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Effect of Signaled Reinforcer Magnitude on Delayed Matching-to-Sample Performance in Individuals with Intellectual Disabilities

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Abstract

The present study investigated effects of signaled reinforcer magnitude in a delayed identity matching-to-sample procedure. Four individuals with intellectual disabilities were trained on conditional discrimination with three geometric stimuli as sample and comparison stimuli. Retention intervals ranged from 0.1 to 16 s. The magnitude of the reinforcer (different durations of access to a video game) was signaled by the background color of the screen. Matching accuracy was overall higher when the larger reinforcer was signaled, independently of retention intervals.

Keywords

attention; delayed matching-to-sample; humans; intellectual disabilities; memory; reinforcer magnitude; touch screen

1. Introduction

From a behavioral perspective, *memory* can be understood in terms of retention and loss of stimulus control as a function of time (Branch, 1977). That is, remembering as discriminative behavior is said to be under delayed stimulus control (White, 1985, 2001). This conceptualization of remembering as discriminative behavior suggests that such behavior is subject to both stimulus and reinforcement variables in the environment. Relative to stimulus variables such as physical similarity of the sample stimuli (e.g., White, 1985), less empirical attention has been paid to reinforcement variables that affect remembering. There are some notable exceptions, however, that investigated effects of the consequences for remembering.

When some parameters of reinforcers, such as magnitude (Nevin & Grosch, 1990), probability (e.g., White & Wixted, 1999), or delay (e.g., Sargisson & White, 2003) are manipulated, accuracy of remembering is higher in the relatively rich condition (higher reinforcer magnitude or probability, and shorter delay of reinforcement). In the phenomenon termed the signaled magnitude effect, Nevin and Grosch found that pigeons' accuracy in a delayed matching-to-sample (DMTS) procedure was overall higher when the signal

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indicated that the upcoming reinforcer was large (e.g., 4.5-s access to grain) than when it was small (e.g., 1.5-s access). While this finding has been replicated in different laboratories (e.g., Brown & White, 2005a; McCarthy & Voss, 1995), all of these studies used pigeons as subjects: the generality of this finding to human subjects has not been explored. The first purpose of the present study, therefore, was to investigate the generality of effects of signaled reinforcer magnitude on DMTS accuracy in human subjects.

The second purpose of the present study was to investigate whether signaled transitions in reinforcer magnitudes (e.g., Perone & Courtney, 1992), rather than the reinforcer magnitude of a given trial, affect DMTS accuracy in a systematic manner. In Bejarano et al.'s (2003) study, for example, the multiple-schedule components with different magnitudes of money reinforcer (rich, 25 cents and lean, 1 cent) alternated quasi-randomly such that four types of transitions between past and upcoming reinforcer magnitudes (e.g., rich-to-lean transitions) appeared equally often. They found that simultaneous matching-to-sample performance in a man with intellectual disabilities was disrupted, as measured by presence of extended pausing, when reinforcer magnitudes shifted from rich to lean, but accuracy was not. The current study extends Bejarano et al.'s study by investigating disruptive effects of such transitions on DMTS accuracy. The current study also extends previous studies on the signaled magnitude effect. Given that only the main effect of the upcoming reinforcer magnitude was reported, it is possible that an interactive effect of transition between past and upcoming reinforcer magnitudes underlies the reported main effect (e.g., accuracy on upcoming-lean trials may vary as a function of past reinforcer magnitude). The current study explored this possibility.

2. Materials and methods

2.1 Participants

Three participants (KB, MV, and RM) had mild intellectual disabilities (IQ 85-70) and one (BF) had moderate intellectual disability (70-65). They were all male, aged from 17 to 41 years, and had high receptive and expressive language. To participate in this study, they were required to demonstrate at least 90% accuracy on a simultaneous-MTS version of the procedure with the same stimuli used in this study. To encourage participation, participants earned one dollar following the completion of each session, which was exchangeable for snacks or soda.

2.2 Setting and Apparatus

Sessions were conducted in a small, sound attenuating room equipped with a touch sensitive monitor (37.5 cm by 29.5 cm). For three participants, three letter "C"-like shapes with different orientations were used as samples and comparison stimuli: if we exemplify the shapes with a letter "C", they were a letter C rotated 30, 150, and 270 degrees clockwise. For Participant RM, three geometric shapes (circle, diamond, and triangle) were used. All stimuli were presented over 4.5-cm white squares that served as the operanda. Access to a video game (Angry Birds; Rovio Entertainment, Espoo, Finland) served as a reinforcer. The participants played the game by directly touching the screen. All auditory stimuli were presented through external speakers. All session events and responses were programmed and automatically recorded by custom-written software developed utilizing Visual Basic 2010 on a computer running the Windows XP operating system.

2.3 Procedure

At the beginning of a trial, the screen was illuminated green or red that signaled a rich (32-s access to the video game) or lean (4-s access) reinforcer for correct matching, respectively. After 2 s, the sample stimulus appeared in the center of the screen. A touch to the sample

stimulus immediately removed it from the screen and initiated a retention interval of 0.1, 2, 4, 8, or 16 s. Following the retention interval, comparison stimuli were presented in three of the four corners of the screen. A correct response (i.e., touching the one that matched the sample) removed all stimuli, presented an auditory jingle, and displayed a large or small Angry-Bird icon to signal the rich or lean upcoming reinforcer, respectively. When participants pressed the icon, the icon was removed and the game stimuli were presented on the whole screen. Following the reinforcement period, there was a 2-s intertrial interval (ITI) during which the screen was all white. The game was placed in the pause status at the end of each reinforcement period so that the next time participants had access to the game, they could resume the game from the moment when they left the game. An incorrect response produced a buzz sound and a 2-s blackout, which was followed by the ITI.

A session consisted of 61 trials with the first trial not contributing to data analysis. Rich and lean trials were presented quasi-randomly such that each type of transition (e.g., rich-to-lean) occurred 15 times in a session, and that the same reinforcer magnitude was not presented on more than four consecutive trials. The sequence of the sample stimuli and retention intervals was quasi-randomly determined, with the restrictions that each combination of three samples and five retention intervals was presented once for each transition type, and that the same sample stimulus and retention interval were not presented on more than three consecutive trials. Location of comparison stimuli was randomized within a trial. Thirty-two different sequences of trials that met these criteria were created, half of which started with a lean trial and the other half with a rich trial. Every other session, one sequence was chosen at random; if the sequence was rich, the following session would begin with lean and vice versa.

After a minimum of 10 sessions, the stability was judged over the last five moving windows of the most recent 6 sessions (e.g., for sessions 1-6, 2-7, 3-8, 4-9, and 5-10) on accuracy for rich and lean trials with all retention intervals grouped together. The performance was considered as stable if the accuracy of each window did not differ more than 15% from the ground mean of the five windows and there was no upward or downward trend, as judged by visual inspection.

3. Results and Discussion

Figure 1 shows discriminability (logit p) as a function of retention intervals and reinforcer magnitudes pooled over the last six sessions. Logit p was calculated using Formula 1 (see Williams et al., 2006):

$$\text{logit } p = \log [(C+0.25)/(I+0.25)] \quad (1)$$

where C and I refer to the number of correct and incorrect choices, respectively. The constant 0.25 was added to the numerator and the denominator because logit p cannot be calculated without errors (Brown & White, 2005b). Forgetting functions were fitted to the data using the following exponential function with the square root of time (White, 2001):

$$\text{logit } p_t = a \cdot \exp(-b \cdot \sqrt{t}) \quad (2)$$

where a refers to discriminability when $t = 0$ (initial discriminability), b refers to the slope of the function (rate of forgetting), and t refers to duration of the retention interval. The curves were fitted to the data using least squares nonlinear regression performed with Solver function of Microsoft Excel 2007.

The top panel of Figure 1 shows, in three out of the four participants, discriminability was overall higher when the signal indicated the upcoming reinforcer was rich, with the slope of

the function relatively similar between the rich and lean conditions. That is, signaled reinforcer magnitudes affected initial discriminability but not rate of forgetting, with the former reflecting attentional (i.e., delay-independent) and the latter memorial (i.e., delay-dependent) components of forgetting functions (White, 2001). This finding is consistent with previous research (e.g., Brown & White, 2005a). Nevertheless, the present study extends previous research to a different population of subjects (individuals with intellectual disabilities). Along with the bottom panel of the figure demonstrating overall higher discriminability on the rich trials, the current study provides further support to behavioral theories of remembering and forgetting (e.g., Brown & White, 2009; Nevin et al., 2007), which predict that reinforcement is a major determinant of DMTS performance.

Figure 2 shows discriminability as a function of retention intervals and signaled transitions in reinforcer magnitude pooled over the last six sessions. The results were equivocal. For two participants (MV and KB), the discriminability on rich-to-lean transitions was somewhat lower than the other three (particularly the rate of forgetting was steeper on the top panel), but the difference disappears with all retention intervals combined together (bottom panel). For the other two participants (RM and BF), the discriminability on lean-to-lean transitions were overall lower than the other three (both panels). In either way, no robust interactive effect of past and upcoming reinforcer magnitudes was observed. It is possible, however, that the lack of interactive effects was due to the reinforcement schedule used in the present study. Perone (2003) demonstrated that disruptive effects of signaled reinforcer magnitudes (increased post-reinforcement pauses) were a direct function of the fixed-ratio (FR) requirements: the higher the ratio requirement, the greater the disruptive effects. Perhaps, the FR 1 schedule for correct matching in the present study was too rich and it may have masked the disruptive effects of the transitions. Indeed, lack of systematic effects of the transitions on pausing in the present study (data not shown) supports this possibility. Future studies should address this issue by employing a higher FR requirement.

It is important to note that period between DMTS trials following rich trials was considerably longer relative to the period following lean trials. Previous research has shown that longer ITI improves DMTS accuracy (e.g., Williams et al., 2006) by decreasing inter-trial interference. It is possible that discriminability on trials that followed a delivery of the rich reinforcer would be higher due to the longer separation between trials. To assess this possibility, we calculated discriminability on trials following rich and lean reinforcers regardless of the reinforcer magnitude on the current trial (i.e., assessing only the contribution of the past reinforcer). The magnitude of the past reinforcer did not systematically affect discriminability, thus reinforcer magnitude, when signaled, primarily affects discriminative control of the sample on the current trial regardless of previous trial conditions.

As a methodological innovation, the current study demonstrated that different durations of access to a video game differentially affected a dependent measure other than response allocation, such as DMTS accuracy. While previous research has shown that response allocation in a concurrent schedule was sensitive to different durations of access to a video game (e.g., Millar & Navarick, 1984), sensitivity to reinforcer magnitude differs across different dependent variables (Catania, 1963). Indeed, magnitude effects are easier to obtain in a concurrent schedule than in other schedules, with other factors being equal (Bonem & Crossman, 1988). The present results are particularly important to the field of human operant research, in which discrepancies in the behavior of humans and animals have been often observed (Perone et al., 1988). According to Shull and Lawrence (1998), one potential source of the discrepancies is the use of reinforcers that do not evoke consummatory behavior in human operant research (e.g., points exchangeable for money). The present

procedure using immediately consumable reinforcers, therefore, has a potential to contribute to the reduction of the human-animal discrepancies.

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Highlights

Effects of signaled reinforcer magnitude on delayed matching-to-sample performance were examined in individuals with intellectual disabilities

Matching accuracy was overall higher when the signal indicated the upcoming reinforcer was rich

Signaled reinforcer magnitude affected initial discriminability but not rate of forgetting

Figure 1.

Top panel: Discriminability as a function of retention intervals and reinforcer magnitudes pooled over the last six sessions. Bottom panel: Discriminability as a function of reinforcer magnitudes pooled over the last six sessions. All retention intervals were combined together for this analysis.

Figure 2.

Top panel: Discriminability as a function of retention intervals and signaled transitions in reinforcer magnitude pooled over the last six sessions. Bottom panel: Discriminability as a function of signaled transitions in reinforcer magnitudes pooled over the last six sessions. All retention intervals were combined together for this analysis. For both panels, the abbreviations RR, RL, LR, and LL, respectively, refer to Rich-to-Rich, Rich-to-Lean, Lean-to-Rich, and Lean-to-Lean transitions.