

CONTRAST AND RESISTANCE TO EXTINCTION IN THE RAT: A TEST OF

INCENTIVE AVERAGING AND REWARD LEVEL MODELS

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ABSTRACT

Two theories, Capaldi's (1975, Note 1) reward level theory and McHose & Moore's (1976) incentive averaging theory, which attempt to predict contrast effects and differential resistance to extinction are reviewed. Predictions derived from McHose & Moore's (1976) incentive averaging theory were tested in a three phase runway experiment with rats. To do this, three reward conditions, equivalent in terms of average incentive value (1 pellet continuous reward, 3 pellet 40% partial reward and 20 pellet 20% partial reward), were derived from the model. Three separate groups received one of the schedules throughout acquisition. Four additional groups received one phase of the continuous schedule either before or after a phase of one of the partial reward schedules. Since all schedules are assumed to support the same average incentive value the theory predicts equivalent performance for all groups in all phases of the experiment. The acquisition results generally supported this prediction, with no contrast effects observed. However, the extinction results did not support the theoretical predictions, as large group differences were found, including a strong partial reinforcement extinction effect. Capaldi's (1975, Note 1) reward level theory is shown to be compatible with the present extinction results.

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Discrete trial alley running has been one of the most extensively studied responses in the animal learning literature. The apparatus is simple, a straight, narrow runway, varying in length from 1 to about 6 m. The subjects used are typically albino or hooded rats. The dependant variable is usually running speed, defined as the reciprocal of the latency to traverse some portion or all of the runway. Measurement is almost always automated, with timers accurate to .01 sec or better starting or stopping as the subject intersects photocell beams. This apparatus has been used primarily to investigate the role of reward in instrumental conditioning. Two phenomena in particular have held special interest for researchers: incentive contrast and the partial reinforcement extinction effect (PREE).

If a subject which receives a change in reward magnitude shows a change in performance to a level beyond the level displayed by a control subject that received only the second reward magnitude the effect is called incentive contrast. For example, if the performance of a group of subjects shifted from a 10 pellet reward schedule to a 1 pellet reward schedule, drops below the level of performance of a group maintained on the 1 pellet schedule throughout the experiment the effect is labelled negative contrast (NCE). Conversely, if a group was shifted from 1 pellet to 10 pellets, and performed at a higher level following the shift than a control group receiving 10 pellets throughout the experiment, the effect is labelled positive contrast (PCE).

The PREE is observed when a group that received reward on some but not all of the learning trials is found to be more resistant to extinction than a group that received reward on all learning trials.

Resistance to extinction was hypothesized to be a measure of response strength or amount of learning, while acquisition performance was proposed to be more indicative of incentive or motivation (Spence, 1956). The PREE is of theoretical interest then because, subjects that received fewer rewards exhibit greater response strength. This was problematic because response strength was assumed to increase only on reward (R) trials but subjects that received fewer R trials exhibited greater resistance to extinction and therefore presumably greater response strength. The contrast effects similarly were troublesome for theory because subjects shifted from one reward magnitude to another performed at levels different from control subjects maintained on the second reward magnitude. Because acquisition performance was assumed to indicate incentive, which is a function of reward magnitude and percentage, subjects receiving the same reward schedule were expected to show the same level of performance, regardless of previous history of reward schedules. The fact that these phenomena were at variance with early conditioning theories is in part responsible for the empirical activity invested in them. More recent theoretical approaches to instrumental conditioning have largely been built around these phenomena. Thus contrast and extinction have evoked a great deal of interest in most students of conditioning.

Incentive Contrast.

There are two types of contrast effects, initially described by Crespi (1942) as elation and depression effects. These effects are now referred to, in less cognitive language, as positive (PCE) and negative contrast effects, (NCE) respectively. Crespi demonstrated these effects in two separate experiments. To demonstrate the NCE three groups were used, two shifted groups and one unshifted control group. The postshift reward magnitude was 16 units for all groups; preshift reward magnitude was 256, 64, or 16 units. The runway was 6.3 m long and subjects were run at 1 trial per day. Both shifted groups showed a reliable NCE, running slower than the unshifted control group in the postshift phase.

To demonstrate the PCE Crespi used the same runway and three groups were again run. All groups began training on a 16 unit schedule, and then 2 groups were shifted to either a 4 unit or a 1 unit reward schedule after 21 trials. A 3 day intermission was interpolated and then the two shifted groups (16-4 and 16-1) were shifted back to the 16 unit schedule. The control group was not run in this third phase because its performance had become asymptotic and therefore the terminal level was used as the control level. A strong elation or PCE was observed, with both the 16-4-16 group and the 16-1-16 group running faster than the asymptotic level of the control group.

Negative Contrast Effects.

The NCE has been repeatedly demonstrated (eg. Crespi, 1942; DiLollo & Beez, 1966; and see Dunham, 1968), with the size of the

NCE being an increasing function of the discrepancy between preshift and postshift reward magnitude, if postshift reward magnitude is held constant (DiLollo & Beez, 1966). Mikulka, Lehr & Pavlik (1967) showed that the NCE is eliminated following partial reward training at a reward magnitude for pretraining where the NCE is found with continuous reward. However, McHose & Peters (1975) demonstrated that the NCE is found if partial reward was used, provided that the shift in reward magnitude was large enough. Incentive averaging theory (McHose & Moore, 1976), which provides a quantitative definition of "large enough", will be elaborated later in this paper.

Positive Contrast Effect.

The PCE was viewed at one time not to be a replicable phenomenon (see Dunham, 1968). However, most of the early attempts to replicate Crespi's elation effect failed to maintain continuity with his procedures (see Dunham, 1968). Crespi (1942) used a very long (6.3 m) runway and pretrained the subjects with large reward (L) before small reward (S) training. After the S training the subjects were shifted back to the L schedule and the PCE was observed. The NCE requires neither the pretraining nor the long runway (see Dunham, 1968). Recently, it has been shown that the PCE can be reliably reproduced, without the pretraining with large reward and in a much shorter runway, if reward is delayed in the goalbox (Lehr, 1974; Mellgren, 1971, 1972; Mellgren, Seybert, Wrather & Dyck, 1973; Shanab & Biller, 1972; Shanab & Cavallaro, 1975).

It has been suggested that the reason delayed reward training

yields a PCE is that, under immediate reward, the subjects in the large reward control group are responding so quickly that it is virtually impossible for the shifted subjects to run faster than the control group. In other words, the PCE is difficult to obtain under immediate reward due to ceiling effects on running speed. Since delayed reward reduces running speed and hence the ceiling problem, positive contrast is observed under these conditions.

Partial Reinforcement Extinction Effect.

A schedule of reward in which all running trials are followed by reward (R) is termed a continuous (C) schedule of reward. A schedule in which subjects are provided with a mixture of nonreward (N) and R trials is labelled a partial reward (P) schedule. Subjects trained on a P schedule have been found to be more resistant to extinction than subjects trained on a C schedule, an effect which has been labelled the partial reinforcement extinction effect (PREE). The PREE is a very robust effect, however a number of parameters in addition to the mere presence of nonrewarded trials have been shown to affect the size of the PREE.

Reward Magnitude.

In general, increasing the reward magnitude increases the size of the PREE (Gonzalez, Roberts & Bitterman, 1966; Hulse, 1958; Padilla, 1967; Roberts, 1969; Wagner, 1961). This results from an interaction between reward magnitude and schedule (see Sperry, 1965 a, b). That is, resistance to extinction and reward magnitude are inversely related with C training and either

positively related (Hulse, 1958; Wagner, 1961) or not related (Brooks & Dufort, 1967; Roberts, 1969) with P training. In other words, the effect of the reward magnitude variable on the PREE might act primarily on the C controls and not on the P subjects.

Percentage of Reward.

Weinstock (1954, 1958) has shown that there is an inverse relationship between percentage of reward and resistance to extinction. Thus as reward percentage increases resistance to extinction decreases.

Number of Trials.

In general it has been found that increasing the number of training trials will increase the PREE (Bacon, 1962; Brooks & Dufort, 1967; Hill & Spear, 1963; Lewis & Cotton, 1959, Wagner, 1961; Wilson, 1964), but the PREE is still found if very few trials of acquisition are given (Amsel, Hug & Surridge, 1968; Bowen & McCain, 1967; Capaldi & Deutsch, 1967; Capaldi, Lanier & Godbout, 1968; Capaldi & Walters, 1970; McCain & Brown, 1967; Padilla, 1967).

Reward Magnitude and Number of Acquisition Trials.

It has been found that reward magnitude interacts with number of training trials on the PREE. With limited training reward magnitude is positively related to resistance to extinction while with extended training the relationship is reversed (Campbell, Crumbaugh, Rhodes & Knouse, 1971; Capaldi & Capaldi, 1970; Capaldi & Freese, 1974; Hulse, 1958; McCain, 1970; Wagner, 1961).

Patterns of Reward and Nonreward.

The effects of the pattern of reward (R) and nonreward (N) trials interacts with the effect of the number of trials. After limited training, a schedule with more N trials followed by R trials (N-R transitions) will yield greater resistance to extinction than a schedule with equal reward percentage and magnitude but with fewer N-R transitions. Extended training yields greater resistance to extinction from a group trained on a schedule with more consecutive N trials (N length) before an R trial than for a group trained on a schedule with fewer consecutive N trials before an R trial (Capaldi, 1966, 1967). Leonard (1969) presents data which show that the magnitude of reward on a trial which precedes an N trial is inversely related to resistance to extinction. That is, a group trained with the pattern large reward, nonreward, small reward (LNS) is less resistant to extinction than a group trained with the pattern SNS. The effect of patterns of R and N trials forms the basis of Capaldi's (1967) sequential theory of the PREE.

Effect of Initial N Trials.

It has been shown that a block of N trials before R trials will increase resistance to extinction (Robbins, Chait & Weinstock, 1968; Spear & Spitzner, 1967; Spear, Hill & O'Sullivan, 1965) relative to a C only control group. The effect is called the initial nonreward effect (INE) and is usually smaller than the PREE (Robbins, 1968). Furthermore it has been shown that the number of N trials prior to C does not affect resistance to extinction while as the number of N trials prior to P is

increased, resistance to extinction is increased (Mellgren, Seybert & Dyck, 1978).

Theoretical Interpretations of the Phenomena

Because of the similarities of the experimental paradigms used to investigate contrast and differential resistance to extinction, theorists have attempted to provide a unified interpretation that encompasses both phenomena.

Two theories which have been presented to account for both contrast and differential resistance to extinction are Capaldi's (1974, 1975, Note 1) reward level theory and McHose & Moore's (1976) incentive averaging theory.

Reward Level Theory.

Capaldi divides instrumental learning phenomena into three classes of interest:

- 1) providing a reward magnitude or percentage greater than expected, such as a shift from small to large reward,
- 2) providing reward magnitude or percentage less than expected, and
- 3) providing reward which is both less than and greater than expected, such as partial reinforcement or discrimination learning. The fourth possible class, where expected reward magnitude is the same as obtained reward, is said to be uninteresting because it is assumed that no conditioning takes place.

According to the reinforcement level principle, the growth of habit and of conditioned inhibition depend upon the discrepancy between expected reward and obtained reward. Expected reward is

a construct which is hypothesized to represent the cumulative effects of the subject's reinforcement history. Expected reward is positively related to reward magnitude and percentage and becomes increasingly accurate as the number of trials increases. As the number of trials increases, expectancy also becomes increasingly more stable or resistant to change.

Habit represents the acquired tendency of a stimulus to elicit a response. Increments in habit growth will occur as obtained reward exceeds expected reward and the increments will be larger the more obtained reward exceeds expected reward. If expected reward exceeds obtained reward inhibition increments proportionately to the magnitude of the difference. Importantly both habit and inhibition are conditioned to available stimuli, which include reward stimuli such as the memory of reward [S(R)] and the memory of nonreward [S(N)] as well as apparatus and background cues. Running speed is a negatively accelerated increasing function of effective habit strength (EH) which is defined as habit minus inhibition. Let us now consider how conditioning is affected in the three classes of instrumental learning phenomena outlined above.

1) Obtained reward exceeds expected reward.

If obtained reward exceeds expected reward, performance is predicted to be increased in both postshift and in subsequent extinction. If expectancy is small and stable, then an increase in reward magnitude will result in an increase in habit strength relative to a control group trained under large reward only. Because running speed is an increasing function of habit

strength, this increase in habit strength is predicted to yield a PCE.

The PCE is predicted because the stable expectancy of small reward provides a large number of trials in which expected reward is exceeded by obtained reward, which yields large increments in habit growth and therefore faster responding. This theory also accounts for the fact that the PCE is more reliably obtained under delayed reward than under immediate reward. It is postulated that the asymptote of habit growth is determined by the magnitude of reward and that inhibition will grow during the delay interval in amounts determined by two factors, the magnitude of expected reward and secondly by the duration of the delay interval. Therefore, delayed reward will result in less EH than immediate reward because while habit will be the same in delayed and immediate reward, inhibition is assumed to be greater under delayed reward. Since running speed is assumed to be a negatively accelerated increasing function of EH, increments in EH will produce larger changes in running at lower levels of EH. According to reward level theory then the PCE is more likely to occur under delayed reward due to ceiling effects.

It also follows from the theory that animals shifted from smaller to larger rewards should show greater resistance to extinction than nonshifted subjects, if the appropriate number of trials are run in pre and postshift acquisition. Because the upshift yields habit strength in excess of a nonshifted control group the shifted group will be more resistant to extinction. If too many trials are run in postshift, the shifted group will no

longer have the excess habit and will not show increased resistance to extinction. There are two other reasons why the theory predicts that an upshifted group should be more resistant to extinction than the unshifted control. If the upshifted group has a smaller expectancy of reward at the start of extinction then it should accumulate less inhibition than an unshifted control group over the extinction trials, resulting in greater resistance to extinction. Also, if trials in extinction are massed and expected reward is lower in the shifted group, nonreward is assumed to be less frustrative for the shifted group, again leading to greater resistance to extinction. This treatment of the effects of upshifted reward is also consistent with the INE (Spear et al., 1965; Spear & Spitzner, 1967).

2) Expected reward exceeds obtained reward.

Let us now consider the second class of instrumental learning phenomena, the case where expected reward exceeds obtained reward. If expected reward exceeds obtained reward, inhibition will grow in amounts determined by the discrepancy between expected and obtained reward. Also, a frustrative trace (memory) will contribute to the decrement in performance if the intertrial interval (ITI) is short.

If a downshifted group is compared to a group maintained on the lower magnitude schedule, the theory predicts both a NCE and reduced resistance to extinction if there is sufficient difference between expected and obtained reward. DiLollo & Beez (1966) and Peters & McHose (1974) have shown that, all other things equal, the more preshift reward exceeds postshift reward,