THE DIFFERENTIAL OUTCOMES EFFECT: A USEFUL TOOL TO IMPROVE DISCRIMINATIVE LEARNING IN HUMANS

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One of the most robust and reliable learning phenomena documented in the animal learning literature is the enhancement of discriminative performance by differential outcomes. To date, very few studies have focused on this effect in humans. The results obtained in these studies support the potential use of the differential outcomes procedure in human beings as a technique for facilitating memory and learning of conditional discriminations. The main aim of this paper is to describe the differential outcomes effect and to summarize experimental studies of this effect in human beings.
Key words: differential outcomes effect, discriminative learning and humans

In daily life human beings learn to discriminate between different events and to act in consequence. For example, let us imagine that it is raining and we are going out. The rain is for us a discriminative signal that indicates what decision we should make: to carry an umbrella to avoid getting wet. If instead of taking the umbrella we take sun glasses we will end up wet and we may even catch a cold. This type of learning (it's raining-catch an umbrella), called discriminative learning, is really important in our daily life. However, there are people who have discriminative learning deficits so it is necessary to use techniques to ameliorate them. The present paper summarizes studies concerned with a technique that seems to be useful for teaching and training difficult discriminations. I refer to the differential outcomes effect.

WHAT IS THE DIFFERENTIAL OUTCOMES EFFECT?

The differential outcomes effect, refers specifically to the increase in speed of acquisition or terminal accuracy that occurs in a conditional discrimination training when each discriminative stimulus-response sequence is always followed by a particular outcome (for example, a different type of reinforcer).

Trapold (1970) provided an early demonstration of this phenomenon. He exposed rats to a discrimination problem that required a response to one lever (for example, the right lever -R1-) in the presence of one stimulus (a tone), and a response to a second lever (the left lever -R2-) in the presence of another stimulus (a click). Trapold observed an increased rate of acquisition and greater accuracy when the correct R1 was followed by pellets and the correct R2 was followed by sucrose than when both correct responses produced the same reinforcer, for instance, pellet.

Let us return for a moment to daily life. We are going to imagine a child that have to learn to cross a street in the presence of a green signal and to stop when the signal is red. The results obtained by Trapold suggest that the child might learn the task better when he receives differential outcomes following his correct responses (for instance, a kiss when he correctly chooses to cross the street and the phrase 'well done' when he correctly chooses to stop).

The differential outcomes effect has been demonstrated with a considerable range of subjects and with a variety of different consequences (for a review, see Goeters, Blakely and Poling, 1992). The matching to sample task (MTS) has been used in most studies. This task usually consists of the presentation of a sample stimulus followed by the presentation of two choice alternatives or comparison stimuli. The participant has to choose the alternative that 'goes with' the sample. In the differential outcomes condition correct responses to one sample stimulus are followed by one reinforcer and correct responses to the other sample stimulus are followed by a different reinforcer. A common variation of the matching to sample task inserts a time delay between the offset of the sample stimulus and the onset of the comparison stimuli. This arrangement is referred to as delayed matching to sample task (DMTS). Figure 1 shows an example of the DMTS. An interesting result, reported in several studies, is that the magnitude of the differential outcomes effect increases when there is a long delay between the discriminative stimulus and the choice opportunity (e.g., Brodigan & Peterson, 1976; Peterson & Trapold, 1980).

EXPERIMENTAL EVIDENCE IN HUMANS

So far, most evidence comes form animal subjects, mainly rats (e.g., Carlson & Wielkiewicz, 1972, 1976; Kruse & Overmier, 1982) and pigeons (e.g., Alling, Nickel, & Poling, 1991; Delong & Waserman, 1981;

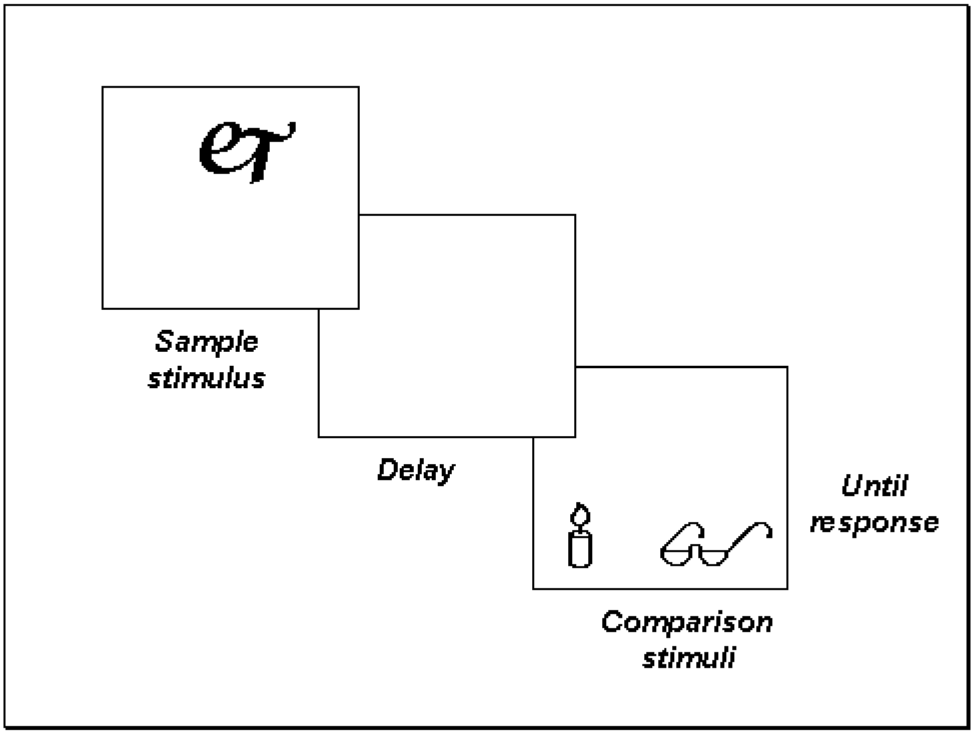

Figure 1. An example of the delayed matching of sample task (DMTS).

Peterson & Trapold, 1980; Urcuioli & DeMarse, 1997). However, the differential outcomes procedure also appears to be useful for humans, although surprisingly very few published studies have explored this possibility.

The early hints that specific outcomes might play some role in human learning come from Shepp (1962, 1964), who demonstrated that consistent response-reinforcer relations could be arranged to interfere with learning. Later on, an effect was evident in a study that examined acquisition of a two-choice successive conditional discrimination by two mentally retarded children (Saunders & Sailor, 1979). Malanga and Poling (1992) also found the DOE in a study involving four adults with mental handicaps that were taught to discriminate letters by using a two-choice discrimination task. Their terminal accuracy was significantly greater when a correct response to a given letter was consistently followed by a particular outcome than when non-differential outcomes were arranged. Dube, Rocco, and MacIlvane (1989), in contrast, found no facilitatory effect of the differential outcomes methodology among four mentally retarded adults in a delayed matching to sample task.

Maki, Overmier, Delos, and Gutmann (1995) also found the effect with normal children ranged in aged from 4 years and 6 months to 5 years and 5 months performing a conditional symbolic discrimination task (see also Estévez & Fuentes, 2003, for a similar study). They demonstrated that children learn conditional discriminations more readily when taught with the differential outcomes procedure than with the common, or non-differential, outcomes procedure. Furthermore, in an effort to understand the mechanism of differential outcomes facilitation, Maki et al. (1995) demonstrated, using the classic transfer of control procedure, that children who received differential outcomes following correct responses had expectancies for outcomes, which function to guide choice behavior.

To explore whether differential outcomes procedure is useful in children with a broader range of age, Estévez, Fuentes, Mari-Beffa, González, and Alvarez (2001) conducted a study using a delayed symbolic matching-to-sample task similar to that used by Maki et al. (1995). Participants received primary (toys and food) and secondary (green and red tokens) outcomes following their correct choice responses. There were two conditions in the experiment (see Figure 2). Participants in the differential outcomes condition consistently received one reward following correct responses to one discriminative stimulus and a different reward following correct responses to the other discriminative stimulus. For example, when the participant correctly matched the cross with the circle, he always received a green token. And he received a red one when he correctly matched the Greek letter gamma with the star. Children in the non-differential out-

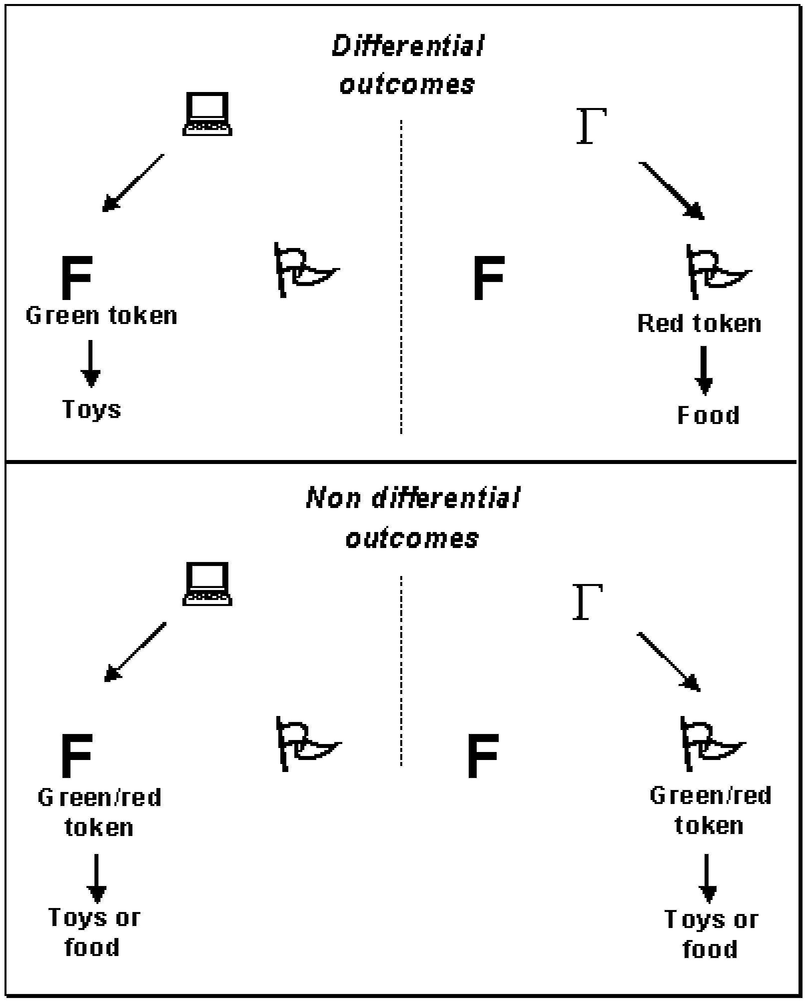

Figure 2. An example of the conditions used by Estévez et al. (2001).

comes condition also received a reward for each correct response, but the rewards given were randomized with respect to the particular discriminative stimulus. The results indicated that children from 4 years and 6 months to 7 years and 6 months learned the conditional discrimination task faster and showed a higher terminal accuracy when differential outcomes were arranged. They also found that the advantage of this effect decreased with age and was not significant in the oldest group of children. However, the differential outcomes effect was evident in children from 7 years and 6 months to 8 years and 6 months when a more difficult task was used.

In three recent studies, investigators examined the effectiveness of this procedure to ameliorate deficits presented by different clinical patients. Joseph, Overmier and Thompson (1997) found facilitative effects of the differential outcomes methodology in a study with adults with Prader-Willi syndrome –a congenital disorder that is associated with incomplete physical development, emotional liability, life-threatening obesity, and mild mental retardation or learning difficulties. In fact, participants in this study learned concepts and complicated equivalence relations only when differential outcomes were used.

Hochhalter, Sweeney, Bakke, and Overmier (2000) extended the research about the differential outcomes effect in humans by studying people with alcohol-induced amnesia. They found that participants showed a significantly better delayed face recognition when differential outcomes were arranged. Thus, these findings suggest the potential use of this procedure as aid to memory in old adults with memory impairment.

Finally, Estévez, Fuentes, Overmier, and González (2003) demonstrated that children and adults with Down's syndrome showed a better overall accuracy and learned a conditional discrimination task faster when differential outcomes were arranged. In fact, they learned the task only when their correct responses were followed by differential outcomes. Thus, the differential outcomes procedure enables Down's syndrome people to learn symbolic conditional discrimination tasks that in other circumstances would be very difficult for them to learn.

In the last years, there has been some debate over the generality of the DOE. Several authors have suggested that the validity of the differential outcomes procedure could be limited to early developmental stages and to people with cognitive deficits (Goeters et al., 1992; Maki et al., 1995). That is, as soon as the person would be able to use more sophisticated learning strategies such as verbal rules, the DOE would disappear. However, this effect has been observed in two studies that have investigated the differential outcomes procedure in healthy adults in order to aid teaching. Miller, Waugh, and Chambers (2002) found that university students (between 18 and 38 years) learned the meanings of Japanese kanji characters more quickly, although did not exhibited a better terminal accuracy, when a differential outcomes procedure was employed than when outcomes were randomly given. It’s worth noting that in their experiment, all participants showed a high terminal accuracy indicating a ceiling effect. It might be that the correcting feedback supplied after the incorrect responses also contributed to the learning observed and may have masked the contribution of differential outcomes to terminal accuracy.

Finally, Estévez, Vivas, Alonso, Marí-Beffa, Fuentes, and Overmier (submitted) investigated whether the differential outcomes procedure would influence performance of healthy adults in a discrimination task with mathematical symbols (‘> ‘ and ‘ <‘). Participants had to decide if the symbols ‘> ‘ and ‘ <‘ were used correctly in a mathematical statement. In a first experiment, the results showed that this procedure only improved performance, as evidenced by faster reaction times (RTs), of those participants who initially showed difficulties in discriminating between the two symbols. In a second experiment, the difficulty of the task was increased by changing the sign (positive or negative) of the two decimal numbers connected by either the symbol ‘>’or the symbol ‘<’. Challenged university students exhibited now the differential outcomes effect only with accuracy data. These results –as those found in a previous study with children (Estévez et al., 2001)- fully support the hypothesis that the difficulty of the task used is an important variable to take into account when exploring the application of differential outcomes training procedures in humans. Moreover, the results from both studies suggest that the differential outcomes procedure maybe a useful tool in order to improve performance in healthy adults when they perform difficult symbolic discriminations.

CONCLUSIONS

The results obtained in the aforementioned studies demonstrated that: (1) the differential outcomes effect is a general effect which is not limited to early stages of development and (2) when a task is simple and subjects can easily solve it, there is no benefit of using the differential outcome procedure. So, to obtain learning benefits from the differential outcomes methodology we must consider the difficulty of the task being used.

These results also suggest that the differential outcomes procedure may be useful as a technique for facilitating learning and memory of conditional symbolic relationships. This type of conditional discriminative choice learning is relatively common and important for our success in everyday life. For instance, when cooking a recipe we might have to discriminate between the letters “t” and “T” that may be contained in the words teaspoon and tablespoon, respectively, which refers to different spoon size. That is, we need to correctly associate the letters “t” and “T” with their respective spoon size; and a failure to do so might result in a disastrous meal. There are people who have deficits in conditional discriminative learning and, therefore, simple tasks that require this type of discriminations may be a challenge for them. Our daily life is plenty of similar examples, so it is important to validate techniques that may ameliorate their learning deficits and may facilitate their discriminative performance in such tasks. The differential outcomes procedure appears to be such a technique, which can be easily implemented in a teaching environment. Teaching new tasks and discriminations with the differential outcomes procedure could allow patients with discriminative learning disabilities to circumvent the limitations imposed on them.

However, given the scarce number of studies about the differential outcomes effect in humans, further investigation is needed to test (i) the boundary conditions of this effect, (ii) the usefulness of the differential outcomes procedure in other populations and (iii) the adequacy of this procedure in more ecologically valid educational settings such as schools.

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