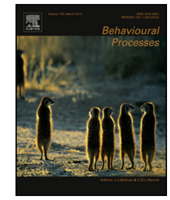
Behavioural Processes 108 (2014) 7–10

Contents lists available at ScienceDirect

Behavioural Processes

journal homepage: www.elsevier.com/locate/behavproc



Attentuation of the differential outcomes effect by extraneous reward

K. Geoffrey White*, Jessica Grace Millar

University of Otago, New Zealand

ARTICLE INFO

Article history:
Received 2 May 2014
Received in revised form 10 August 2014
Accepted 18 August 2014
Available online 16 September 2014

Keywords:
Memory
Differential outcomes effect
Delayed matching to sample
Extraneous reward
Reinforcement context

ABSTRACT

The reinforcement context model for performance in delayed matching to sample tasks (White and Brown, 2014) predicts the course of forgetting based on the assumption that rewards for extraneous behavior compete with rewards for accurate matching and increase as a linear function of retention-interval duration. In the differential outcomes effect, greater matching accuracy occurs when correct choices produce different outcomes, which the model assumes have greater reward effectiveness than same outcomes. The model was tested in the present experiment with pigeons by arranging an additional task during the retention interval of a delayed matching to sample task, center-key pecking rewarded by food delivered at variable intervals. This additional source of extraneous reward resulted in attenuation of the differential outcomes effect as predicted by the model. The model was supported by satisfactory quantitative fits to the forgetting functions for same and different outcome conditions with and without additional extraneous reward.

1. Introduction

In delayed matching to sample (DMTS), accuracy or discriminability decreases with increasing duration of the retention interval between the sample to be remembered and a subsequent choice response (see review by White, 2013). When the different choice responses produce different rewards or outcomes, accuracy at long retention intervals is enhanced, compared to when choice responses produce the same outcome (Brodigan and Peterson, 1976; DeLong and Wasserman, 1981; Peterson et al., 1987; Santi and Roberts, 1985; Urcuioli, 1990). Urcuioli (2005) reviewed substantial evidence for the theoretical view that this differential outcomes effect (DOE) involves reward expectancies, as originally envisaged by Trapold (1970). The present report offers evidence for a different view, that the DOE is a function of the reinforcement context.

Recently, White and Brown (2014) outlined a reinforcement context theory of forgetting in DMTS and applied this new theory to the DOE, as well as to a range of other findings typical of DMTS. Their theory added reinforcement context to the model originally proposed by White and Wixted (1999), in order to make quantitative predictions of the course of forgetting over a retention interval, something that the original model did not do. White and Brown assumed that during the retention interval, extraneous or other behaviors which compete with the task of remembering are rewarded by other rewards, R_o. As explained by Herrnstein (1970), extraneous or other rewards are part of the reinforcement context for the effects of rewards for performance in the main task, in this case, DMTS. In White and Brown's view, the rewards for remembering become less effective as R_o increases. Because R_o increases over the course of the retention interval, DMTS accuracy decreases as shown by the forgetting function.

In White and Wixted's (1999) model, the animal's choice between two alternatives at a given retention interval is based on the ratio of rewards gained in the past for the two choices, R_{1i}/R_{2i}. The reward ratio is specific to a point *i* on a 'stimulus value' continuum, analogous to the evidence variable in signal detection theory. The modification introduced by White and Brown (2014) was that rewards for other behavior, R_o, provided a background reinforcement context for the choice, so that at stimulus value *i*, the ratio of choices is $B_{1i}/B_{2i} = (R_{1i} + R_o)/(R_{2i} + R_o)$. That is, the effect of the R_{1i}/R_{2i} reward ratio in determining the choice at stimulus value *i*, is diluted by rewards for other behavior, R_o. By summing the choice probabilities across the distributions of stimulus value created by the two samples, frequencies of correct (c) and error (e) responses following samples 1 and 2 can be obtained, and a discriminability measure calculated, that is, $\log d = 0.5 \log_{10} ((c_1/e_1) \times (c_2/e_2))$—the measure used in the present report. By making the additional and parsimonious assumption that R_o grows as a linear function of retention interval duration (t), $R_o = a + b \times t$, White and Brown predicted forgetting functions in quantitative terms, and showed that

* Corresponding author at: Department of Psychology, University of Otago, Dunedin, New Zealand. Tel.: +64 34797629.
E-mail address: geoff.white@otago.ac.nz (K.G. White).

http://dx.doi.org/10.1016/j.beproc.2014.08.028
0376-6357/

the functions were influenced in different ways by the intercept *a* and slope *b* of the R_o growth function. Apart from these two parameters, the only other parameter in the model was stimulus disparity *D*, the distance in z units between discriminal dispersions, as in the original White and Wixted (1999) model.

White and Brown (2014) showed that the DOE could be predicted by a slightly larger background R_o on trials with same outcomes (SO) than on trials with different outcomes (DO), and which grows at a faster rate (*b*) on SO trials. This assumption makes sense if it is assumed that rewards on DO trials have a stronger effect than on SO trials and are less diluted by R_o, consistent with the finding that rewards in mixed or variable schedules of reinforcement have stronger effects in maintaining behavior than do rewards in fixed schedules of reinforcement (Davison, 1969; Fantino, 1967). White and Brown showed that their reinforcement context model provided very satisfactory fits to forgetting function data from the DOE study reported by Jones and White (1994).

The aim of the present experiment was to test the application of the reinforcement context model to the DOE, by arranging an additional source of extraneous rewards (cf. Brown and White, 2005). In the present DMTS procedure, during the retention interval following red or green samples, the center key was illuminated white and pecks had no consequence (extinction or EXT) in one set of conditions, or could produce reinforcers at variable intervals (VI) averaging 15 s in other conditions. Thus the two conditions during the retention interval arranged low (or zero) and high rates of R_o rewards which could compete with rewards for performing the DMTS task. Extraneous reward was not arranged during sample or comparison stimulus presentation in order to keep conditions for observing the red or green sample and choosing between red and green comparison stimuli the same for EXT and VI conditions. Different conditions were conducted with SO and DO trials and with EXT or VI in the retention interval. The reinforcement context model predicted a DOE in both EXT and VI conditions, with greater slopes of the R_o growth function for SO than for DO. Importantly, with the addition of a constant rate of extraneous reward, attentuation of the DOE was predicted as a result of further dilution of the effect of rewards for DMTS performance.

2. Method

2.1. Subjects

Three experimentally naïve homing pigeons (*Columba livia*) were maintained at least at 85% of their free feeding body weight. The pigeons were weighed prior to their daily experimental session, with those underweight receiving supplementary food after the session. The pigeons were individually housed in a colony room illuminated on a 12-h light:12-h dark cycle supplemented by natural light. Grit and water were continuously available in the home cages.

2.2. Apparatus

Three identical custom-built experimental chambers were 32 cm high, 35 cm wide and 35 cm deep. Each chamber had a grid floor and a front intelligent panel containing a row of three 2.1-cm diameter plexiglass response keys, 21 cm above the floor and spaced 6 cm apart (center to center). They could be lit with red, green, and white light. Sufficiently strong (>0.15 N) pecks to an illuminated key produced a relay click. A hopper in an aperture 12.5 cm below the center key could provide access to wheat, with hopper duration timed from the relevant choice or center-key response. A lamp inside the aperture and above the hopper was lit when wheat was available. The chambers were enclosed in an external box equipped with a fan that provided ventilation and masking noise. Events were controlled and recorded by a PC running Med-PC® Version 4 for Windows, in an adjacent room.

2.3. Procedure

Experimental sessions were conducted 7 days a week, approximately at the same time of the day. Preliminary shaping to peck the white center key was followed by 4 sessions of 60 trials each, with each trial requiring 5 pecks on the center key to produce 4-s access to grain. In these and all subsequent sessions, trials were separated by 12-s intertrial intervals during which the chamber was dark and responses had no effect. In each of the next 25 sessions, 5 pecks at a red or green center key darkened the center key and produced a corresponding color, red or green, on one of left or right side keys with the other key dark. Red and green samples on the center key were presented equally often over 60 trials, and the left-right location of red and green side keys were equally frequent. Five delays between the fifth center-key peck and onset of a side-key color ranged from 0.2 to 1.2 s for the first 12 sessions, and were increased to 0.2, 0.5, 1.5, 3, and 6 s for the next 13 sessions.

The DMTS procedure used in all subsequent conditions followed preliminary training. Daily sessions consisted of 97 trials for each pigeon, but data from the first trial were not analyzed. A pigeon's session was terminated if it did not finish all 97 trials in 50 min. Each trial began when a red or green sample was presented on the center key. Once this was pecked five times, the retention interval commenced and lasted for 0.2, 1, 4 or 12 s. During the retention interval, the center key was illuminated white, and in the VI 15-s conditions, pecks to it were rewarded with 2.5-s wheat access. The constant-probability VI schedule (Fleshler and Hoffman, 1962) operated solely within the retention interval, and its timing was only reset when reinforcers were delivered.

Following the retention interval, the center-key light was extinguished and the side keys were illuminated, one red and one green. A single response to the side-key color that matched the sample was reinforced with wheat access, the duration of which differed for SO and DO conditions. In SO conditions, 3-s access to wheat followed both correct red and green choices. In DO conditions, correct red choices produced 4-s access to wheat and correct green choices produced 1-s access to wheat. The order and frequency of the different delay intervals, sample colors, and side-key colors was fully counterbalanced within each experimental session (disregarding the first trial) so that each combination occurred equally often.

Four separate conditions combined SO and DO trials with EXT or VI arranged for center-key pecking in the retention interval. Each was conducted for 25 sessions, in the order: SO/EXT, DO/EXT, SO/VI, DO/VI. Each condition was then replicated for 15 sessions in the order: DO/EXT, SO/EXT, SO/VI, DO/VI. Because of an apparatus failure for one pigeon in the first DO/EXT condition, data from this condition were replaced by data from a replication for a further 15 sessions for each pigeon in a ninth condition.

2.4. Data analysis

Correct and error matching responses at each retention interval, and total center-key responses during the retention interval, were summed over the last 5 sessions of each condition. Sums of correct and error responses were used to calculate the discriminability measure $\log d$ (see above) at each retention interval for each condition and their replications, and these were averaged across replications. Averaging across replications was justified by no significant main effect of replication, or interactions with replication, in a preliminary repeated measures analysis of variance. As recommended by Brown and White (2009), 0.25 was added to each cell frequency for correct and error responses, in order to