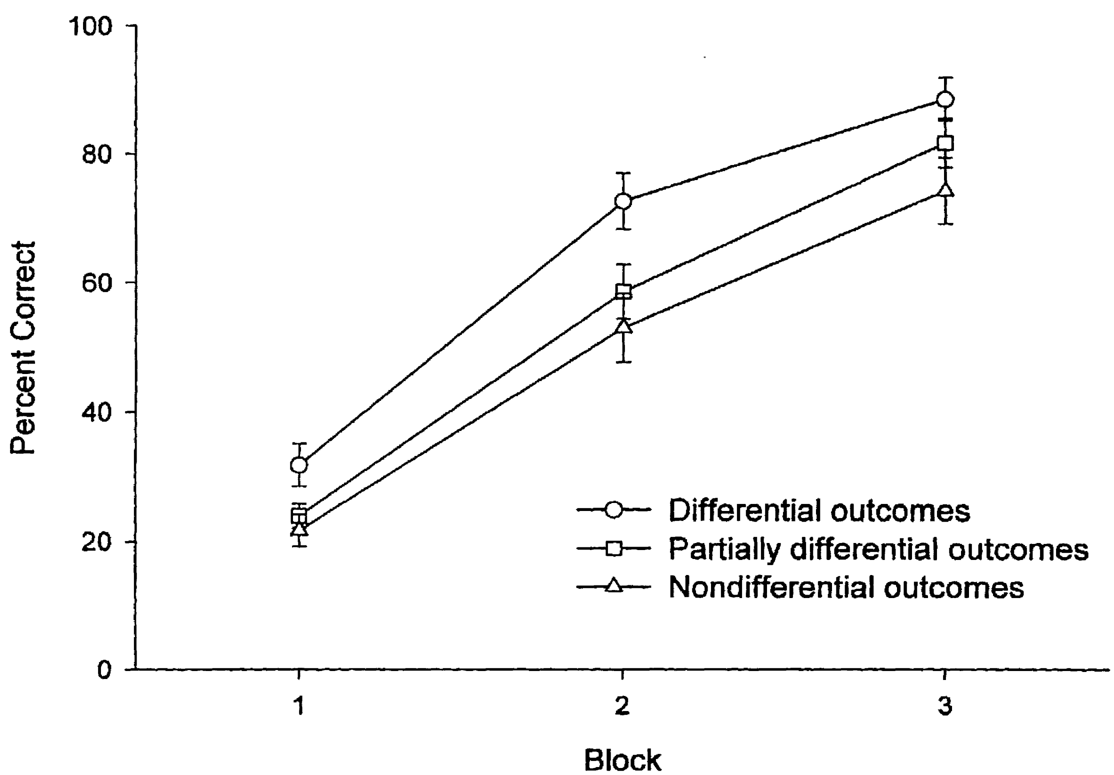

Figure 1. Mean percent correct obtained in each block of trials by participants in the three outcome conditions. Standard error bars are shown.

significantly higher in the differential condition than in the partial differential condition ($p = .036$), however there was no difference in accuracy between the partial differential and nondifferential conditions ($p = .395$).

To assess the possibility that participants in the differential condition were simply better at the task right from the start, accuracy was examined for each set of 15 trials in Block 1. Figure 2 displays these data. It can clearly be seen that there were no differences between the three groups of participants during the first 15 trials. A two-way ANOVA revealed a significant effect of experience on the task [$F(2, 120) = 33.5$, $p < .001$] and a significant effect of experimental condition [$F(2, 60) = 4.2$, $p = .020$, *partial* $\eta^2 = 0.12$]. Post hoc analyses (Tukey's HSD) showed participants in the differential condition were significantly more accurate than those in the nondifferential condition ($p = .021$). Perhaps more interestingly, there was also a significant interaction between experience and condition [$F(4, 120) = 4.9$, $p = .001$, *partial* $\eta^2 = 0.17$], showing that participants in the differential condition learned the task more quickly than those in the nondifferential group.

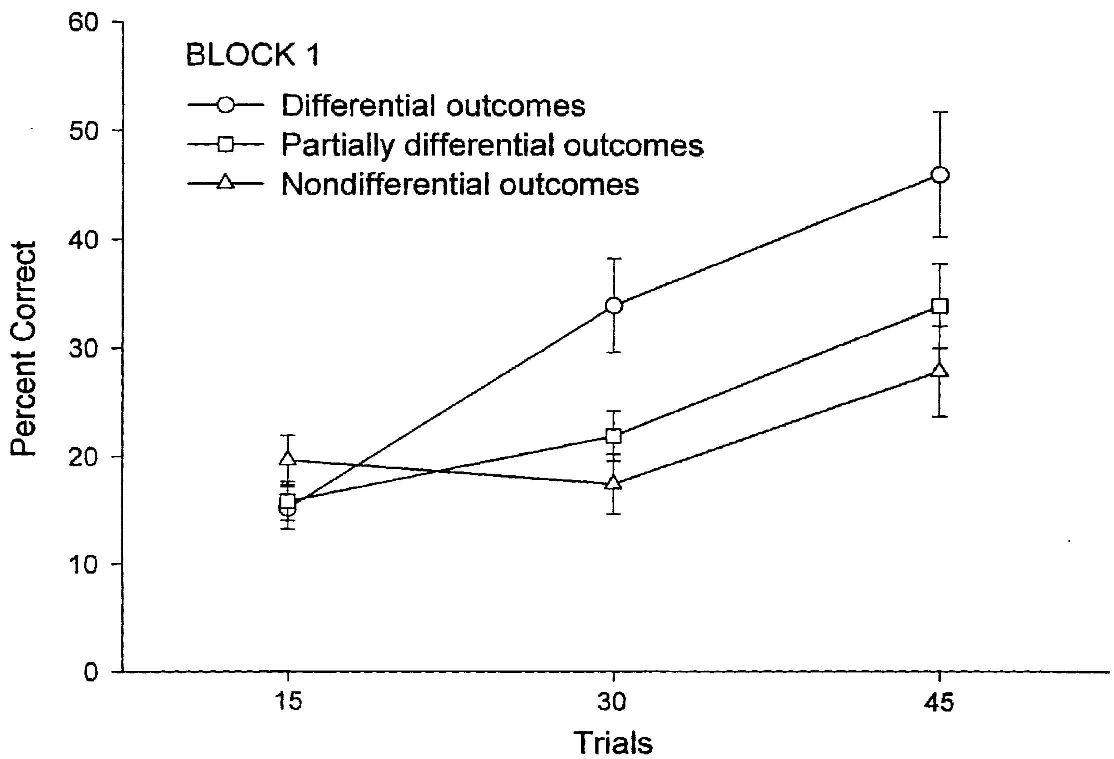

Figure 2. Mean percent correct obtained in each set of 15 trials in Block 1 by participants in the three outcome conditions. Standard error bars are shown.

Discussion

A DOE was obtained in the current experiment. Specifically, participants who experienced differential outcomes learned to discriminate kanji characters more quickly than those who experienced nondifferential outcomes. It was not possible to assess the effect of differential outcomes on terminal accuracy as all groups of participants were performing at a high level by the third block of trials. A ceiling effect may have obscured possible differences between the conditions in the last stages of the experiment. Mean accuracy in the partial differential outcomes condition fell between that obtained in the differential and nondifferential conditions. There was some evidence to suggest that accuracy in the partial differential condition was lower than that obtained in the differential condition and not different from that obtained in the nondifferential condition.

The results obtained in the present experiment support the generality of the DOE. Not only can this effect be obtained with pigeons (e.g., Delong & Wasserman, 1981), rats (e.g., Friedman & Carlson, 1973), chickens (e.g., Poling, Temple, & Foster, 1996), dogs (e.g., Overmier, Bull, & Trapold, 1971), and horses (e.g., Miyashita, Nakajima, & Imada, 2000), but it can be obtained with adult humans in more complex discrimination tasks.

Maki et al. (1995) obtained similar results to those obtained in the current experiment. In an experiment of Maki et al., children were divided into three groups. The first, the differential outcomes condition, experienced differential tokens and backup rewards. The second group experienced differential tokens but nondifferential backup rewards. The third group experienced nondifferential outcomes. As with the current experiment, mean accuracy decreased with progressively nondifferential allocation of rewards. However, Maki et al. obtained a statistically significant difference between the latter two conditions (despite a small sample size) although there was no such difference found here. It is possible that a significant difference was not found between the partial differential and nondifferential conditions used here because of the salience of the photographs used as immediate outcomes. These may have been too similar (in size, color, and subject) and/or been overshadowed by the very salient lottery prizes (which were presented last, emphasized in the instructions, and displayed in the testing room).

The use of lotteries rather than certain prizes as rewards was a successful innovation. Students were interested in the prizes and very pleased to be part of a project that had the potential for some return. Given the limited budgets of many research projects, this seems an effective and economical way of assessing the effects of differential outcomes in normally functioning humans.

One improvement to the experiment would be the addition of a fourth condition where participants experienced nondifferential immediate outcomes (photos) and differential delayed outcomes (lottery prizes). Limited resources led to the exclusion of this condition in the present research, however future researchers should consider its inclusion to ensure a more complete experimental design. The results from this fourth condition would be particularly interesting in light of the results obtained here.

A second improvement to the current procedure relates to correcting feedback supplied after incorrect responses. In most discrimination tasks of this type, no correcting feedback is given. In the task used here, correct-response feedback or KCR (knowledge of the correct response) was provided after incorrect responses but not after correct responses (i.e., it was asymmetric). In other words, participants were told the correct English meaning as part of their feedback only if they selected the wrong meaning. This is important because KCR is a form of stimulus specific feedback; each English meaning was uniquely associated with a kanji character. In future, if KCR were to be used, it would be preferable for it to be provided after both correct and incorrect responses. This would ensure that the amount of stimulus specific feedback is not dependent on accuracy levels. It is important to note, however, that any effects of asymmetrical KCR in the present experiment would work to reduce the effect shown here (individuals who made more errors, received more stimulus-specific feedback).

Further research is necessary to ensure the DOE can be replicated in an adult sample. If it can, the ramifications for improving human learning are immense. Given that the DOE appears to generalize well to multiple stimuli, there are many potential applications that have not previously been conceived. These range from the simple, for example, a child learning to count receiving different forms of praise and applause with each number; to the apparently sophisticated discriminations made by working adults.

There are many questions that future research exploring the DOE in humans can assess. It would be interesting to know how subtle the differences between outcomes can be before the effect is lost. Also, how complex can the stimuli to be discriminated be? For example, would the procedure extend to learning situations as complex as the classification of medical symptoms involving multifaceted stimuli? Finally, what are the best ways to maximize the effect in realistic learning situations?

In summary, the current research demonstrated that a DOE can be obtained in a sample of normally functioning humans when multiple stimuli are involved. This finding has important implications for human learning and should be investigated further.

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