RETROACTION AND PROACTION IN RATS AND GUINEA PIGS

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TO THE RESIDENT INSTRUCTIONAL STAFF:

We the undersigned have read and recommend approval of this thesis.

Chairman, Thesis Committee

Member

Member

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ABSTRACT

Sixty-day-old rats and guinea pigs and 75-day-old rats were tested on a brightness discrimination task to ascertain whether or not they exhibited the effects of proaction and/or retroaction. Proaction was evaluated by requiring Ss to 1) acquire a discrimination to a criterion of 18 out of 20 responses; 2) learn its reversal to the same criterion; and 3) relearn the same problem to criterion. The corresponding control Ss rested while the experimental Ss acquired the first discrimination but learned the second and third problems in the same manner and to the same criterion as the experimental Ss. In the test for retroaction Ss were required to: 1) learn the discrimination to criterion; 2) learn the reversal of this discrimination to the same criterion; and 3) relearn the initial discrimination, again to the same criterion. Subjects in the corresponding control groups acquired the initial and final tasks to criterion while the experimental group Ss were learning their respective tasks, but rested during the second stage when Ss in the experimental group were learning the reversal. Twenty-four hours separated criterion performance and succeeding reversal tasks in all experimental and control groups. Analysis of variance on the percentage errors to criterion indicated that the 60-day-old rats exhibited proactive interference (PI) while the 75-day-old rats and the guinea pigs showed no PI effects. In contrast, all Ss displayed the effects of retroactive interference (RI). The results were discussed in terms of the relation of the two mechanisms to improvement in SDR learning as well as in terms of their relevance to other studies which tested for proaction and/or retroaction in non-human species.

INTRODUCTION

Summary of Problem

Performance on successive discrimination reversal (SDR) tasks has been related to phylogenetic status or cortical development (e.g., Bitterman, 1965a). Subsequent studies have shown that species capable of displaying progressive improvement on SDR also exhibit proactive interference (PI), whereas species which do not improve show no PI (Behrend, Powers, & Bitterman, 1970). Recently, however, it has been pointed out that, in addition to the phyletic level, the extent of physical development of the organism at birth (i.e., developmental rate) is also correlated with SDR performance. For example, Braveman (1971), using daily reversals of a brightness discrimination, has found only marginal improvement in 60-day-old guinea pigs, early developing (precocial) organisms, while substantially better improvement was found in 60-day-old rats, late developing (altricial) organisms.

The present study was designed to test whether or not there were correlated differences in proaction between 60-day-old rats and guinea pigs. In addition, 75-day-old rats were also tested in order to assess the influence of maturational differences of the visual modality between rats and guinea pigs on the development of proaction. This interest evolved from the work of Campbell, Riccio, & Rorbaugh (1971) which indicated that maturational differences such as these appear to be influential in the retention of responses controlled by aversive stimuli.

Review of the Literature and Statement of Problem

Successive discrimination reversal (SDR) and probability learning (PL) are both discrimination tasks which have been used to test the presence of higher mental processes in various organisms. Successive discrimination reversal involves alternating the conditions of reinforcement so that an instrumental response to a particular stimulus (or stimuli) is rewarded and, then, after a predetermined criterion has been reached, the response to another stimulus is rewarded. Once the criterion has been met for the second discrimination, the reward contingencies are reversed so that a response to the first stimulus is again rewarded. The SDR task, then, is one which involves alternating the reward associated with the stimulus cues between discriminations. Similarly, PL is a task which involves the use of inconsistent rewards. The reward inconsistency in the PL task, however, is within a single discrimination rather than between discriminations in that the reward is associated with one stimulus on only a certain percentage of the total trials and with the other on the remaining trials.

The performance of different species on both SDR and PL has been described in terms of certain patterns of responses by which the organisms typically adapt to the inconsistent reward. For example, depending on the species tested, SDR performance may reveal various degrees of progressive improvement on successive reversals. That is to say, some species may become more proficient at acquiring successive discrimination reversals in that they require fewer trials and/or make fewer errors to reach criterion. Moreover, for those species which typically show progressive improvement, the SDR curve assumes a particular shape. Typically there is a performance decrement on one of the reversals shortly after the original learning (OL). In most instances this performance decrement occurs on the first reversal while performance on succeeding reversals improves to the extent that on later reversals it is at least as proficient as that on OL. Sometimes, however, the improvement exhibited can be characterized as 'steady', in that performance continues to improve beginning with OL, and, thus, there is no initial decrement. The performance of the 'steady' improvers, however, has been attributed to habituation and, consequently, should not be considered equivalent to the performance of those that exhibit an initial decrement (Mackintosh, 1969). Finally, there are those species which do not appear to benefit from successive reversal training. These organisms tend to make as many errors and/or take as many trials to reach criterion on later problems as they did on earlier ones.

Bitterman's (1960, 1965a, 1965b) concern with the factors underlying the type of performance exhibited by various species led him to the conclusion that the performance on SDR (and PL) tasks was determined by the extent of cortical development. He developed a behavioural taxonomy in which the rat and fish were chosen as standards because they differed greatly in terms of cortical development, yet they were both amenable to testing in analogous situations. At the same time, moreover, the rat and fish displayed behavioural tendencies which were clearly distinguishable from each other

(Bitterman, Wodinsky, & Candland, 1958). The rat, for example displayed progressive improvement in SDR and maximized, or non-randomly matched, in PL. The fish, on the other hand, failed to show progressive improvement on SDR and randomly matched during PL acquisition. The performance of the species which were subsequently tested was dichotomized as fish-like or rat-like and produced the basis for a behavioural taxonomy which turned out to be consistent with the common phyletic ordering. Several recent experiments with fish, however, have reported improvement in SDR (Mackintosh & Cauty, 1971; Setterington & Bishop, 1967; Squier, 1969; Woodward, Schoel, & Bitterman, 1971), a finding which seriously challenges the validity and generality of Bitterman's taxonomy. In each instance, however, the results can be traced to a procedural variation which appears to have been responsible for the reported findings.

Even so, attempts at an explanation for the species differences which typically are found, have centered around the idea that performance on SDR is dependent not only on the learning of a given set of contingencies (Gonzalez, Behrend, & Bitterman, 1967; Bitterman, 1968; Behrend, Powers, & Bitterman, 1971). That is to say, it has been argued that the level of performance attained by an organism ultimately depends on how well an organism can forget the immediately preceding problem. It seems to be a reasonable argument that the quicker or more completely S can forget a response to one stimulus, the quicker he can make the same response to another stimulus, even in the presence of the first stimulus. Gonzalez, et al. (1967) have suggested that species such as fish, which typically show no improvement in SDR, do not forget previously acquired responses. On the other hand, species such as the pigeon, which do show improvement, do forget which stimulus was last rewarded. The differential ability of the two species to forget has been attributed by Gonzalez, _et al_. (1967) to the action of PI--the interference produced by some event learned prior to the learning of another event.

The conclusions regarding PI in fish and pigeons were based on the results of an experiment by Gonzalez, _et al_. (1967) in which it was found that the retention differences postulated to exist between the fish and pigeon should be apparent in the analysis of performance by these species on reversal (R) and non-reversal (NR) days of a visual SDR task. The experiment was designed so that the stimulus associated with the reward was changed every two days. The first day of each reversal was the R day, i.e., the discrimination of the previous day was reversed, while the second was the NR day. It was predicted that if forgetting occurred, there would be a reduction in the strength of the performance established on the previous day. Thus, there should be a progressive decline in errors on R days and, at the same time, there should be an increase in errors on the NR days. The results of the experiment revealed precisely this function.

To account for their results, Gonzalez, _et al_. suggested that after the acquisition of the OL, the second and subsequent problems were influenced by PI. Specifically it was maintained that once _S_ had learned OL and its reversal (R_1), the next reversal (R_2), which was the same as OL, was easier than R_1 because the retention of OL interfered with the retention of R_1 causing it to be forgotten. Having forgotten R_1, S was then ready to acquire R_2 without interference from R_1. Similarly, PI arising from R_1 acted on R_2 causing it to be forgotten and left S ready to acquire R_3 and so on. An important assumption at this point was that PI accumulated over the course of successive reversals and contributed an increasingly greater influence on each reversal. This assumption handled the problem raised by the fact that R_1 having been previously forgotten was supposed to provide PI for the forgetting of R_2. As a consequence of PI accumulation, there was a greater likelihood that fewer errors were committed on later reversals than on earlier ones. In this way then, the role of PI was tied directly to performance on SDR.

The retention decrement hypothesis suggested by Gonzalez, et al. (1967) has been questioned on logical grounds by Weiner and Hupert (1968), who pointed out that Ss often improve to such an extent that they acquire discriminations later in the series faster, or with fewer errors, than OL (e.g., see Gossette, 1968). In such cases, they maintained, it was logically impossible for a PI of a previous reversal to reduce error scores to below the level of OL in that Ss are not able to forget more than they have learned. At best, they claimed, the retention decrement hypothesis could only explain instances in which performance on later reversals was equal to that on OL. In addition, Gossette (1969) has supported Weiner and Hupert's argument with a replication of the study by Gonzalez, et al.

(1967) in which he was unable to show convergence between the R and NR functions. In fact, in Gossette's study NR performance was consistently superior to the R performance, indicating that the preference established on the R day was not forgotten but carried over to the NR day.

These findings were used by Gossette (1969) as evidence against the adequacy of the retention decrement hypothesis in the explanation of progressive improvement on SDR tasks. He suggested instead that there were two processes which operated simultaneously to produce improvement. Specifically, during the early discriminations, when error scores were above that for OL, PI was influencing SDR performance. During later reversals, however, when error scores were below the level of OL, the new source of stimulus control was the reversal habit itself. In the latter case, the cue for responding was the non-reinforcement of an incorrect response on the first trial of a new problem. This would suggest that, after extensive training, errors should not occur after the first trial of a reversal, a finding which has been reported by Gossette (1968) for several species. Furthermore, with some mammals it had been found that the error score eventually dropped to zero (Gossette, 1969), suggesting that the first choice was a matter of chance with a strong win-stay/lose-shift aftereffect.

Although Gossette (1968) and Gonzalez, _et al_. (1967) differed in their conceptualization of how interference facilitated improvement in SDR performance, both agreed that PI was involved. That is to say, Gonzalez, et al. attributed improvement in SDR largely to PI, whereas Gossette pointed out that in addition to PI, retroactive interference (RI)--the interference of an interpolated task on the re-acquisition of a task--and the reversal habit also played a major role in performance on SDR. As noted by Gossette (1968), any effect RI might have on performance, however, is not readily available for analysis since its effects are completely confounded with the effects of PI after the first reversal, i.e., performance on the second reversal could be either a function of PI produced by OL acting on the memory of the first reversal or a function of RI produced by the first reversal acting on the memory of OL. It is clear from this analysis, however, that both PI and RI might be involved in the reversal process but, as yet, the function of these processes and their specific roles have not been empirically tested in situations outside the SDR paradigm.

In summary, then, PI and/or RI have been said to influence reversal learning by acting on the memory of a previous discrimination which could interfere with the acquisition of a new discrimination. That is, the absence of PI has been shown to be associated with SDR performance which characteristically shows no improvement, while the presence of PI has been correlated with progressive improvement on SDR. Furthermore, experiments not involving the SDR paradigm have demonstrated PI in the rat under certain conditions (Cole & Hopkins, 1968; Gleitman & Jung, 1963; Maier & Gleitman, 1967; Rickard, 1965) and not under others (Gleitman & Steinman, 1963).

The major difference is that in those studies which found PI, the Ss were 60 days old (i.e., Rickard, 1965), while those studies in which PI was not found the Ss were between 90 and 120 days old. It is possible that the older Ss, by virtue of their more extensive extra-experimental experiences, would not show PI under the same conditions of testing as the younger ones (cf. Campbell, Riccio, & Rohrbaugh, 1971). Working with pigeons, Kehoe (1963) also failed to find PI. In contrast, there has been little empirical work on the influence of RI on SDR performance. However, both Crowder (1967), working with rats, and Kehoe (1963), working with pigeons, have found RI in both species.

Although the validity of the arguments proposed by Gonzalez, et al. (1967) and by Gossette (1968) is increased by the studies which independently demonstrate PI and/or RI in species which typically show improvement in SDR, at least two problems still exist before one can conclude that the underlying relationship between RI and/or Pi and SDR performance is a function of cortical development. First is the problem concerning studies which fail to show PI in rats and pigeons, Ss which typically show progressive improvement in SDR. A possible inference is that PI is not necessary for SDR improvement, as noted above. A second problem is that the assessment of cortical development has, for the most part, remained correlational in nature, i.e., it is confounded with phyletic level. In fact, an examination of Bitterman's (1965) behavioural taxonomy suggested that there is, in addition to the relationship between phyletic status and performance on SDR and PL, a strong relationship between developmental rate and performance on these tasks (Braveman, 1971). Specifically, Braveman noticed that Ss which showed rat-like performance on brightness SDR and PL tasks tended to be organisms whose perceptual-motor development is not very advanced at birth (i.e., altricial), while those that showed fish-like performance tended to be fully developed at birth (i.e., precocial). These differences in developmental rate, moreover, produce organisms who, at the same chronological age (CA) have vastly different kinds and amounts of prior experience. The altricial rat, for example, has its eyes closed for the first 15-16 days of life (Bolles & Woods, 1964) and, therefore, at weaning (21 days) has had only 6-7 days of patterned vision. The precocial guinea pig, on the other hand, has its eyes open immediately after birth and can experience patterned vision within an hour after birth as demonstrated by the optomotor response (Katz, unpublished data). A 21-day-old guinea pig, then, has had 21 days of patterned vision--more than three times the amount of a rat of equal CA.

The relationship between performance on SDR and developmental rate, furthermore, was found not to be unique to Bitterman's data. For example, an analysis of the results of several studies by Gossette (1968; 1969) revealed that altricial organisms made fewer total errors than precocial organisms on visual SDR tasks, χ^2 (1) = 10, $p < .01$. Furthermore, direct examination of the influence of developmental rate on SDR performance of closely related rodents by

Braveman (1971) has led to similar conclusions. Comparisons, for example, between 60- and 101-day-old rats and guinea pigs on a brightness SDR task produced an interaction between age and species as a result of significantly more errors on 20 daily reversals by the young guinea pigs than by the other groups. The fewest errors, on the other hand, were exhibited by 101-day-old guinea pigs, while both age groups of rats were intermediate to these extremes. Braveman noted that these results were not merely the product of a failure of the young guinea pigs to acquire a visual discrimination in that he found that (1) they had indeed showed marginal improvement on SDR and (2) prior to daily reversals, they had acquired a simple discrimination faster and with fewer errors than any of the other groups.

In light of these performance differences on SDR between the 60-day-old guinea pigs and the 60-day-old rats, and in light of the postulated relationship between PI and/or RI and SDR performance, the present experiment was designed to test for proaction and retroaction in these closely related Ss who develop at different rates. Employing the standard test for proaction and retroaction (e.g., Ellis, 1969), comparisons were made between 60-day-old rats, 60-day-old guinea pigs, and 75-day-old rats on a brightness discrimination. Comparisons between the 60-day-old guinea pigs and 60-day-old rats were between Ss of different species at different stages of development who had developed at different rates. Comparisons between the 60-day-old guinea pigs and 75-day-old rats, on the other hand, were between Ss of different species and different developmental rates but who had 60 days of visual experience. Thus, in the first instance the comparisons were between species at different stages of development, whereas the second involved comparisons between species that were supposed to be at equal stages of visual development. Based on the results of Braveman (1971) and others (e.g., Gonzalez, *et al*., 1967) it was predicted that the 60-day-old guinea pigs would show less PI than the young rats but about the same as the 75-day-old rats. It was also predicted that the rats and guinea pigs would show RI. However, there being no information available on the possible interactions that might occur between RI and PI, no directional hypothesis could be made concerning the amount of RI present as a function of age or species.

METHOD

Subjects. The *S*s were 40 female guinea pigs and 40 female albino rats, 50 days old at the beginning of adaptation, and 40 female albino rats, 65 days old at the beginning of adaptation. The *S*s were obtained from colonies maintained at the Medical School of Memorial University of Newfoundland and from the Canadian Breeding Laboratories.

Apparatus. The apparatus consisted of two identical, single-unit T-mazes with start-boxes 20.6 cm. long, 9.4 cm. wide and 13.8 cm. high. The 39.4 cm. alleyway was the same height and width and led to goal-boxes 46.9 cm. long, also of the same height and width. In one T-maze the white goal-box was on the left and the black one on the right, while this arrangement was reversed in the other maze. The start-boxes and runways of both mazes were painted grey. Each maze had hinged, one-way doors between the start-box and the alleyway and between the choice point and each of the goal-boxes. In an attempt to reduce extra-maze cues, the T-mazes were housed in identical environments constructed of white linen. Three sides and the top were completely covered, while the fourth side was left partially open to allow easy access to the E.

Procedure. On each of 10 days before the beginning of testing, all Ss were habituated to the maze for 30 min. per day with food and water available. On the last two days of habituation training, Ss were placed in the start-box and allowed to explore the maze for the regular 30 min. period but with no food or water available in the goal-boxes. All habituation training as well as all discrimination training took place before the four-hour feeding period. Water was available on an ad lib. basis during all phases of the experiment.

The task on which Ss were compared was a 100:0 brightness discrimination with 20 trials per day and an inter-trial interval averaging 5 min. On the first day of discrimination training Ss were placed in the start-box and allowed to make a choice of one of the two unbaited goal-boxes. A response was considered to have been a completed choice when Ss hind feet entered either goal-box. The brightness of the goal-box was considered its preferred brightness and Ss were detained there for 5 sec. Then, in order to equalize exposure to both brightnesses, Ss were guided to their non-preferred goal-box, where they remained for an equal length of time.

All trials began when S was placed in the start-box and ended when three pellets of the appropriate food reward had been ingested (45 mg. Purina Guinea Pig Chow for guinea pigs and 45 mg. Noyes food pellets for the rats). No time limit was placed on the Ss in the start-box. However, once at the choice points, Ss were allowed only 30 sec. in which to select a goal-box. If Ss did not respond within the alloted time, they were gently prodded in the direction they were facing. Any S that was moving, however, even after the alloted 30 sec., was allowed to make an unaided response. If S selected an unbaited goal-box, i.e., made an incorrect response, it was returned to the start-box and restarted. This procedure was followed until a correct choice was made and the reward consumed. Each error following the first on any trial was counted as a repetitive error.

The Ss of each age group and species were divided into subgroups corresponding to the sequence of brightness discriminations they were required to learn, i.e., for proaction: group ABB' and group -BB'; for retroaction, group ABA' and group A-A'. The letters used to identify the groups refer to explicit phases of the traditional experimental procedure employed to evaluate the effects of proaction and retroaction. Task A consisted of a 100:0 black-white discrimination problem where the stimulus associated with the reward was the brightness opposite to the one selected on day 1. Task B was also a brightness discrimination but the reward stimulus was the one which had not been rewarded in task A. Thus Ss in group ABB' learned task A first, then task B, and then relearned task B (B'). Similarly Ss in group ABA' were first required to learn task A, then task B, and then relearn task A (A'). Groups -BB' and A-A' refer to the control groups required for proaction and retroaction, respectively. That is, Ss in group A-A' first learned task A, then rested while Ss in ABA' learned task B, and then were required to relearn task A (A'). Subjects in group -BB', on the other hand, rested while Ss in group ABB' were learning task A, then learned task B and were required to relearn task B (B'). Subjects were required to acquire all discriminations to a criterion of 18 out of 20 correct responses before they were shifted to the next phase of the experiment, e.g., from task A to B.

RESULTS AND DISCUSSION

Proaction

The percentage of errors to criterion on task B' was calculated for each S. A 2 x 3 (Treatment (T)--experimental or control; group (G)--60- and 75-day-old rats and 60-day-old guinea pigs) factorial design analysis of variance revealed a significant interaction between T and G, $F(2/54) = 3.8$, $p < .05$. Inspection of Figure 1 reveals that both experimental groups of rats made a greater percentage

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Insert Figure 1 about here

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of errors than their corresponding control groups on task B'. The experimental group of guinea pigs, on the other hand, made fewer errors than its corresponding control. Neuman-Keuls multiple comparisons, however, revealed that the only significant difference was between the experimental and control groups of the 60-day-old rats ($\underline{p} < .05$). In addition, these comparisons revealed that the experimental groups of rats made significantly more errors than the experimental group of guinea pigs ($\underline{p} < .05$). The results of this analysis, therefore, support the conclusion that only 60-day-old rats showed any sign of PI. On the other hand, based on the trends in these data, it appears that the 75-day-old rats showed a tendency toward PI and the 60-day-old guinea pigs revealed a tendency toward proactive facilitation (PF).

One possible reason for these findings, which is not related to any difference in retention between Ss, is that Ss in the experimental groups might have required more days to acquire the discrimination on task B', and, hence made more errors than the corresponding controls. In order to evaluate this possibility, a 2 x 3 factorial design analysis of variance was calculated on the number of days Ss took to reach criterion on task B'. The results of this analysis revealed no significant differences for any of the main effects or interactions. Thus, it is unlikely that the results of the analysis

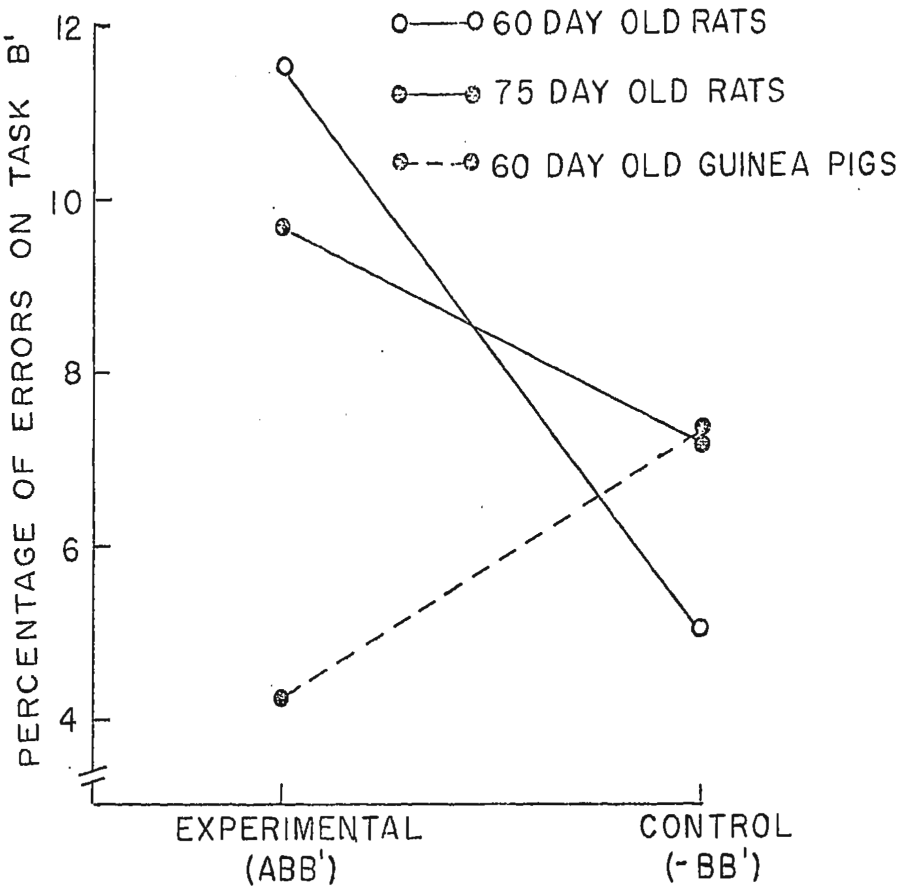

Fig. 1 Percentage of errors on task B' by groups ABB' and -BB'(P1).

or the percentage errors to criterion, reported above, reflected differences in length of time (i.e., number of days) Ss required to attain task B'.

Another possible basis for the difference among the groups is that the acquisition of the first task B was differentially difficult for the three experimental groups. That is to say, the relative facility with which the guinea pigs learned task B' could merely have been the result of the fact that task B was easier for them than for the other Ss--possibly because they were better able to transfer information acquired on task A to task B. The performance of the various groups was compared with a 2 x 3 x 4 (Treatment (T)--experimental or control; group (G)--60- and 75-day-old rats and 60-day-old guinea pigs; block of 5 trials (B)) repeated measures design analysis of variance which was computed on the percentage errors on task B. The results of the analysis revealed a significant T effect, $F(1/54) = 38.94$, $p < .001$, a significant B effect, $F(3/162) = 35.16$, $p < .001$, and a significant interaction between T and B, $F(3/162) = 9.19$, $p < .001$. It is evident from Figure 2 that the experimental Ss tended to make a greater percentage of

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Insert Figure 2 about here

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errors on each trial block than the control Ss, and that the interaction resulted from the fact that the experimental Ss reduced their rate of errors more than the controls. A Neuman-Keuls analysis

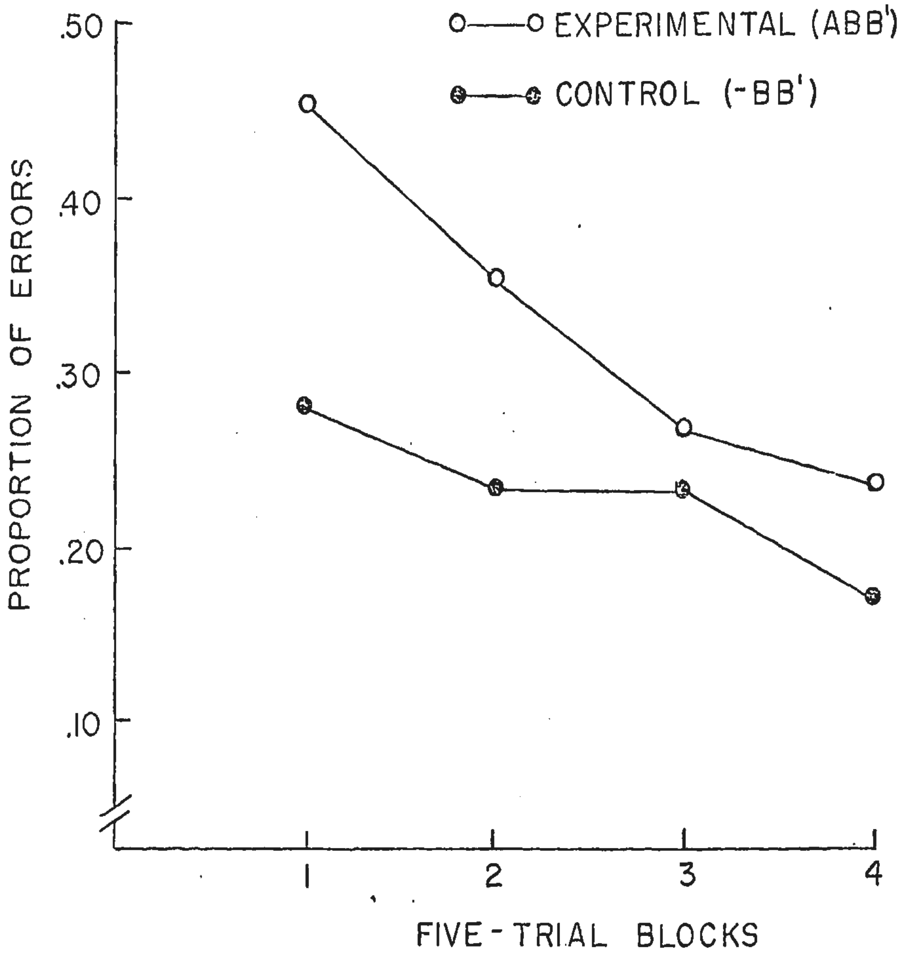

Fig. 2 Learning of original task B by groups ABB' and -BB'.

revealed that the only significant differences between the experimental and control Ss occurred on the first two blocks of trials. This finding can be directly traced to the fact that the experimental Ss had previously acquired task A while the controls had not. Thus task B represented a reversal for the experimental Ss and original learning for the controls. By the time Ss had completed 15 trials, however, the effects of the previous experience on task A disappeared. The important finding from this analysis is that negative transfer from task A to task B did not occur differentially for the three groups of Ss. Thus task B was no more difficult for the 60-day-old rats, than for the 75-day-old rats, or the 60-day-old guinea pigs.

Finally, it is possible that the first tasks were not comparable for the experimental and control Ss and in some way contributed to the pattern of obtained results. A 2 x 3 factorial design analysis of variance on the percentage of errors to criterion on the first task for all groups revealed a significant main effect for experimental vs. control Ss, $F(1/54) = 13.46$, $p < .01$. Neuman-Keuls multiple comparisons revealed that this effect was due to the experimental group of guinea pigs making significantly more errors on task A than the corresponding control group of Ss on task B. Similar comparisons were not significantly different for both groups of rats. It is therefore possible that because it took them longer to learn the task, the experimental group of guinea pigs learned more about the discrimination on task A than other Ss on their first task. This could have made task B relatively more easy for the experimentals than for the controls and could have produced the tendency toward PF found in the guinea pigs. The previous analysis, however, has revealed that task B performance for the experimental group of guinea pigs was not different from task B performance of any other experimental Ss and, as a result, it is not likely that the first task performance influenced the results to any great extent. Thus, by the time Ss had acquired task B, the performance differences which had appeared on the initial discrimination for experimental and control guinea pigs were equally as evident for experimental and control Ss in all groups.

As a consequence of these analyses, it can be concluded that the differences in task B', previously reported, represented differences which were not artifacts of some other aspect of the experimental paradigm. From these results, then, it would appear that the 60-day-old rats showed PI, whereas no evidence of PI was found in the 75-day-old rats and 60-day-old guinea pigs. Trends for the last two groups do, however, suggest a tendency toward PI in the former and PF in the latter.

Retroaction

The second analysis corresponds to the question concerning the existence of retroaction in the three groups. As before, a 2 x 3 (Treatment (T)--experimental or control; group (G)--60- and 75-day-old rats and 75-day-old guinea pigs) factorial design analysis of variance was done on the percentage errors to criterion on task A'. The only significant effect was that for T, *F*(1/54) = 101.38,

$\underline{p} < .0001$. Inspection of the group means revealed that the experimental groups made a greater percentage of errors to criterion than the control groups (see Figure 3). This effect did not interact with the groups of Ss, indicating that each of the groups tested showed similar degrees of RI.

Insert Figure 3 about here

In addition to the above analysis, a 2 x 3 factorial design analysis of variance was done on repetitive errors (i.e., the number of times Ss selected the unbaited goal-box before selecting the rewarded one following an initially unrewarded response). A similar analysis on the proaction data showed nonsignificant differences between groups, whereas the present analysis revealed a significant interaction between T and G, $\underline{F}(2/54) = 6.35$, $\underline{p} < .01$. Neuman-Keuls comparisons on the means involved in the interactions (see Figure 4) revealed that 60-day-old guinea pigs and 75-day-old rats in the experimental group made more repetitive errors than Ss in the control groups. This confirms, in part, the finding reported by Braveman (1971) that these Ss do not respond to the occurrence of a non-rewarded selection in the same way as the other Ss in that they tend to perseverate following non-reward to a greater degree.

Insert Figure 4 about here

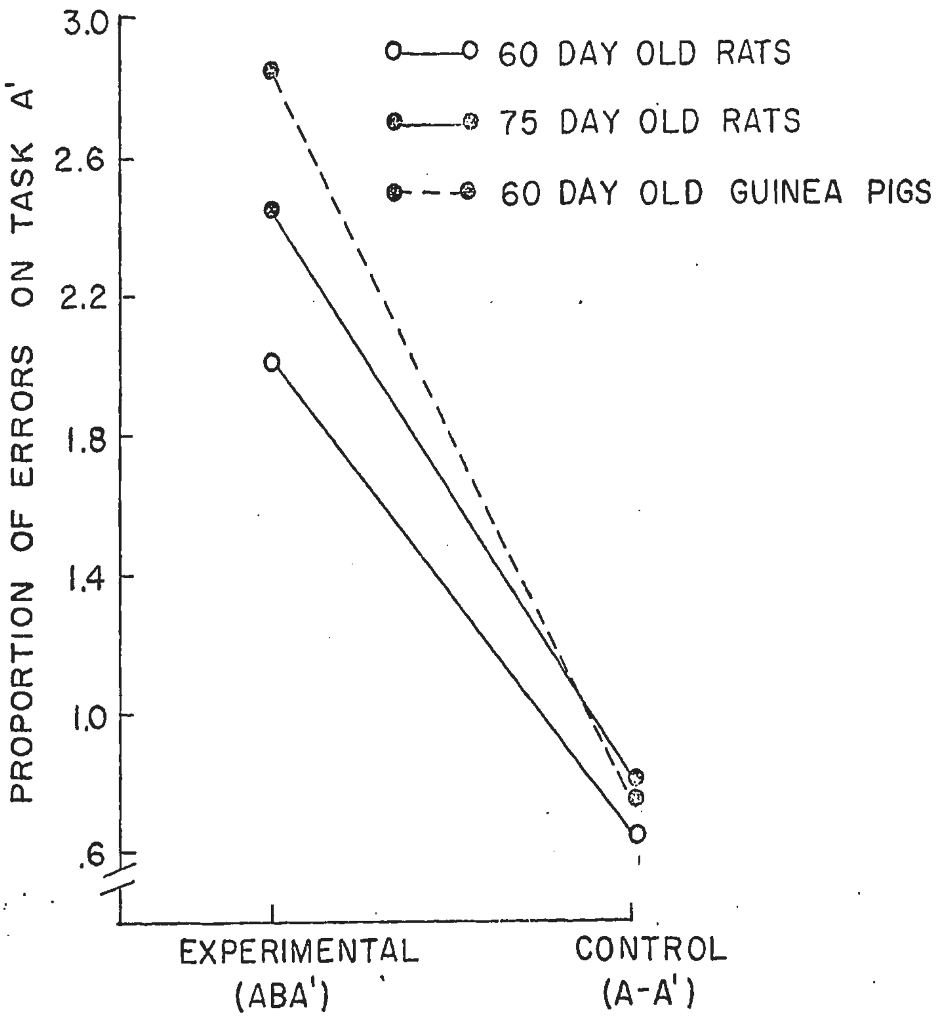

Fig. 3 Proportion of errors on task A' by groups ABA' and A-A'(RI).

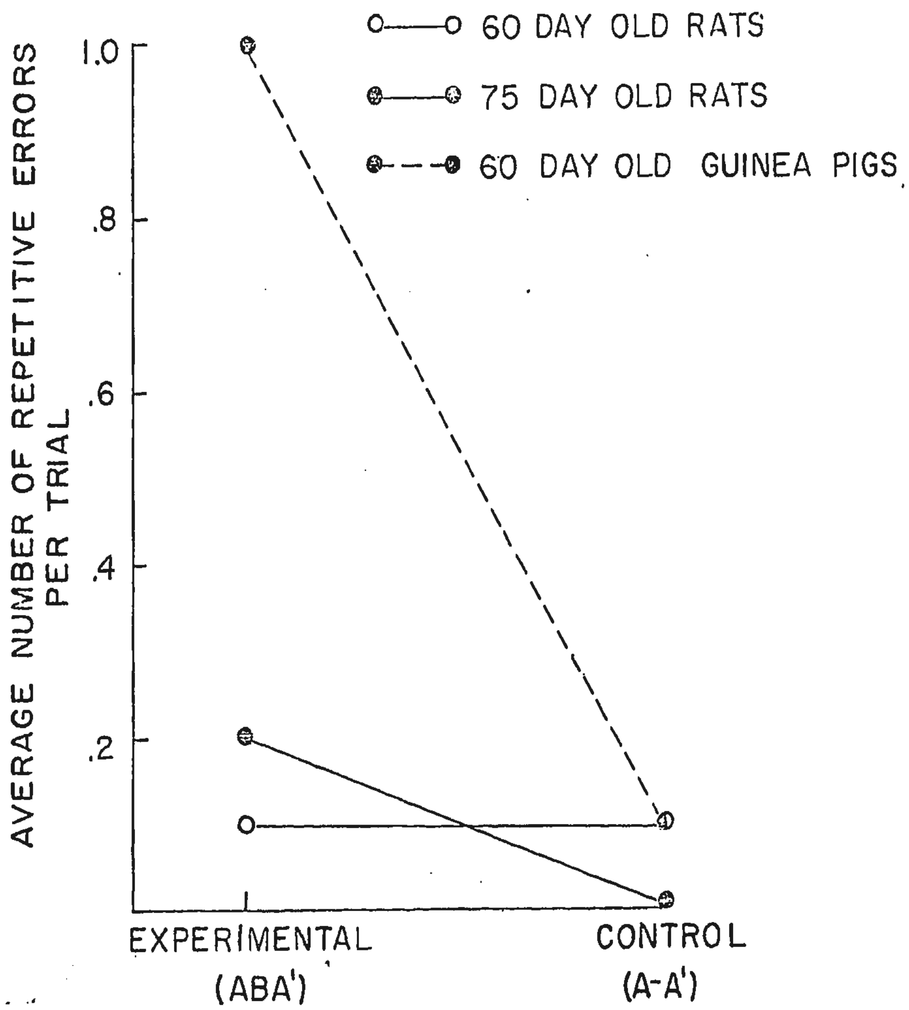

Fig. 4 Repetitive errors per trial by groups ABA' and A-A'(RI).

CONCLUSION

The results of the present study revealed that, under similar conditions of testing, PI occurred in 60-day-old rats but was absent in 60-day-old guinea pigs and 75-day-old rats, whereas RI occurred in all Ss tested. In part, the pattern of results suggests that PI appears to be related to the extent of visual experience, as noted by Campbell, et al. (1971), independent of the species factor. Specifically, the performance differences reported between the 60-day-old rats and 60-day-old guinea pigs could be attributed to either species differences or to developmental rate differences. However, the performance differences between 75-day-old rats and 60-day-old guinea pigs, i.e., Ss who had had the same amount of visual experience, were not statistically reliable. Moreover, comparisons between Ss who had not had equivalent lengths of visual experience, i.e., between 60- and 75-day-old rats and between 60-day-old rats and guinea pigs, revealed that the 60-day-old rats had shown evidence of PI, whereas the 75-day-old rats and guinea pigs revealed no reliable evidence of PI. Thus, it appears that the experiencial factor is of greater importance in the determination of performance than the species factor.

On the other hand, consideration of trends in PI data from the 60-day-old guinea pigs and 75-day-old rats suggests that the species factor may have been important. That is, the fact that Ss from different species, who had been equated for length of visual experience, showed evidence of opposite types of proaction suggests that, in a more sensitive task, the species factor may influence the type of proaction exhibited. It is possible, for example, that the primacy of visual experience per se in the guinea pig was an important influence in this respect. This point is in reference to the fact that even though the 75-day-old rats and the 60-day-old guinea pigs both had had 60 days of visual experience, one major developmental difference between them was that the guinea pig was born with adult-like capacities while the rat was without vision for approximately the first 15-16 days of life. As such, the primary sensory experiences of the rat are via other modalities, e.g., tactile, olfactory, kinesthetic (see Bolles & Woods, 1964), whereas vision plays an important role in the sensory experiences of the guinea pig from birth. Thus, it is possible that when the rats began to use their visual inputs, a certain amount of information was transferred from the other modalities to the visual mode. For example, activities such as food-getting behaviours, which prior to vision had been under the control of olfactory and tactual inputs, come under the additional control of visual inputs once the rats' eyes are open. In contrast, the entire developmental sequence of the guinea pig involved vision as well as the other sensory modalities. It is possible, then, that this sequence-related difference in the maturational characteristic of the two species is an important factor and influences whether or not the facilitory or inhibitory effects of proaction are exhibited.

Consistent with this idea is the suggestion made by Campbell, et al. (1971) that the extended visual experience of the guinea pig is important in the formation of non-specific proactive pools of experience, which, in turn, influence the ability to retain certain information.

The method used to equate the animals could also have been the basis for the differences in trends exhibited by the 60-day-old guinea pigs and 75-day-old rats. Specifically, Bolles & Woods (1964) have reported that rats first opened their eyes at 15-16 days. It was assumed from this that the animals also began to use their visual system for pattern vision at this time. If true, it follows that the 75-day-old rats and 60-day-old guinea pigs both have had 60 days of visual experience with patterned stimuli since, as previously pointed out, the guinea pig can see patterns within an hour after birth. Observations by the present investigator, however, cast doubt on this simplistic formula for equating rats and guinea pigs on patterned visual experience. For example, it has been observed that although rats do open their eyes for the first time at approximately the age of 15 days, they do not keep them open nor do they make use of the visual modality consistently until several days later. Starting at 15 days, then, the rat appears to undergo a transition from a complete reliance on other modalities to a partial reliance on the visual system. Based on these observations, the 75-day-old rat cannot be said to be equivalent to the 60-day-old guinea pig. Thus, it is possible that differences in trends as divergent as those reported for the 60-day-old guinea pig and the 75-day-old rat would have resulted from either the fact that they had not been equated for visual experience or from the fact that species differences per se were important in determining whether Ss exhibited the inhibitory or facilitory aspects of proaction.

The analysis of the number of repetitive errors to criterion also suggests that the developmental differences between the rats and guinea pigs could have produced differences in the type of proactive pool of reward-related information which may be formed during development. The results of the analysis suggested that the guinea pigs formed more extensive visual reward-related proactive pools than the 60-day-old rats. Specifically, when the guinea pigs were required to reverse their responses to the brightness stimuli, they tended to repeat incorrect responses more than Ss in other groups. It could be that the persisting memory of previous contingencies between visual stimuli and reward allowed the animals to consistently respond to the currently non-rewarded stimulus. The 60-day-old rats, on the other hand, not having had as much visual experience, and presumably having a smaller proactive pool of information, made exactly the same number of repetitive errors when the task followed a rest period as when it was the reversal of an immediately preceding task. In addition, the 75-day-old rats once again followed the example of the guinea pigs and produced significantly more repetitive errors when acquisition of a discrimination was the reversal of an immediately preceding discrimination rather than when it followed a rest period (see Figure 4).

The results of the present study, in conjunction with those reported by Braveman (1971), provide an extremely interesting pattern. For example, Braveman demonstrated marginal improvement in the 60-day-old guinea pig on a brightness SDR task and normal improvement in the 60-day-old rat. The results of the present experiment reveal that the 60-day-old rats were influenced by the effects of PI and RI, while the 60-day-old guinea pigs and 75-day-old rats were influenced by the effects of RI only. In one sense these findings substantiate the position taken by Gonzalez, et al. (1967) in that another species, the rat, exhibiting progressive improvement on SDR, also exhibited the effects of PI in an experimental paradigm independent of the SDR paradigm.

The fact that the Ss in the present study also exhibited RI supports the suggestion made by Gossette (1968) that it is possible for progressive improvement in SDR to be related to two processes instead of one. The results of the present experiment also suggest that these processes may be two different aspects of an interference phenomenon--namely retroaction and proaction. However, conclusions regarding the action of retroaction are not immediately clear. From the present results it is known that all Ss tested are influenced by RI to the same extent. Therefore, it could be argued that retroaction effects do not appear to be important in differentiating SDR behaviour. Given that RI effects are present, however, the question arises concerning the way in which RI influences SDR performance. Gossette (1968) has suggested that RI acts on later reversals when performance falls below the level attained on OL. At the same time, Gossette maintains that the action of PI is strongest on early reversals before performance returns to the level attained on OL. Although the present data do not refute this conjecture, the question concerning the action of RI on _early_ reversals is left unanswered. One possibility is that RI might somehow have an effect on within-day learning. In Braveman's (1971) data, for example, even though there were significant differences between the rates of improvement over reversals exhibited by the various _S_s, all the _S_s appeared to improve at approximately the same rate within daily sessions (Braveman, personal communication). If daily improvement were a function of proactive events and if different groups of _S_s showed different amounts of proaction, then the functions describing daily improvement should be different for the different groups. They were, however, very similar in shape and slope, suggesting that whatever produced them affected all _S_s to the same extent. Since RI has been shown to influence all _S_s to the same extent, it is suggested that RI acted on within-day improvement. This conclusion is only speculative as is the conceptualization of how RI might function on SDR learning. It is suggested, for example, that when _S_ acquires the new discrimination, interference from it acts retroactively on the memory of the previous problem causing the latter to be forgotten and, as a result, leaving _S_ more favourably disposed to learning the new discrimination more completely.

Relationship of the Present Study with Other RI-PI Studies

As noted in the introduction, other studies have attempted to discover whether or not RI and/or PI can be found in organisms phyletically lower than the humans. The results of the present experiment appear to be consistent with certain of these studies and at variance with others. For example, as in Kehoe's (1963) experiment with pigeons and Crowder's (1967) study with rats, RI was found for all Ss tested. Similarly, so far as the 75-day-old rats and 60-day-old guinea pigs are concerned, the present experiment is consistent with others which have been unable to demonstrate PI in rodents and pigeons (e.g., Gleitman & Steinman, 1963; Crowder, 1967; Kehoe, 1963). One notable exception to this is that the 60-day-old rats in the present experiment showed strong PI effects. A possible reason for this discrepancy between this group and the other studies could be the age of the Ss. This assumption is, in part, confirmed by the results of a study involving young rats in which PI was found (Cole & Hopkins, 1968). However, age cannot be the sole determinant of whether PI will be found since Maier & Gleitman (1967) have also found PI in Ss who were 100-120 days old--Ss of the same age as those in studies in which no PI was found. Thus, with the exception of the Maier & Gleitman study, it would appear that PI is an age-related phenomenon in rodents. It is possible, however, that Maier & Gleitman's findings were a function of the task employed. Whereas T-mazes were used in all the rodent studies cited above, Maier & Gleitman used a bar-press situation. A T-maze allows the organism to build up a repertoire of stimulus cues associated with different aspects of the maze, including proprioceptive and visual feedback from running in the alleyways, turning corners, and pushing through swinging doors. At the same time brightnesses are changing from grey in the start-box-runway area to black and white at the choice point, to either black or white after a choice has been made. The Skinner box, on the other hand, provides minimal visual stimulation other than the stimulus cues for reinforcement or non-reinforcement. The simultaneous presentation of the stimulus cues in a Skinner box, as in the Maier & Gleitman (1967) study, is analogous to only one small part of the maze situation--namely, the point in time when S is at the choice point.

Perhaps, then, the difference in the amount of information available to Ss in the maze and Skinner box can account for why older and, thus, more experienced Ss failed to show PI in certain experimental situations yet showed it in others. For example, when an animal has had a limited amount of visual experience on which to base ongoing behaviour, either because of age or because of experimental manipulation, newly-learned responses can become confused with previously-learned responses which would allow PI to be demonstrated. In contrast, the older animal, by virtue of his greater experience, has formed certain response habits which are not easily disrupted by newly-learned responses. As a result, newly-learned responses and formerly-learned responses do not interfere with each other but remain separate. Thus, it would be more difficult to demonstrate PI in these organisms. However, placing the older Ss into a restrictive test environment, as was the procedure in the Maier & Gleitman study, could have neutralized the benefits of prolonged visual experience resulting in the disruption of newly-learned habits and, hence, PI.

In conclusion, then, it must be stressed that although retroaction and proaction effects were found in the present study, only proaction, including the evidence from the trends, allows one to differentiate between species and age groups. If PI, or PI along with RI, is the mechanism underlying the improvement on SDR, then testing animals on the many discriminations involved in SDR seems redundant. If the results of the present study are reliable and differentiation among species with PI and RI is possible, then all that would be necessary in order to compare different species in a manner comparable to that of the SDR proponents would be to test for proaction effects in different species. Species could then be placed on a continuum ranging from PI to PF and not be dichotomized as rat-like and fish-like or improvers and non-improvers.

REFERENCES

Behrend, E. R., Powers, A. S., & Bitterman, M. E. Interference and forgetting in bird and fish. Science, 1970, 167, 389-390.

Bitterman, M. E. Toward a comparative psychology of learning. American Psychologist, 1960, 15, 704-712.

Bitterman, M. E. Phyletic differences in learning. American Psychologist, 1965, 20, 394-410. (a)

Bitterman, M. E. The evolution of intelligence. Scientific American, 1965, 212, 92-102. (b)

Bitterman, M. E. Reply to Weiner and Hupert. Science, 1968, 160, 100.

Bitterman, M. E., Wodinsky, J., & Candland, D. K. Some comparative psychology. American Journal of Psychology, 1958, 71, 94-110.

Bolles, R. C. & Woods, P. I. The ontogeny of behaviour in the albino rat. Animal Behaviour, 1964, 12, 427-431.

Braveman, N. S. Probability learning and successive discrimination reversals. Unpublished doctoral dissertation, Washington State University, 1971.

Campbell, B. A., Riccio, D., & Rohrbough, M. Ontogenesis of learning and memory. In M. Meyer (Ed.). Western Symposium on Early Learning. Western Washington State College Press: Bellingham, 1971, 76-109.

Cole, M. & Hopkins, D. Proactive interference for maze habits in rats. Psychonomic Science, 1968, 10, 365-366.

Crowder, R. Proactive and retoactive inhibition in the retention of a T-maze habit in rats. Journal of Experimental Psychology, 1967, 74, 167-171.

Ellis, H. C. Transfer: Nature, measurement and fundamental processes. In M. H. Marx (Ed.). Learning: Processes. The Macmillan Co.: Toronto, 1969, 381-399.

Gonzalez, R. C., Behrend, E. R., & Bitterman, M. E. Reversal learning and forgetting in bird and fish. Science, 1967, 158, 519-521.

Gossette, R. L. Examination of the retention decrement explanation of comparative successive discrimination reversal learning by birds and mammals. Perceptual and Motor Skills, 1968, 27, 1147-1152.

Gossette, R. L. Analysis of reversal and non-reversal training: further examination of the retention decrement hypothesis. Perceptual and Motor Skills, 1969, 24, 171-178.

Gleitman, H. & Jung, L. Retention in rats: the effects of proactive interference. Science, 1963, 142, 1683-1684.

Gleitman, H. & Steinman, F. Retention of a runway performance as a function of proactive interference. Journal of Comparative and Physiological Psychology, 1963, 56, 834-838.

Katz, L. The optokinetic effect in young guinea pigs and chickens. Unpublished data, 1971.

Kehoe, J. Effects of prior and interpolated learning on retention in pigeons. Journal of Experimental Psychology, 1963, 65, 537-545.

Mackintosh, N. J. Comparative studies of reversal learning. Paper presented at American Psychological Association, Washington, Sept. 1969.

Mackintosh, N. J. & Cauty, A. Spatial reversal in rats, pigeons and goldfish. *Psychonomic Science*, 1971, *22*, 281-282.

Maier, S. F. & Gleitman, H. Proactive interference in rats. *Psychonomic Science*, 1967, *7*, 25 -26.

Pickard, S. Proactive interference involving maze habits. *Psychonomic Science*, 1965, *3*, 401-402.

Setterington, R. G. & Bishop, H. Habit reversal improvement in the fish. *Psychonomic Science*, 1967, *7*, 41-42

Squier, L. Reversal learning in fish. *Psychonomic Science*, 1969, *14*, 143-144.

Weiner, N. & Hupert, F. Reversal learning and forgetting. *Science*, 1968, *160*, 99.

Woodward, W. T., Schoel, W. M., & Bitterman, M. E. Reversal learning with singly presented stimuli in the pigeon and goldfish. *Journal of Comparative and Physiological Psychology*, 1971, *76* 460-467.