Average reward as a determinant of S— performance in differential conditioning*

JAMES H. McHOSE, EARL R. McHEWITT†, and DOUGLAS P. PETERS
Southern Illinois University, Carbondale, Ill. 62901

A total of 68 albino rats, distributed across three experiments, received differential reward magnitude training in a nonchoice brightness discrimination apparatus. The results showed that performance to a given amount of S— reward varied between groups that received the same average reward in the runway situation, and between groups that received the same stimulus-specific incentives but different amounts of average reward in the situation.

In differential instrumental conditioning, the performance of discrimination Ss to a particular incentive condition associated with one discriminandum is depressed relative to that of nondiscrimination Ss which receive that incentive in both discriminanda (cf. Black, 1968; McHose, 1970). Thus, performance to the large reward stimulus (S+) is depressed relative to that of nondiscrimination control Ss that receive large reward in both "S+" and "S—." Similarly, the performance of discrimination Ss to S— is depressed relative to that of small-reward control Ss. Furthermore, S+ depression increases as S— reward decreases, while S— depression increases as S+ reward increases (cf. Black, 1968; McHose, 1970). Clearly, then, the amount of response depression in one discriminandum is in some general way dependent upon the difference between the reward received in that discriminandum and the reward received in the other discriminandum.

While it is clear that an incentive difference is implicated in determining both S+ and S— performance levels, there are at least two different viewpoints as to the precise nature of this difference variable. Black (1968), for example, attributes S— depression to a discrepancy between S— incentive and the average incentive in the runway situation. Thus, as the difference between S+ and S— incentives increases, so, of course, does the difference between S— incentive and average reward amount. Alternatively, McHose (1970) attributes S— (and S+) depression to a difference between S+ and S— incentive directly.[1]

The set of "variables" including average reward, specific S+ and S— reinforcement contingencies, and the relationships between these factors contains variables that are not orthogonal and thus cannot be manipulated in, for example, factorial fashion. Interest should thus be focused on which group of orthogonal variables within this set is best suited to describe the data of differential conditioning (cf. Leventhal, 1970). The present paper is concerned with a preliminary evaluation of the incentive difference variable critical in producing S— depression effects. First, data across two experiments are presented that provide for the comparison of discrimination performance between groups which received the same average amount of reward and the same S— reward amount, but which differed with respect to the reward amount associated with S+.

EXPERIMENTS 1 and 2

Method

The Ss were 36 naive male albino rats, 90-110 days old, obtained from the Holtzman Company, Madison, Wisconsin.

The differential conditioning apparatus consisted of a gray startbox (SB) and parallel flat black and flat white alley-goal sections. The SB could be aligned in series with either the black or the white alley-goal section. The SB, alley, and goal sections were 10, 32, and 10 in. long, respectively, with an interior width and height of 3.5 and 4 in., respectively, throughout the apparatus. Opaque doors separated the SB and goal sections from the alley segment of the apparatus. Photocell clock circuitry provided traversal times over the first three 12-in. segments of the alley-goal section (Experiment 1) and the first two 6-in. and second 12-in. segments in Experiment 2.

Ten days prior to the first training day (Day 11), Ss were placed on a 23-h food deprivation schedule maintained throughout the experiment. On Days 9 and 10, each S was handled for approximately 5 min, allowed 2 min exploration of the alley sections of the apparatus, and fed 20 45-mg Noyes pellets, identical to the subsequent reinforcement pellet, in addition to its regular 1-h feeding.

In Experiment 1, eight Ss were assigned randomly to each of two groups labeled according to the number of pellets received on each trial in the positive discriminandum (e.g., black alley) and in the negative discriminandum (white alley), respectively: Groups 9/1-1 and 9-1. Group 9/1-1 received nine pellets on one half of its S+ trials and one pellet on the remaining trials, while Group 9-1 received nine pellets on all S+ trials and one pellet on all S— trials. The brightness of the positive (S+) alley was counterbalanced within each group. All Ss received four trials per day. Group 9/1-1 was administered two black (B) and two white (W) trials per day according to the following recursive schedule: BWBW, WBBW, WBWB, BWWB, for a total of 96 trials. This group received nine pellets on one-half of the S+ trials and one pellet on the remaining S+ trials according to the following recursive schedule: 9119. Group 9-1 received one S+ and three S— trials in each daily block of four trials such that the daily trial position of the S+ trial was counterbalanced over each block of 16 trials.

In Experiment 2, 10 Ss were assigned randomly to Groups 12/0-0 and 12-0 and administered a total of 120 runway trials. All other procedural details were identical to those of Experiment 1.

In both experiments, trials were administered to squads of Ss comprising an even number of Ss from each experimental condition, half of which were assigned to each brightness counterbalance condition. These squads also contained Ss assigned to experimental conditions of no interest to the present report. Each S within a squad received its first daily trial before any S received its second trial, etc., resulting in an intertrial interval of approximately 6 min. On each trial, the start door was opened after S had oriented toward the door for 3 sec, and S was removed from the goalbox immediately after consuming the reward.

Results

Group mean start speeds (first 12-in. segment) for the various conditions of Experiments 1 and 2 are plotted as a function of blocks of 12 total trials in Fig. 1. This measure and the next 12-in. measure yielded essentially equivalent results, with the greatest statistical reliability in Experiment 2 actually occurring in the second 6-in. component of this 12-in. measure. However, since such a division of response measures was not possible in Experiment 1, the 12-in. start measure will be presented for both Experiments 1 and 2. For each group, speeds on the S+ trials within

*Supported by Research Grant NSF-GB30510 from the National Science Foundation.

†Now at Bard College, Annandale-on-Hudson, N.Y. 12504.

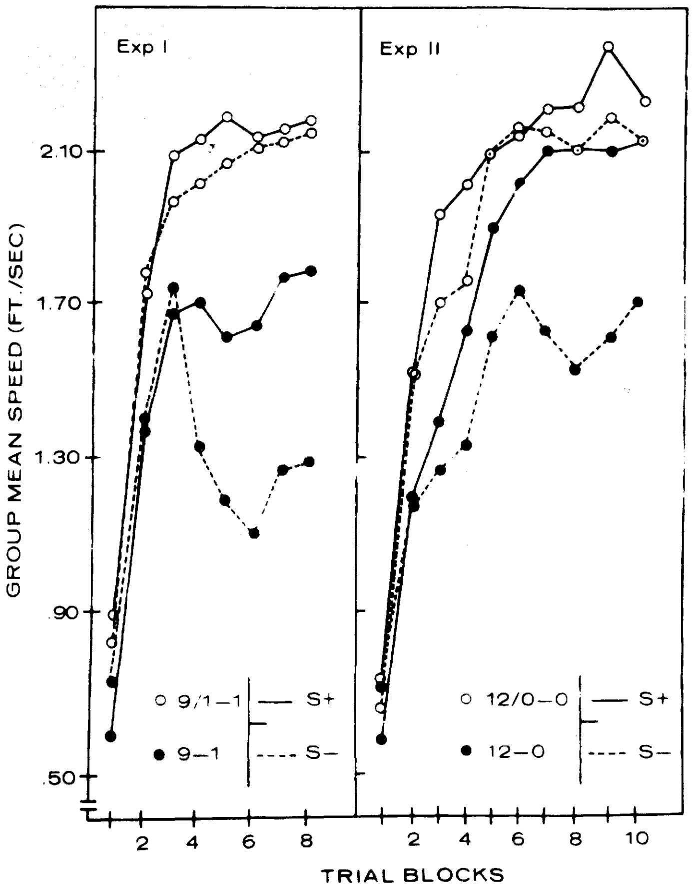

Fig. 1. Mean speeds for the various conditions of Experiments 1 and 2 as a function of blocks of 12 trials.

each block are plotted separately from those on S— trials. As may be seen in Fig. 1, the groups that received constant large reward in S+, Groups 9-1 and 12-0, displayed substantially faster speeds to S+ than to S—, while the groups that received varied reinforcement in S+ displayed minimal differences in speeds to S+ as compared with S—. Analysis of variance of the data of Experiment 1 over Trials 61-96, including groups, discriminanda, and S+ brightness as factors, yielded a significant Groups by Discriminanda interaction, $F(1,12) = 18.74$, $p < .01$. Subsequent pair comparisons (t tests) indicated that only Group 9-1 developed significantly faster speeds to S+ than to S—. Similar analysis of the data of Experiment 2 (Trials 73-120) yielded a significant Groups by Discriminanda interaction, $F(1,16) = 6.59$, $p < .025$. Subsequent pair comparisons of S+ to S— speeds within groups yielded a significant ($p < .01$) difference for Group 12-0, and a marginal ($.10 < p < .05$) difference for Group 12/0-0.

In both experiments, the S— performance levels of the group that received constant large reward in S+ were depressed relative to those of the varied S+ reward condition. Pair comparisons (Tukey a) subsequent to the analysis reported above proved these differences to be statistically reliable ($\alpha = .05$). Similarly, the S+ speeds of Groups 9-1 and 12-0 were reliably ($\alpha = .05$) slower than those of Groups 9/1-1 and 12/0-0, respectively.

Discussion

In Experiments 1 and 2, speeds to a given S— reward clearly varied between groups that received the same average amount of reinforcement in the runway apparatus. Thus, Group 9-1 ran more slowly to 1-pellet S— reward than did Group 9/1-1, even though both groups received a total of 12 pellets over each block of four trials. Similarly, Group 12-0 ran more slowly to nonreward in S— than did Group 12/0-0. Thus, while previous data are equally amenable to the notion that S— performance decreases as the discrepancy between S— and average incentive increases (cf. Black, 1968), or the assertion that S— performance decreases as the difference between S+ and S— reward conditions increase (cf. McHose, 1970), the latter viewpoint is most compatible with the present data.

In placing the present observation of minimal discrimination and attendent S— depression in Groups 9/1-1 and 12/0-0 in the context of previous literature, it is important to note that such groups typically display minimal discrimination (McHose, 1970; McHose, Maxwell, & McHewitt, 1971). This observation alone is consistent with a notion that S— depression decreases as the discrepancy between average reward and S— reward decreases. What little previous evidence exists also suggests that groups such as 9-1 and 12-0, which received a greater proportion of S— compared with S+ trials, show minimal discriminations as compared with groups receiving equally frequent S+ and S— trials (Perkins, 1970). This observation alone is also consistent with an "average reward hypothesis." However, the present observation that Groups 9/1-1 and 9-1, and Groups 12/0-0 and 12-0, differ in discrimination behavior vitiates the averaging hypothesis, a hypothesis that heretofore seemed to provide a reasonable account of the effects of variation in S+ reward amount and proportion of S+ trials.

While the present data rule out the notion that a discrepancy between average and S— reward magnitude is solely responsible for S— depression effects, they do not demonstrate that direct differences between S+ and S— incentive are solely responsible for S— depression effects. What is needed, in this context, is a comparison between groups that receive the same S+ and S— incentives but different average rewards in the runway situation. Experiment 3 provides such information by varying the proportion of S+ and S— trials, and thus average reward, between groups that receive the same S+ and S— reward conditions. In this experiment, S+ reward magnitude was also manipulated as a second means of varying average reward.

EXPERIMENT 3

Method

The Ss were 32 naive male albino rats, 90-110 days old, obtained from the Holtzman Company, Madison, Wisconsin.

The apparatus was the same as that used in Experiment 2, as were the deprivation, prefeeding, and individual trial procedures.

Eight Ss were assigned randomly to each of four groups labeled according to the number of pellets received in the positive discriminandum (e.g., black alley) and the proportion of S+ to total trials: Groups 12-75, 7-75, 12-50, and 7-50. All Ss always received one pellet reward in the negative discriminandum (e.g., white alley). The brightness of S+ was counterbalanced within each group.

All Ss received a total of 96 trials at the rate of four trials per day. The 75 groups were administered three S+ (P) trials and one S— (M) trial per day according to the following recursive schedule (for black-positive Ss): MPPP, PMPP, PPPM, PPMP, or (for white-positive Ss): PMPP, MPPP, PPMP, PPPM. The 50 groups received two black (B) and two white (W) trials per day according to the following recursive schedule: BWBW, WBBW, WBWB, BWWB.

Results

While the first three response measures yielded essentially similar results, the early run (second 6-in. segment) measure data proved most statistically reliable. Group mean early run speeds for the various groups are presented in Fig. 2, collapsed over the magnitude of S+ reward variable (left panel) or the proportion of S+ trials variable (right panel). Each trial block contains the data over eight total trials, with speeds on S+ trials plotted separately from those on S— trials.

Looking first at the effects of the proportion variable, it may be seen in Fig. 2 that in the later stages of training the 75 groups ran more slowly to S— than did the 50 groups, while the 75 group speeds to S+ were faster than those displayed by the 50 groups. Analysis of variance of the data over Blocks 10-13, including proportion S+, magnitude S+, brightness of S+, and discriminanda as factors, yielded a significant Proportion by Discriminanda interaction, $F(1,24) = 18.11$, $p < .01$. Subsequent contrast comparisons indicated that the 75 groups ran significantly ($p < .01$) more slowly to S— and faster to S+ as compared with the 50 groups.

As may be seen in the right panel of Fig. 2, performance to S— varied with S+ reward, with the 12-pellet groups eventually running more slowly to S— than did the 7-pellet groups, while these conditions displayed minimal differences in S+ performance. The analysis reported above yielded a significant S+ Magnitude by Discriminanda interaction, $F(1,24) = 8.94$, $p < .01$, and subsequent contrast comparisons showed that the S+ magnitude effect was significant only with respect to S— performance. Because the effects of S+ magnitude on S+ performance were not statistically reliable in this analysis despite a small but consistent mean difference in 12- as compared with 7-pellet S+ speeds, an analysis of the S+ data over Blocks 10-13 was conducted. This analysis, which included the proportion, magnitude, and S+ brightness factors, yielded a significant effect of S+ proportion, $F(1,24) = 6.81$, $p < .025$, but the effects of S+ magnitude were, again, unreliable ($p > .20$).

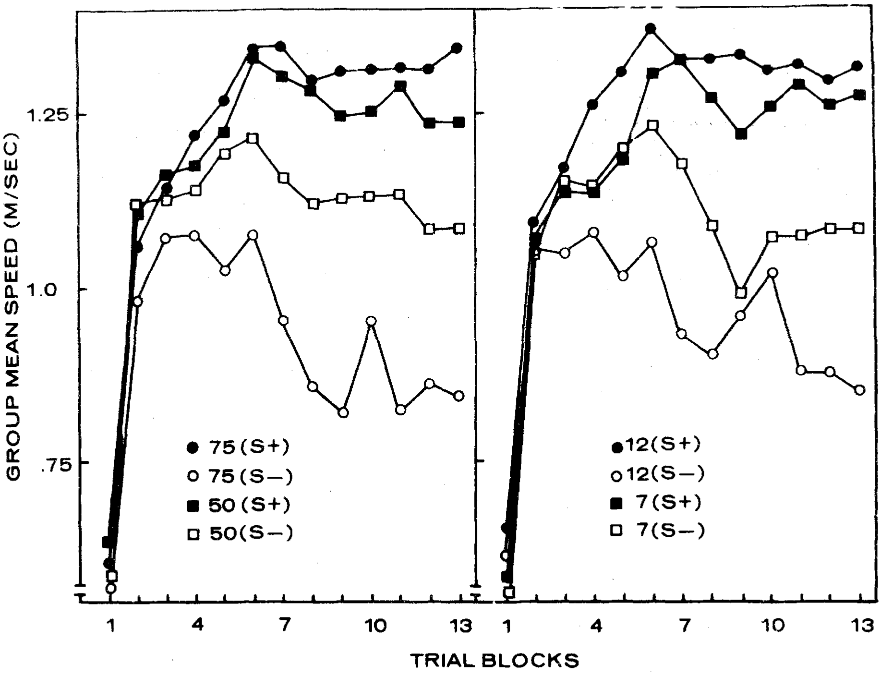

Fig. 2. Mean speeds for the various conditions of Experiment 3 as a function of blocks of 8 trials.

Finally, two salient features of the present data are not depicted in Fig. 2. First, all four groups ran reliably ($p < .01$) faster to S+ than to S—, as evidenced by postanalysis t tests. Secondly, neither the S+ Magnitude by S+ Proportion interaction nor the triple interaction of these variables with discriminanda yielded F ratios approaching conventional levels of significance. Thus, the S+ magnitude effects depicted in Fig. 2 are representative of the 50 and 75 groups and, similarly, the proportion effects shown in Fig. 2 are representative of both the 12- and 7-pellet S+ reward conditions.

DISCUSSION

The present data show that as the proportion of S+ to total runway trials increases, performance to a given reward associated with S— decreases. Thus the 75 groups ran more slowly to S— than did 50 groups which were comparable in terms of S+ and S— reward amount. These findings are, of course, consistent with theoretical interpretations (e.g., Black, 1968) of S— contrast effects which assume that a discrepancy between average reward in the situation and S— reward inhibits S— performance. Within this framework, the observation that S— speeds decrease as the proportion of S+ trials increases is attributable to the same inhibitory mechanism that accounts for the observation in the present as well as in previous studies (cf. Black, 1968; McHose, 1970) that as S+ reward magnitude increases S— performance decreases. Following Black (1968), this mechanism is frustration which results from a discrepancy between average expectancy (r_g) and the reward received in S—. The observed effects of proportion of S+ trials on S— performance are clearly inconsistent with the suggestion (McHose, 1970) that S— depression results solely from a difference between S+ and S— incentives since 75 and 50 groups should have the same S+ and S— incentive values.

While the effects of proportion of S+ trials on S— performance are seemingly consistent with the notion that S— performance is depressed as a result of a discrepancy between S— incentive and average incentive, at least two observations mitigate the "averaging" hypothesis and the particular frustration-expectancy theory variant in which it is embedded. First, with respect to the averaging variable per se, the data of Experiments 1 and 2 indicate that even when average reward in the runway and S— reward are equated between conditions receiving different S+ reinforcement contingencies, S— performance decreases as S+ incentive increases. Secondly, Black's (1968) frustration-based theory, which accounts for the present S— data, would appear to encounter difficulties with the present S+ data. Several previous studies have shown that the S+ performance level of discrimination groups is depressed relative to that displayed by nondiscrimination Ss, which always receive the S+ reward (cf. Black, 1968; McHose, 1970). This S+ depression may be attributed to a generalization of the inhibition that occurs in S— as a result of a discrepancy between S— and average incentive values (Black, 1968). One apparent implication of this viewpoint is that S+ as well as S— speeds will decrease as the proportion of S+ trials increases, since S— inhibition presumably increased with an increasing proportion of S+ trials. The data of Experiment 3 clearly contradict this implication in that the 75 groups ran faster to S+ than did the 50 groups. Moreover, note that, in the present study, proportion of S+ trials affected S+ performance while S+ magnitude did not, even though these variables should jointly determine average incentive value. Parenthetically, it is important to recognize that the absence of an S+ magnitude effect on S+ performance is consistent with a number of previous results (cf. McHose, 1970), as, apparently, is the observed effect of S+ proportion on S+ speeds (Perkins, 1970).

Summarizing the present experiments with respect to the "average reward" variable, it should be clear that the manner in which "average reward" is manipulated (e.g., S+ reward contingency or proportion of S+ trials) is critical in determining the effects of "average reward" on differential conditioning performance. Since the manner of manipulation must be specified and average reward is nonorthogonal to variables such as S+ reward contingency and proportion of S+ trials, the present data would seem to rule out the use of average reward in the situation as an explanatory variable in interpreting differential conditioning performance.

On the basis of the preceding considerations, it would seem that neither a theory which attributes S+ and S— depression effects solely to differences between S+ and S— incentives (McHose, 1970) nor one that employs the averaging hypothesis (Black, 1968) is entirely suitable to account for all of the data. Probably the best fashion in which to view the role of the proportion of S+ trials variable is to assume that rather than affect traditional r_g-based expectancies, manipulation of the proportion variable affects the predictability of an S+ or S— event prior to S's exposure to the discriminanda. In this connection, Ludvigson & Gay (1967) have shown that when an impending S— trial is signaled in the startbox (SB), S— depression in the alley portions of the apparatus is markedly attenuated. Similarly, it may be assumed that signaling an S+ trial will attenuate S+ depression, a notion which finds some theoretical precedent in Perkins's r_g-preparedness hypothesis (Damman & Perkins, 1969; Perkins, 1970). For 75 groups, placement in SB signals an impending S+ trial, thus maximizing S— depression and minimizing S+ depression effects relative to conditions in which SB cues are uninformative, i.e., the 50 groups of the present study. From this viewpoint, both S+ and S— depression effects are attributable to one behavioral process, uncertainty, rather than to separate processes for S+ and S— depression effects. Uncertainty would, in turn, vary positively with both the *importance* of resolving the uncertainty and the *degree* of uncertainty. Presumably the incentive equations presented by McHose (1970) deal only with the importance factor, and a more general set of descriptive equations for differential conditioning performance, including the degree of uncertainty (proportion of S+ trials in the present study) factor, will be required.

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NOTE

1. The present viewpoint is that, while Black's interpretation employs the "average reward" concept, his theoretical approach does not necessitate the use of "average reward." The different viewpoints as to the nature of the critical incentive difference variable, as represented by Black (1968) and McHose (1970), merely serve to emphasize that the previous literature affords no basis for distinguishing between the roles of average reward and stimulus-specific incentives in determining differential conditioning performance.