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The effects of differential outcomes on learning and memory in young and aged rats

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ABSTRACT

It is claimed that using a differential outcomes procedure (DOP) generally results in (1) a faster acquisition of discrimination and (2) less disruption in accuracy when a delay interval is inserted between the stimulus cue and the opportunity to respond; this effect is best known as the differential outcomes effect (DOE). The DOE has been especially evident in aged participants. However, when acquisition in a matching-to-position task under DOP was compared to that under a non-differential outcomes procedure (NDO) by Savage, Pitkin, and Careri (1999), no difference in rate of acquisition was found between young and old rats. In the present experiment, we evaluated the effect of using a differential outcomes procedure on both learning and memory in young (3 months) and aged (24 months) rats in a more standard two-choice stimulus discrimination task. The results reported in this article showed in both young and aged subjects that DOP led to faster acquisition and less disruption in the percentage of correct responses as the delay interval was lengthened. These results confirm that employing DOP is an effective training strategy that can increase speed of acquisition and enhance memory in both young and aged subjects, with larger effects being seen in older rats.

1. Introduction

It is known that age is a factor related to memory deficit (Kubanis & Zornetzer, 1981; Morris & Kopelman, 1986). For example, in conditional choice tasks, some studies have reported that aged rats show a greater loss of correct responses compared to younger rats when a delay interval between a stimulus and the opportunity to respond is lengthened (Dunnett, Evenden, & Iversen, 1988; Dunnett, Martel, & Iversen, 1990).

The usual laboratory procedure for training conditional discriminative choice tasks, called the common outcomes (CO) consists in reinforcing each correct response (R1 and R2) with the same outcome (O1). Another procedure is non-differential outcomes (NDO); in this task two different outcomes are presented randomly after a correct response. The Differential Outcomes Procedure (DOP) basically consists of reinforcing a response (R1), in the presence of a stimulus (S1), with a

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specific outcome (O1), and reinforcing a second response (R2), in the presence of another stimulus (S2), with a different specific outcome (O2).

It has been reported that the decrement in the percentage of correct responses caused by a delay between a stimulus and the opportunity to respond can be reduced by using the DOP. Also it has been reported that DOP may facilitate learning; subjects trained with DOP require fewer sessions to reach higher levels of correct responses compared to a NDO procedure (Peterson, Linwick, & Overmier, 1987; Trapold, 1970; Trapold & Overmier, 1972).

Faster acquisition in discrimination and higher levels of correct responses in memory tasks produced by DOP have been named the differential outcomes effect (DOE). The DOE has been explained by suggesting that each stimulus (S1 and S2) comes to evoke a specific outcome expectancy (O1 and O2), and that those expectancies have stimulus properties that exert control over choice behavior (Chatlosh & Wasserman, 1992; Holden & Overmier, 2014; Linwick, Overmier, Peterson, & Mertens, 1988; Peterson, Linwick, & Overmier, 1987; Trapold, 1970; Trapold & Overmier, 1972). Alternatively, it has been suggested that the NDO and the DOP activate different brain systems (Savage, 2001). In any case, note that there are two things being labelled the DOE, one an effect on acquisition (rate or asymptote) and the other an effect on asymptotic performance under challenge (e.g., a delay between stimulus and the opportunity to respond).

A DOE has been consistently observed across different species and using different tasks (for reviews see Goeters, Blakely, & Poling, 1992; Mok, Estevez, & Overmier, 2010; Urcuioli, 2005). The most commonly used tasks have been delayed matching-to-sample (DMTS), and delayed matching to position (DMTP). The DMTS task consists in the presentation, on each trial, of one of two possible stimuli (called sample stimuli); after a delay without the sample stimulus, two comparison stimuli are presented. A response to each comparison stimulus is the correct response following one sample stimulus and not the other. The DMTP task involves presentation of one of two retractable levers to provide a sample. An animal must then choose between the levers (make a position response) after a delay (Dunnett et al., 1988, 1990; Ramos & Savage, 2003; Savage, 2001). Several studies have described the contribution made by the DOP in learning and memory in both human and non-human animals (e.g., Hochhalter, Sweeney, Bakke, Holub, & Overmier, 2000; Hochhalter & Joseph, 2001; Martínez et al., 2012; Plaza, Antúnez, Estévez, López-Crespo, & Fuentes, 2012; Plaza, Estévez, López-Crespo, & Fuentes, 2011; Savage, 2001; Savage & Langlais, 1995; Savage, Pitkin, & Careri, 1999).

There has been one notable exception to this summary. Savage et al. (1999) trained young rats (3 months old) and aged rats (23 months old) in a matching-to-position (MTP) task. One group of young rats and another group of aged rats were trained using differential outcomes (DOP), whereas other two groups (young and aged) were trained using non-differential outcomes (NDO) and then tested with a DMTP. No differences between DOP and NDO groups were observed in the acquisition phase; all groups met the acquisition criterion at the same time (12 sessions). This result is not consistent with the vast number of studies which have reported faster acquisition in subjects trained with DOP (e.g., DeLong & Wasserman, 1981; Urcuioli, 1990, 2005; Goeters et al., 1992). However, during the DMTP phase, they did find a clear beneficial effect of using differential outcomes. The groups trained with a DOP showed less disruption in the percentage of correct responses when a delay was imposed between the cue and the opportunity to respond than did groups trained with NDO. Additionally, they did not find differences in accuracy between the young and aged rats trained with delayed DOP. In contrast, subjects trained with NDO showed a dramatic decrease in the percentage of correct responses in the aged rats as well as a less dramatic decrease in the young rats as the delay interval was lengthened.

The results of this study are interesting because they reveal that DOP training, especially in aged rats, enhanced memory-based asymptotic DMTP performance relative to NDO. However, the lack of differences in the initial learning speed could be a result related to the type of task used (MTP). That is, in a MTP task used by Savage et al. (1999), the sample was exposure to a spatial location and the response was made to that same spatial location.

Based on the above, it is possible that the task used by Savage et al. (1999) represents a lower degree of difficulty for the rats resulting in a ceiling effect that does not allow observation of the contribution that the DO training has to learning speed. To evaluate this possibility, the present study was designed with the purpose of assessing the contribution that the DO in a two-choice conditional discrimination MTS-type task in young (3 months) and aged (24 months old) rats.

2. Method

2.1. Subjects

The subjects were 32 male experimentally naive Wistar rats; 16 rats were 3 months old (young rats) while the other 16 rats were 24 months old (aged rats) at the start of the experiment. All rats were food deprived and maintained at 80% of their initial body weights, individually housed and had free water access in their home cages.

2.2. Apparatus and procedure

The apparatus consisted of eight operant test chambers (Med Associates Inc., ENV-008) equipped with a food dispenser (Med Associates Inc., ENV-203M-45), a water dispenser (Med Associates Inc., ENV-202RM), and two retractable levers (Med Associates Inc., ENV-112CM) separated by 12 cm, one on each side of the food dispenser: each lever required a 0.25 N force to be activated. On the wall opposite to the levers and the feeder panel was a general lighting lamp of 28-V. A white noise amplifier (Med Associates Inc., ENV-225SM) and a speaker were used to produce a sound at 80 dB of 2000 Hz as a conditional