THE RATE OF ACQUISITION AND EXTINCTION OF A PASSIVE AVOIDANCE RESPONSE AS A FUNCTION OF LEVEL OF TRAINING AND AGE IN RATS

By

Erma Jean Chattaway

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ABSTRACT

It has been reported that young rats are slower to acquire and faster to extinguish a simple passive avoidance response than adults. Such results have been interpreted through the assumption that young subjects have difficulty in inhibiting active responses. The extinction data are difficult to interpret since level of acquisition was not held constant across age. The present investigation explored the contributions of an inhibitory deficit and the level of acquisition to the rate of extinction in preweanling and adult rats. Latency of response was employed as the dependent measure.

The design of the experiment was a 2 x 2 x 3 factorial, including factors of age (18 days and 100 days), level of training (one acquisition trial and two acquisition trials), and treatment condition (experimental or response-contingent, Pavlovian control or placed, and stimulation control). Level of training was varied in order to examine its effects both within and between age groups on extinction rate. Since some evidence suggests that young and adult subjects may respond differently to Pavlovian and instrumental contingencies involved in passive avoidance settings, the Pavlovian control group was employed. In addition, there is also evidence which suggests that handling and shock may increase the activity level of young rats compared to that of adults. Thus, a yoked stimulation control group was used to partial out the effects of these procedures.

No age differences were found in acquisition level or extinction rate. Two training trials produced longer crossover latencies in acquisition than one training trial. In addition, subjects in the response-

contingent training condition had longer crossover latencies in acquisition than subjects in the Pavlovian and stimulation control groups after two training trials. Extinction rate was independent of acquisition level. Furthermore, extinction rate was the same for both the experimental and Pavlovian groups, suggesting that Pavlovian conditioning is importantly involved in passive avoidance.

The lack of age differences as reflected in acquisition was related to the use of apparatus which was scaled to the size of the animal. In previous studies, with the use of unscaled apparatus, age differences have been reported. The use of scaled apparatus may have facilitated acquisition of the response in young subjects. The lack of an age difference in extinction rate appeared to be the result of the same type of learning (i.e., Pavlovian fear conditioning) in both age groups. A further investigation of the effects of apparatus size on the acquisition of a passive avoidance response in both young and adult rats is suggested.

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CHAPTER ONE: THE NATURE OF THE PROBLEM

The importance of early experience to an organism's subsequent development and adult behaviour has been a major concern of psychologists. Investigators have explored the effects of stimulation (Ader, 1959; Denenberg, 1964), rearing conditions (Harlow & Harlow, 1962), and deprivation conditions (Cooper & Zubek, 1958) on adult behaviour. In addition, the development of learning (Campbell, 1967) and memory processes (Campbell & Spear, 1972) have been the object of investigations.

Some evidence from experimentation concerning the ontogeny of learning in rats suggests that young organisms differ quantitatively, and perhaps qualitatively, from adult organisms (Riccio & Marrazo, 1972). It has also been suggested that age differences may be explained, at least partially, with reference to inhibitory capacities, subsequent competing responses, and activity level (Campbell, Lytle & Fibiger, 1969; Egger, Livesey & Dawson, 1973; Fibiger, Lytle & Campbell, 1970; Mabry and Campbell, 1974). A number of questions remain unanswered, however. Qualitative differences in learning behaviour have not been substantiated experimentally. The contribution of amount of training has been investigated minimally (Kirby, 1963) and requires further clarification. The effect of apparatus size has been, for the most part, ignored even though Feigley and Spear (1970) have provided evidence of its importance. Each of these (i.e., qualitative differences in learning behaviour, amount of training, and apparatus size) may affect, or be affected by, inhibitory capacities. Thus, the present investigation was designed to explore further the role of inhibitory capacities in age differences in learning.

Inhibitory Deficits in Young Rats

Inhibition Hypothesis

Carlton (1963) has suggested that some inhibitory system in the brain acts to antagonize that system in the brain which in normal situations activates behaviour. He hypothesized that the activation system controls "the tendency for all responses to occur" (p. 27) but that the inhibitory system would "antagonize this action on nonreinforced responses" (p. 27). A central cholinergic system was the inhibitory system that Carlton suggested was involved in this process.

Carlton (1963) cited neuropharmacological research with adult rats and mice which supported his hypothesis. The administration of atropine, a drug known to block cholinergic activity in the brain, resulted in the exhibition of behaviours that were rarely produced in a Sidman avoidance learning situation. Responding during extinction, and perseveration of response topography were noted after the administration of cholinergic blocking agents, suggesting a lack of inhibition. In addition, animals were unable to extinguish irrelevant and competing responses during acquisition of a complex learning behaviour after a cholinergic blocking agent had been administered to them.

If young rats have an inhibitory deficit, then, according to the system outlined by Carlton (1963), young rats would continue to respond even though such responding is no longer reinforced (i.e., during extinction). In addition, acquisition of a response by young animals would be slower compared with adults because a young animal would have relatively greater difficulty inhibiting competing responses.

Carlton (1963) demonstrated that since cholinergic inhibitory activity aids in the habituation process and leads to an inhibition of nonrewarded responses, anticholinergic drugs such as scopolamine and atropine, which can block the influence of the cholinergic inhibitory system, can lead to the disinhibition of certain responses. It follows from such a suggestion that if young rats have an inhibitory deficit, then anticholinergic drugs would produce no observable effect on their behaviour. Of course, in adults a disruption of behaviour would be produced.

Age Differences in Inhibitory Control: Neuropharmacological Evidence

A number of investigators have evaluated the hypothesis that young rats have inhibitory deficits by studying age differences in the effects of anticholinergic drugs on such unlearned behaviours as activity level and spontaneous alternation in a T-maze. Campbell et al. (1969) found that the anticholinergic drug scopolamine only increased the activity level of rats which were 20 days of age or older whereas the stimulant drug amphetamine produced a dosage-dependent increase in activity level of all ages of rats in the study (i.e., 10-, 15-, 20-, 25-, and 100-day-old rats). These results imply that activation processes are salient in rats as young as 10 days of age but that inhibition processes are not able to influence behaviour until some time between 15 and 20 days of age.

Fibiger et al. (1970) investigated the development of inhibitory processes in rats by testing the effects of pilocarpine, a cholinomimetric drug, on amphetamine-induced arousal of rats 10, 15, 20, and 25 days of age. No effect of pilocarpine could be detected in the 20-day-old group; and a marked effect could been seen in the 25-day-old-group. Fibiger et al. inferred a gradual development of cholinergically mediated inhibition between 15 and 25 days of age in rats. Egger et al. (1973) investigated the effects of scopolamine on spontaneous alternation behaviour and found that the drug increased spontaneous alternation in 50- and 100-day-old rats, but did not affect the behaviour of 16- and 24-day-old rats. Two hypotheses are supported by the results of this experiment: young rats have an inhibitory deficit in comparison with mature rats, and the lack of inhibitory control does lead to perseveration of responding.

Mabry and Campbell (1974) evaluated the development of a serotonergic inhibitory process and its effects on behavioural arousal. They obtained results which imply that a serotonergic inhibitory process is functional, and does have a certain degree of effect on behaviour by the time a rat is 15 days of age. However, the inhibitory process does not appear to be fully developed at 15 days of age, since a greater effect on behaviour was found in 20- and 25-day-old animals.

An inhibitory deficit which would result in at least some age differences in the acquisition and extinction of a response seems to be present in young rats. In all of the investigations described above it has been found that young animals had an inhibitory deficit (Campbell et al., 1969; Egger et al., 1973; Fibiger et al., 1970; Mabry & Campbell, 1974). Some inhibitory control seems to be present at about 15 days of age (Mabry & Campbell, 1974), but a deficit, as measured by activity level (Campbell et al., 1969; Fibiger et al., 1970) and perseveration of responding (Egger et al., 1973) seems to remain until at least about three weeks of age. The deficit should be reflected probably in terms of rate of acquisition and extinction of various learning tasks.

The Relationship Between Inhibitory Deficits and Learning Tasks

In all of the investigations described above, the finding of an inhibitory deficit in the unlearned behaviour of young rats (Campbell et al., 1969; Egger et al., 1973; Fibiger et al., 1970; Mabry & Campbell, 1974) implies that an inhibitory deficit could result in at least some age differences in acquisition and extinction of a learned response.

In reviewing the literature on age differences and learning, it is important to note that different learning tasks may involve different processes or combinations of processes. Since different tasks may call into play different learning processes, it should not be assumed that age differences in inhibitory control will be reflected in all learning tasks. Some tasks seem more suitable than others in the investigation of age differences in learning capacities, and the contribution of inhibitory deficits. Schulenburg, Riccio, and Stikes (1971) have commented that the passive avoidance technique is sensitive to certain developmental changes which affect learning ability, but they do not attempt to specify the processes which would be involved, such as the development of inhibitory control.

The Task of Interest

Although the components of the passive avoidance task and age differences in acquisition and extinction of a passive avoidance response will be described below, the reasons for choosing this particular learning task will be presented here.

Passive avoidance learning involves training the subject to remain stationary in order to avoid receiving an aversive stimulus such as shock. Such a task minimizes age differences in locomotor ability, since it is the lack of movement which constitutes the objective of the task. The technique has been used extensively in the literature on the ontogeny of learning.

Consideration of Variables of Interest

If inhibitory deficits in young rats are to be examined adequately be the use of a passive avoidance technique, then a number of important variables, other than inhibition, that may contribute to age differences in passive avoidance behaviour should be considered. A listing of such relevant variables would include (1) level of learning; (2) Pavlovian conditioning control; (3) stimulation control; (4) apparatus size; and (5) extinction behaviour.

Level of Learning

Carlton (1969) has suggested that inhibitory capacities may be measured by rate of extinction of a learned response, since the ability to extinguish a learned response may in part be controlled by such processes. However, in any evaluation of extinction of a learned response, the original level of acquisition must be taken into account, especially if a trials to criterion measure of extinction is employed. If the level of acquisition is not considered, then the number of trials taken by a subject to reach an extinction criterion may be erroneously interpreted. For example, an animal which has a low level of acquisition and a high or moderate level of resistance to extinction may reach the extinction criterion in fewer trials than another animal which has a higher level of acquisition and a low level of resistance to extinction. If an investigator simply measured the number of trials to an extinction criterion, he would probably draw the conclusion that the former animal was less resistant to extinction than the latter. With the exception of Kirby (1963), in the context of an active avoidance procedure, the effect of level of acquisition on extinction rate has not been investigated. Kirby found a nonsignificant trend for resistance to extinction to be greater in young rats as compared to adult rats when the groups were unmatched for level of acquisition. When the groups were matched for acquisition level, no differences among age groups were apparent. Kirby concluded that extinction of an active avoidance response was invariant across age.

There is evidence that differences in acquisition level may occur as a function of age. For example, Snedden, Spevack, and Thompson (1971), in an investigation of conditioned suppression, found that 15-day-old rats did not suppress licking any longer than 15-day-old rats which received the conditioned stimulus (CS) unpaired with the shock. Experimental animals which were 22, 35, and 70 days old suppressed licking significantly more than control animals of the same ages which received the CS unpaired with the shock. The authors concluded that young rats were not as capable of learning a contingency as adult rats, thereby resulting in age differences in acquisition levels. Thus, in any investigation of age differences in extinction rate, level of acquisition must be examined.

The use of a trials to criterion measure of rate of extinction fails to take into account differences in the level of acquisition. Most experimenters attempt to equate acquisition levels across experimental groups, either by administering an equal number of trials to each subject or by imposing an acquisition criterion, but then fail to test for equal levels of acquisition by examining first trial extinction behaviour. If the contributions of both an inhibitory deficit and the level of learning are to be evaluated, then some method of differentiating their effects must be devised.

Pavlovian Conditioning Control

The use of the passive avoidance conditioning technique requires some evaluation of the possible contribution of different types of associations to overall performance. It is not certain, without the use of proper control procedures, whether the subjects are associating the shock with the situational cues of the shock compartment or with the response of entering the shock compartment. It is possible that a subject that has associated the shock with certain cues in the environment will exhibit a conditioned emotional response (CER) or Pavlovian conditioning to the situational cues as opposed to a punishment effect (i.e., instrumental conditioning), as follows:

Blanchard and Blanchard (1968) administered passive avoidance training to adult rats and then administered the same number of shocks, at the same frequency, to subjects in a yoked control condition. A third group of subjects received treatment identical to that of the yoked control group except that no shock was administered. When the three groups of animals were tested for passive avoidance of the shock compartment, the experimental and yoked shock control groups both took a significantly longer amount of time to enter the shock chamber than the third group. The yoked control group latencies were not significantly different from those of the experimental group, suggesting that passive avoidance in this experiment was based on conditioned fear.

Randall and Riccio (1969) have presented evidence which suggests that both punishment and fear conditioning occur when rats learn a passive avoidance response. They hypothesized that a delay of punishment gradient, which is a weakening of response strength as the response-shock interval increases, would reflect a punishment effect in passive avoidance training. A delay of punishment gradient was obtained, but even with a 60 second response-shock interval, the response strength of experimental animals was greater than that of naive control animals. These results suggest that conditioned fear is also a factor in passive avoidance conditioning (Randall & Riccio, 1969).

In a second experiment, Randall and Riccio (1969) hypothesized that if conditioned fear was present, then response strength would diminish as a function of time spent in the fear chamber. The hypothesis was confirmed. Randall and Riccio concluded that both instrumental and Pavlovian conditioning components are involved in passive avoidance learning.

The results of the two studies just reported (Blanchard & Blanchard, 1968; Randall & Riccio, 1969) both imply that passive avoidance responding is probably a result of both a punishment effect and a CER. This, in itself, is not of any particular concern. However, punishment effects have been found to be less resistant to extinction (Church, 1963) and more effective for the suppression of a response than a CER (Church, Wooten & Matthews, 1970). The possibility thus arises that age differences may reflect not a difference in either inhibitory control or level of acquisition but a difference that is due to young and adult subjects attending to different experimental cues. Certainly some theoretical models of early experience effects allow the inference that young subjects would attend to the Pavlovian components and adult subjects would attend to the instrumental components of a passive avoidance learning situation (Bronson, 1965; Razran, 1961; Thompson, 1966). Furthermore, Riccio and Marrazo (1972) detected certain age trends in a delay of punishment situation which prompted them to hypothesize that the young subjects were attending to the Pavlovian aspects of the situation whereas the adult subjects were attending to the instrumental aspects. (This study is described more completely in the review of the literature of age differences in passive avoidance learning (see p. 20).)

Stimulation Control

In addition to separating the effects of Pavlovian and instrumental conditioning in the passive avoidance learning situation, it is also imperative to separate the non-associative effects of stimulation from the learned response. Handling and shocking animals may not only affect the activity level of subjects, but also affect young animals more than adult animals. Denenberg (1964) has suggested that handling increases the activity level of animals and that handling before the subject is weaned is more effective in increasing activity level than handling after weaning. As well, some evidence indicates that shock administration may differentially affect the activity level of young and adult rats (Ader, 1959; Meyers, 1965). If this is the case, then it is possible that young subjects will be less able to remain stationary than adults. Such an effect would be reflected in slower acquisition scores and faster extinction scores by young than adult subjects in a passive avoidance task.

Apparatus Size

The size of the apparatus in relation to the size of the animal may affect learning of a response, since in a larger apparatus, cues may be less prominent. That is, young rats, because they are smaller than adult rats, may not notice apparatus compartment differences. Also, movement from one compartment to another compartment may not be noticed by young animals if they are placed in an apparatus which is scaled in size and generally designed for adult rats. Furthermore, age differences in activity level may contribute to apparent age differences in learning if the size of the apparatus is not taken into account.

Feigley and Spear (1970) have presented some evidence that the size of the apparatus in relation to the size of the animal is an important variable in the evaluation of age differences in passive avoidance learning. When both young and adult animals were given passive avoidance acquisition training in the same compartment, the young animals required significantly more trials to reach the acquisition criterion than the adult animals. When young animals received passive avoidance acquisition training in an apparatus which was scaled to their size, no significant age differences were found. (This study is described more completely in the review of the literature of age differences in passive avoidance learning (see p. 17).)

Carlton (1963) has reported experimental results with adult rats which suggest that inhibitory deficits become more prominent as size of the learning chamber increases in proportion to size of the animal. As larger apparatus were employed, lower dosages of scopolamine were required in order to disrupt performance.

Extinction Behaviour

The examination of extinction behaviour of young and adult rats is necessary in order to detect age effects which may not be a result of age differences in inhibitory control. In order to determine whether the response-contingent subjects attend predominantly to the instrumental or Pavlovian cues of the learning situation, extinction rate must be examined in comparison to extinction rate of Pavlovian control animals. Such information would not be available from evaluation of acquisition behaviour. As well, acquisition behaviour may be affected by age differences in inhibitory capacity, whereas extinction behaviour may be controlled by other factors, such as type of learning or activity level. Therefore, in order to investigate the role of inhibitory capacities in age differences in learning, both acquisition and extinction behaviour must be examined.

Summary

A number of investigators have become interested in analyzing early experience effects in terms of factors governing age differences in learning. One factor which has received considerable attention is inhibitory ability, which may control a subject's behaviour in situations such as acquisition of conditioned responses, suppression of activity, and extinction of learned responses. Of interest in the present thesis is the role of inhibition in early learning, as manifested in the acquisition and extinction of a passive avoidance response. It has been observed, however, that in any adequate investigation of passive avoidance behaviour, attention should be paid to control over several extraneous variables. Otherwise, age differences in passive avoidance learning may be attributed to (1) different levels of acquisition across age groups; (2) the behaviour of some animals reflecting a punishment effect and the behaviour of others reflecting a CER; (3) handling or shocking of subjects which is involved in the experimental procedure, and which may differentially affect activity levels of animals in different age groups; and (4) the greater activity levels of the young subjects than those of adult subjects, irrespective of any stimulation effects.

CHAPTER TWO: AGE DIFFERENCES IN PASSIVE AVOIDANCE RESPONDING

The results of studies of age differences in passive avoidance responding suggest that young rats are slower to acquire the response than adults. Also, the young animals appear to be less resistant to extinction than adults. These age difference effects seem to be related to factors involving the ability to inhibit an unrewarded response. However, several difficulties arise from such an analysis, as follows: (1) the contribution of level of acquisition to rate of extinction has been ignored; (2) proper control procedures for Pavlovian conditioning, stimulation, and activity level have in general been ignored; (3) the use of apparatus which is scaled to the size of the animal has been inconsistent; and (4) a measure of rate of extinction has not been employed. These inadequacies in individual investigations will be detailed in the following literature review. The review is divided into five sections, each of which contains material relevant to age differences in passive avoidance learning. The five sections are (1) acquisition of a passive avoidance response as a function of number of acquisition trials; (2) extinction of a passive avoidance response; (3) punishment of an active avoidance response; (4) passive avoidance after active avoidance training; and (5) physiological mechanisms.

Literature Review

Acquisition as a Function of the Number of Acquisition Trials

Brunner (1969) examined age differences in one trial passive avoidance learning using rats 20, 25, 30, 35, 40, 45, 50, 55, 60, and 120 days old. A step-down task was employed. The step-down latency for each subject was measured during one training trial and two test trials, which occurred 24 and 48 hours after the training trial. No age differences in latency of stepping down were found for the training trial, indicating that age differences in activity level were not present. Comparisons of the step-down latencies between the 20 day old and every other age group revealed that the youngest group had significantly shorter latencies in both test trials than groups which were 40 days of age or older.

Because appropriate control groups were not employed in order to assess the contribution of Pavlovian conditioning, stimulation effects, level of acquisition, or possible age differences in retention, it is difficult to determine whether age differences reported by Brunner (1969) were due to age differences in inhibitory control, original level of learning, or memory.

Riccio, Rorbaugh, and Hodges (1968) studied passive avoidance using rats which were 16, 19, 25, 32, or 90 to 120 days old. In one segment of the study, one training trial was administered and then the animals were tested for passive avoidance of the shock side of the apparatus either 2 minutes or 24 hours later. In another segment of the study, half of the subjects in the three youngest age groups received acquisition trials until they failed to enter the shock compartment within 10 minutes of the beginning of the trial.

Because no age differences due to retention interval were observed, the data were pooled across this condition. The results for the acquisition procedure of administering one trial revealed that younger rats moved from the safe to the shock side of the apparatus after a shorter period of time than the older rats. Differences in latency were, in fact, significant for all adjacent and nonadjacent age groups. The trials to criterion results indicated that the three younger groups were capable of learning the passive avoidance response, but only after a greater number of shocks had been delivered. The youngest group of animals received the largest number of trials in order to achieve the acquisition criterion.

The results of a third portion of the study (Riccio et al., 1968) in which an active avoidance task was employed, suggest that 19-day-old animals are slower than adult animals to learn an association between a stimulus and a response, since young animals required significantly more trials to acquire a simple active avoidance response. Therefore, age differences found in passive avoidance responding were probably not simply the result of age differences in the capacity to inhibit active responding, but also the result of age differences in learning a contingency. In addition, no control groups for the effects of Pavlovian conditioning, stimulation, age differences in activity level, or level of acquisition were employed in this study. As well, the apparatus was not scaled to the size of the animals. The results, then, may reflect the effects of a variety of factors rather than age related inhibitory ability *per se*.

Riccio and Schulenburg (1969) attempted to sort out some of the variables contributing to age differences in passive avoidance conditioning by the use of appropriate control measures. The apparatus was scaled to the size of the animal. The first of two experiments was designed to determine age differences in rate of acquisition of passive avoidance responding. The rats were 10, 15, 20, 30, or 100 days old when training began and each response contingent subject received training until it did not step down from the safe side to the shock side of the apparatus for 180 seconds. Control animals placed in the shock side of the apparatus received the same number of shocks at the same time intervals as those of their matched response contingent animals. The test for passive avoidance acquisition was a single test trial in which the step-off latency for each subject was measured.

The increase in latency relative to the first trial and the number of trials to criterion were the acquisition measures employed. The 10 and 15 day old response contingent rats were found to be considerably slower than all the older animals in acquiring the response. In most cases, the adults acquired the response in only a single trial. Riccio and Schulenburg concluded that the results reflected a punishment contingency since the placed control animals exhibited little evidence of the passive avoidance response. The behaviour of the placed control animals is surprising since Brunner, Roth, and Rossi (1970) found conditioned suppression of licking within one trial with adult animals. Also, Blanchard and Blanchard (1968) found no differences between the passive avoidance responding of experimental and matched control groups in their study outlined previously. It is unclear why passive avoidance of the fear chamber was not found in the control group in the study by Riccio and Schulenburg (1969).

In a second experiment, Riccio and Schulenburg (1969) attempted to determine whether or not making an escape response from the shock compartment would improve passive avoidance performance. The animals were 12, 15, 18, and 21 days old. The apparatus was scaled to the size of the subject. The procedure for the inescapable group was the same as that in the first experiment for the response contingent passive avoidance condition. In the escape condition, the procedure was identical except that if the animal had not returned to the safe side of the apparatus within 14 seconds, it was pushed back.

The three younger groups required significantly more trials than the oldest group to learn the response in both the escapable and inescapable conditions. Those animals in the escape group tended to require slightly fewer trials in order to learn the response. However, control groups, whose behaviour would reflect the effects of age differences in activity on acquisition levels were not employed. Therefore, any conclusions concerning age differences in ability to inhibit responding based on these data would be premature.

Feigley and Spear (1970) investigated retention of active and passive avoidance responses in a study which involved three experiments. Only the passive avoidance experiments will be reported here. In the first experiment in which a passive avoidance task was used, the animals were 21 to 25 and 95 to 105 days old. Each of the rats received training at one of three different shock levels. The warning signal was a flashing light, followed by shock when the animal entered the passive avoidance shock chamber. Avoidance of the shock chamber for 60 seconds on two consecutive trials constituted the acquisition criterion. Retention tests occurred 1 and 28 days after training. On the retention trials the animals were retrained to the acquisition criterion, using acquisition parameters.

The crossover latencies on the first trial did not differ significantly as a function of age, indicating that activity levels for the two age groups were similar. The number of trials to reach criterion decreased as the shock intensity increased in both age groups. The young animals required significantly more trials to reach criterion than did the adult animals. The retention measures of response latency and relearning indicated that the young subjects did not remember the task as well as the adults.

In a third experiment, young rats received passive avoidance training in an apparatus which was scaled to their size. The animals were 21 to 25 days of age and training was the same as that in the experiment just reported. Testing occurred in either the small or large apparatus after 24 hours or in the large apparatus after 28 days.

No differences in activity level were found, based on first trial latencies. The response was acquired by the young rats in significantly fewer trials than by the young rats in the previous study which were trained in the large apparatus. The number of trials to criterion required by the young subjects in the small apparatus was not significantly different from the number of trials required by the adults in the large apparatus. (Previous experiment data were used in analysis.) In the one day retention interval condition, the animals tested in the large apparatus showed a large performance decrement whereas the animals tested in the small apparatus did not, implying that fear was conditioned to specific aspects of the apparatus. Since a yoked shock control group was not employed, it is difficult to evaluate the contribution of conditioned fear to the learning of the passive avoidance response. Also, failure to find an age difference in acquisition of a passive avoidance response when the apparatus was scaled to the size of the animal suggests that an inhibitory deficit in young animals is not an adequate explanation of age difference effects in passive avoidance conditioning.

Extinction of a Passive Avoidance Response

Schulenburg et al. (1971) employed resistance to extinction as their measure of age differences in acquisition of a passive avoidance response. The animals were 15, 21, 27, and 90 to 120 days old. Each subject received training until no entrance into the shock compartment occurred within 300 seconds. At each age level, a group of animals received 0, 30, 60, or 300 seconds of inescapable exposure to the shock compartment during each extinction trial. The extinction criterion was movement into the shock compartment within 300 seconds.

The rate of acquisition of the passive avoidance response increased with age. Results indicated that the young subjects had less resistance to extinction as measured by the number of trials to reach criterion. Significant differences in the number of trials to criterion were found between adjacent age groups except in the comparison of 21 and 27 day old subjects. The age difference in resistance to extinction suggests that there was an age difference in the original acquisition level. Furthermore, the results seemed to indicate that although an equivalent criterion was met, young and adult animals had not necessarily attained an equivalent level of acquisition. Rate of extinction over a number of trials would supply a more valid index of resistance to extinction, especially when considered in conjunction with the level of learning. Schulenburg et al. (1971) suggested that rate of extinction be used to indicate age differences in level of acquisition. However, this may also be inappropriate since rate of extinction may be determined by the type of learning (i.e., Pavlovian or instrumental), not by level of learning. Different types of learning in different age groups may then lead to miscalculations of acquisition levels. In addition, Schulenburg et al. did not use apparatus which was scaled to the size of the animal. Therefore, interpretation of the results should be viewed with caution.

Punishment of an Active Avoidance Response

Riccio and Marrazo (1972) trained young and adult rats to equal levels of one way active avoidance responding and then investigated the effects of both immediate and delayed punishment on extinction behaviour. The young subjects were 20 to 22 days old and the adult subjects were 90 to 120 days old. The apparatus was not scaled to the size of the rat. Subjects were first trained to a criterion of five consecutive avoidance and then received either extinction or punishment trials. In the punishment situation, an inescapable shock was delivered either 0, 2, or 10 seconds after the rat entered the goal box. The extinction and suppression criteria were the avoidance of the goal box on five consecutive trials.

Although the young and adult rats did not differ significantly in the number of trials to the acquisition criterion, the young animals had significantly longer total running time than the adult subjects. The suppression criterion was achieved in significantly fewer trials than the extinction criterion, in both young and adult subjects. In the extinction condition, the young animals reached the criterion in significantly fewer trials than the adult animals. It should be noted however that this result may have reflected a difference in the original level of acquisition. Since the actual latencies of young and adult rats were not compared on the first extinction trial, equal levels of acquisition were only inferred. Nevertheless, the extinction results are contrary to the effects which would be expected on the basis of the hypothesis that young rats have less inhibitory control than adults. The young subjects would be expected to persist avoidance responding while the adult animals would be expected to extinguish avoidance responding.

In the zero-delay punishment condition, the young subjects reached the suppression criterion in significantly more trials than the adult animals. For the two delayed punishment conditions, the young and adult rats did not differ significantly in the number of trials they required to meet the suppression criterion. The adult subjects displayed an expected delay of punishment effect; that is, they required more and more trials to achieve the suppression criterion as the delay increased. Riccio and Marrazo reported that the young subjects, however, displayed what appeared to be an almost opposite effect, requiring fewer and fewer trials to achieve the suppression criterion as the delay increased, although the decrease in the number of trials required by the young subjects was not significant.

Riccio and Marrazo remarked that the results obtained in the zero-delay punishment condition are consistent with other findings on passive avoidance research. They also noted that even when subjects were successfully avoiding the goal during extinction and suppression, the young subjects were more active than the adults. These results seem to suggest that an inhibitory deficit is present in young but not adult rats. The different reactions of young and adult subjects in the punishment delay condition prompted Riccio and Marrazo to conjecture that the adult rats were under instrumental control whereas young rats were more influenced by the Pavlovian aspects of the situation. In the adult groups, behaviour appeared to be influenced by the length of the response-shock interval. In contrast, the young rats appeared to have associated the shock with the goal box. Since yoked shock control animals were not employed this hypothesis could not be verified.

Passive Avoidance After Active Avoidance Training

Egger and Livesey (1972) investigated passive avoidance of the shock compartment after animals had received one way active avoidance training. The subjects were 24, 50, and 100 days of age. The apparatus was scaled to the size of the subjects. Animals were trained to a criterion of 10 consecutive active avoidance responses and then were tested for passive avoidance immediately. The acquisition results indicated a significant difference among the age groups for the number of trials required to meet the criterion. Young subjects required more trials than older subjects. The subsequent passive avoidance test results revealed that young animals were inferior to the adult animals but superior to young control animals which had received no training. Passive avoidance learning, therefore, did occur in all age groups. However, the young rats did not learn as quickly as the older rats. The results do not contradict the notion of an inhibitory deficit in young animals, but different levels of active avoidance acquisition could have accounted for the age differences in passive avoidance responding.

Physiological Mechanisms

Feigley (1974) has presented evidence which suggests that passive avoidance responding is disrupted by a loss of cholinergic inhibitory control and that such control is not present in young subjects. The animals in his study were 16 to 17, 20 to 21, 25 to 26, 28 to 29, and 70 to

85 days of age and were assigned to one of three drug conditions. The three drug groups were (1) a group receiving scopolamine hydrobromide (SCOP-HBr) which blocks cholinergic activity in the central nervous system; (2) a group receiving scopolamine methylnitrate (SCOP-MeNO$_3$) which blocks cholinergic activity in the peripheral nervous system; and (3) a group receiving a saline solution. Within each age group and drug condition the dosage levels used were 0, .5, 1.0, and 2.0 mg/kg. The apparatus employed was scaled to approximate young and adult body sizes. Passive avoidance training continued until each animal had not crossed over to the shock side of the apparatus within 60 seconds on two consecutive trials. Photobeam interruptions on the non-shock side of the apparatus were used as a measure of activity level.

As measured by trials to criterion and crossover latencies, SCOP-HBr reliably disrupted passive avoidance responding in the 20-, 24-, and 28-day-old groups but had no significant effect in the 16-day-old or adult groups as compared to the SCOP-MeNO$_3$ and saline conditions. The difference between the two scopolamine drug groups indicated that the disruption of the passive avoidance response occurs centrally, not peripherally, since only the centrally active drug disrupted passive avoidance responding. Although no significant differences were found between SCOP-MeNO$_3$ and saline conditions, the median number of trials required to reach the acquisition criterion was greater at every age level for the SCOP-MeNO$_3$ than for the saline groups, indicating that some peripheral effect was present. Neither drup type nor dosage level had any significant effect on activity level. Activity level was found to decrease as age level increased in the four young age groups and then increased for the adult groups. Feigley suggested that this age difference may have been the result of subject size. Larger pups may have caused fewer discrete photobeam interruptions in the small apparatus.

Because of the unexpected lack of effect in the adult group, the first experiment was replicated using 16-day-old and adult animals, higher dosage levels, and freshly mixed drugs. As measured by trials to criterion, passive avoidance responding by the young subjects was not disrupted by either type of scopolamine and responding of adult subjects was affected by both types of scopolamine but more markedly by SCOP-HBr. High dosage levels of both types of the drug produced slight but significant disruption of performance in the young animals as measured by crossover latencies. The same results were obtained for the adult animals using the crossover latency measure as using the trials to criterion measure. The two types of scopolamine increased the activity level of young animals. The SCOP-HBr increased and the SCOP-MeNO_3 decreased the activity level of the adults. Such results suggest that an inhibitory deficit exists in young rats because the SCOP-HBr was disruptive only in older groups. Presumably, no cholinergic inhibitory system was present in the young subjects: SCOP-HBr would not have an effect on a non-existant system. Also, the older subjects which were affected by the drug acted similarly to the young subjects. The results suggest that the deficit is central in nature, since the centrally active drug significantly disrupted responding but the peripherally active drug did not.

<u>Statement of the Problem</u>

The contribution of an inhibitory deficit, level of acquisition, or a combination of these two factors to age differences in rate of passive avoidance extinction was explored. Previously, level of acquisition had been ignored. In the present thesis, effect of acquisition was investigated by the use of two different levels of acquisition training at two age levels. Shock and stimulation effects were examined by the use of yoked control groups. The contribution of Pavlovian conditioning to rate of extinction was examined by the use of a control group which received the same amount of shock in the experimental chamber as the experimental group. The contribution of shock and handling stimulation *per se* during the experimental session to rate of extinction was examined by the use of a control group which received the same amount of shock and handling as the experimental group, but not in the experimental chamber. The latter group, and the use of scaled apparatus, were used to provide an indication of effects of age differences in activity level.

Another purpose of the present investigation was to evaluate, by examining extinction rates, the influence of Pavlovian and instrumental components of the passive avoidance learning situation at two age levels and two acquisition levels. The possibility arises that different rates of extinction at the two age levels or at the two acquisition levels may be the result of animals in different experimental conditions attending to different environmental cues. A third purpose was to replicate acquisition results of previous investigations.

The problem was explored by the use of a 2 x 2 x 3 factorial design. The factors were age (young or adult), level of training (low or high), and treatment condition (experimental, Pavlovian control, or stimulation control). The measure of importance of age differences in passive avoidance learning was rate of extinction of the response, using latency as the dependent measure. The rate measure is most appropriate because it is not dependent on level of acquisition for interpretation.

Summary

To recapitulate, young rats seem to acquire a passive avoidance response more slowly than adult animals (Brunner, 1969; Egger & Livesey, 1972; Feigley, 1974; Feigley & Spear, 1970; Riccio & Marrazo, 1972; Riccio et al., 1968; Riccio & Schulenburg, 1969; Schulenburg et al., 1971). The results presented by Feigley (1974), who investigated the effects of scopolamine on passive avoidance learning, suggest that a lack of inhibitory control in young rats, which seems to be the result of an underdeveloped central cholinergic system, is a factor involved in the age difference in acquisition. It is not entirely clear, however, that young rats acquire the response more slowly simply as a result of immature inhibitory capacities, since few investigators have ensured equivalent response effort across age groups. In those studies in which the investigators have attempted to control for this factor by scaling the apparatus to the size of the animal (Egger & Livesey, 1972; Feigley, 1974; Feigley & Spear, 1970; Riccio & Schulenburg, 1969) acquisition differences as a function of age have not always been found.

There are other weaknesses with the existing literature on age differences in passive avoidance responding. To recapitulate these, Schulenburg et al. (1971) were the only investigators who measured resistance to extinction so age differences in the type of learning or in inhibitory control have been difficult to evaluate.

Appropriate control measures for the effects of shock, stimulation, and activity level were not employed in any of the studies mentioned above.

As well, only a few investigators used apparatus which was scaled to the size of the animal. The present thesis was designed to explore age differences in rate of extinction of a passive avoidance response, employing the appropriate control procedures.

CHAPTER THREE: METHOD

Subjects

The subjects were 48 male infant rats 18 days old at the time of the test (see below for _a priori_ conditions and resultant number of infant rats) and 36 male adult rats, 100 to 105 days of age, of the Sprague-Dawley strain, obtained from the Holtzman Company. The infants were between 10 and 15 days of age on arrival in the laboratory and the adults were approximately 70 days of age on arrival in the laboratory. Therefore, all animals were maintained in the laboratory for at least two full days before training began. Six rats were assigned to each of the six groups within each age condition described below. No littermates were assigned to the same condition of treatment and level of training in order to control for genetic differences in rate of development and activity level. Littermates in the young age group were used as matched control subjects; that is, an experimental animal and its matched Pavlovian control and stimulation control animals were all littermates. Infants had free access to the mother and adults had free access to food and water at all times except during the experimental session. The colony room in which the animals were housed was reasonably free from noise and stimulation, and was in darkness for 8 of every 24 hours (10:00 p.m. to 6:00 a.m.). Experimentation occurred during the afternoon and early evening.

Apparatus

The apparatus was a double-compartment plexiglass box. The interior dimensions of each compartment of the apparatus for the adult subjects were 10¼ in. long by 4 in. wide by 4 in. high; and for the young subjects, were 5 3/4 in. long by 2½ in. wide by 4 in. high. The two compartments were separated by a plexiglass doorway ½ in. thick. The floor of the safe compartment was a solid sheet of plexiglass. The floor of the shock compartment was a grid of solid copper rods ¼ in. in diameter and placed ¼ in. apart, centre to centre, which ran parallel to the short walls of the apparatus. Scrambled shock was delivered by means of a Grason-Stadler shock generator (model E 1064GS) which was powered by a Lehigh Valley Electronics 15 A power supply. The shock duration was controlled manually with a foot pedal which was attached to the shock generator. The ceiling consisted of two pieces of plexiglass which were attached to either end of the apparatus by means of hinges. Each piece of the lid could be raised independently of the other piece in order to place a subject in, or remove a subject from, one compartment of the apparatus. The two portions of the lids could be secured by a lock which was attached to a stationary piece of plexiglass over the safe side of the apparatus.

A wooden box, painted black, was used in the yoked stimulation control condition for the administration of shock and handling (see below). The interior dimensions of the box were 12 in. long by 12 in. wide by 12 in. high. Stainless steel grids, which were 1/16 in. in diameter, were placed ½ in. apart, centre to centre, and were placed in a direction which was parallel to the sides of the box. The same shock generator and power supply as reported above were used. The lid was a solid piece of plexiglass, attached to one side of the box by a hinge.

The two pieces of apparatus were placed on a table in a brightly lit, quiet experimental room. A stop watch was used to time the latency of movement from the safe to the shock compartment.

Procedure

The design was a 2 x 2 x 3 factorial. The factors were age (young or adult), level of training (1 acquisition trial or 2 acquisition trials), and treatment condition (experimental, Pavlovian control, or stimulation control).

The two levels of training and the intensity of the shock level were determined during two preliminary studies. The following criteria were to be met, in order for the data to be interpretable: (1) data from more than one extinction trial must be available for the young age group; (2) ceiling effects which would affect the rate of extinction must not occur; and (3) the level of acquisition as measured by crossover latency on the first extinction trial for the young rats in the high level of training condition must be greater than that of the adult rats in the low level of training condition. The number of extinction trials to be administered was also determined on the basis of the preliminary data.

Prior to treatment, in all conditions, each animal was placed in the safe compartment facing into the corner away from the shock compartment. The latency to move into the shock compartment was measured. If the subject did not cross into the shock compartment within 30 seconds it was removed from the apparatus and discarded from the study. This *a priori* restriction was introduced in order to reduce intragroup variability since during preliminary investigations it was found that some animals were extremely fearful, both before and during treatment. Some animals would not move out of the corner in which they were placed for as long as 30 minutes. In the experimental condition, the latency was measured on the first acquisition trial. In the Pavlovian and stimulation control conditions, the criterion trial occurred before training began and was followed by a 2 minute intertrial interval. This resulted in two litters (i.e., 12 animals) being discarded from the study in the young age condition. Therefore, only 36 infant rats were included in the acquisition and extinction portion of the study. The respective treatments are detailed below.

Experimental Condition

Each animal in the experimental condition was (1) trained in the passive avoidance apparatus to one or the other training level, and then (2) immediately given four extinction trials. During training trials, each subject was placed in the safe compartment facing into a corner with its back to the opening, and then the doorway separating the compartments was lifted. The latency in seconds was recorded from the time that all four paws were on the floor of the safe side of the apparatus until all four paws were on the grid in the shock compartment of the apparatus. As soon as the subject had moved completely onto the grid, a 0.5 ma scrambled shock was delivered for approximately 0.5 seconds. The animal was then immediately removed from the apparatus and placed in a holding cage for two minutes until the next trial. In the low level of training condition one shock was delivered to the subject and in the high level of training condition two shocks were delivered to the subject. In order to control for the extra handling received by the yoked Pavlovian control animals (see below), extra handling was administered during the second intertrial interval, at 30 second intervals.

On the first trial following acquisition (after the two minute intertrial interval), each animal received four extinction trials. Each subject was placed in the safe side of the apparatus and the latency to move into the shock compartment was recorded in the same manner as in the training session. When the subject moved into the shock compartment, no shock occurred, and the animal was removed to the holding cage for a two minute intertrial interval. The extinction trial did not end until the subject had moved into the shock compartment or until 15 minutes had passed since the beginning of the trial.

Pavlovian Control Group

The Pavlovian control group received two phases of treatment (acquisition and extinction) comparable to that of the experimental groups. One control group within each level of training and age condition was matched for the frequency and distribution of shocks received by the experimental group during acquisition training. Each control animal was exactly matched with one experimental animal. The subject was placed in the safe side of the apparatus for the amount of time the yoked experimental animal spent in the safe compartment. Then the control subject was placed in the shock side of the apparatus, shocked, and immediately removed to the holding cage until it was time for the next trial (i.e., two minutes). Extinction trials began after the conditioning was completed.

Stimulation Control Group

The other control group within each level of training and age condition was matched for amount of handling and number of shocks given to the experimental group. Treatment was administered in the second piece of apparatus so that stimulation effects could be evaluated independently of Pavlovian fear conditioning of the passive avoidance apparatus. Each animal was placed in the large black box for the total amount of acquisition time (including the intertrial interval) experienced by the matched experimental animal. In order to ensure that handling did not become a stimulus associated with the onset of shock, the appropriate amount of handling and shock was administered at random intervals. The four extinction trials in the experimental apparatus followed.

In all conditions, on each of the extinction trials, the latency was recorded from the time that all four of the subject's paws were on the floor of the safe compartment until all four paws were on the grid in the shock compartment of the apparatus for each animal.

CHAPTER FOUR: RESULTS

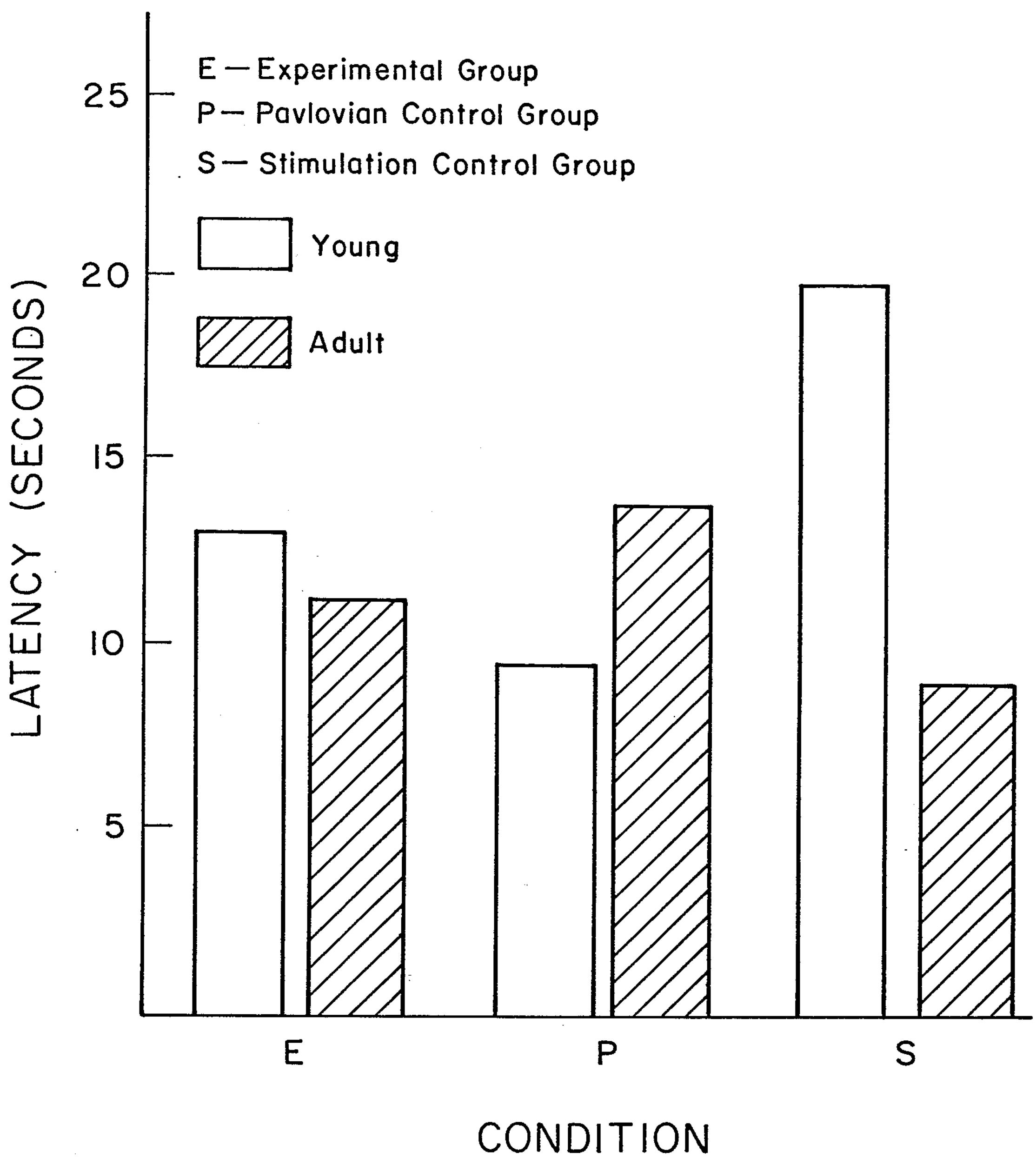
The present chapter is divided into three sections, which are (1) latency prior to treatment; (2) acquisition results; and (3) extinction results. In each section only significant effects are shown graphically. However, tabular summaries of means are presented in Appendix A. Also, analysis of variance summary tables are presented in Appendix B.

Latency Prior to Treatment

The latencies, in seconds, to move from the safe to the grid side of the apparatus on the first trial (i.e., pre-shock) were analyzed in order to determine the presence or absence of age differences in activity level. The step-across latencies were analyzed by means of a factorial analysis of variance, containing two levels of age, two levels of training, and three treatment conditions. The analysis is summarized in Table B.1 in Appendix B, p. 68.

Figure 1 shows the mean latencies on the first trial for each of the three treatment conditions for young and adult animals. Inspection of the figure suggests that activity was not related to age alone or to treatments alone. The analysis yielded no significant main effects for either age (F (1, 60) = 2.10, $p > .05$) or treatment condition (F (2, 60) = .74, $p > .05$). However, inspection of the figure does suggest that in the Pavlovian control condition the young animals were more active than the adult animals, and that in the experimental and stimulation control conditions the young animals were less active than the adult animals. In support, the analysis revealed a significant age x treatment condition interaction (F (2, 60) = 5.19, $p < .01$). The basis of the interaction is unclear. To find if there was a relationship between initial activity level and

Figure 1. Mean latencies on the first trial for the three conditions of treatment in each age group.



E — Experimental Group
P — Pavlovian Control Group
S — Stimulation Control Group
Young
Adult
25
20
15
10
5
LATENCY (SECONDS)
E
P
S
CONDITION

acquisition level, a correlation coefficient was computed between the latency scores on the first trial (i.e., pre-shock) and the latency scores on the first extinction trial. The correlation between initial activity level and the activity level at acquisition was very low ($\underline{r}$ = -.06), suggesting that the originally measured activity level probably had no influence on the acquisition scores of the subjects. The initial latency results thus will not be discussed further.

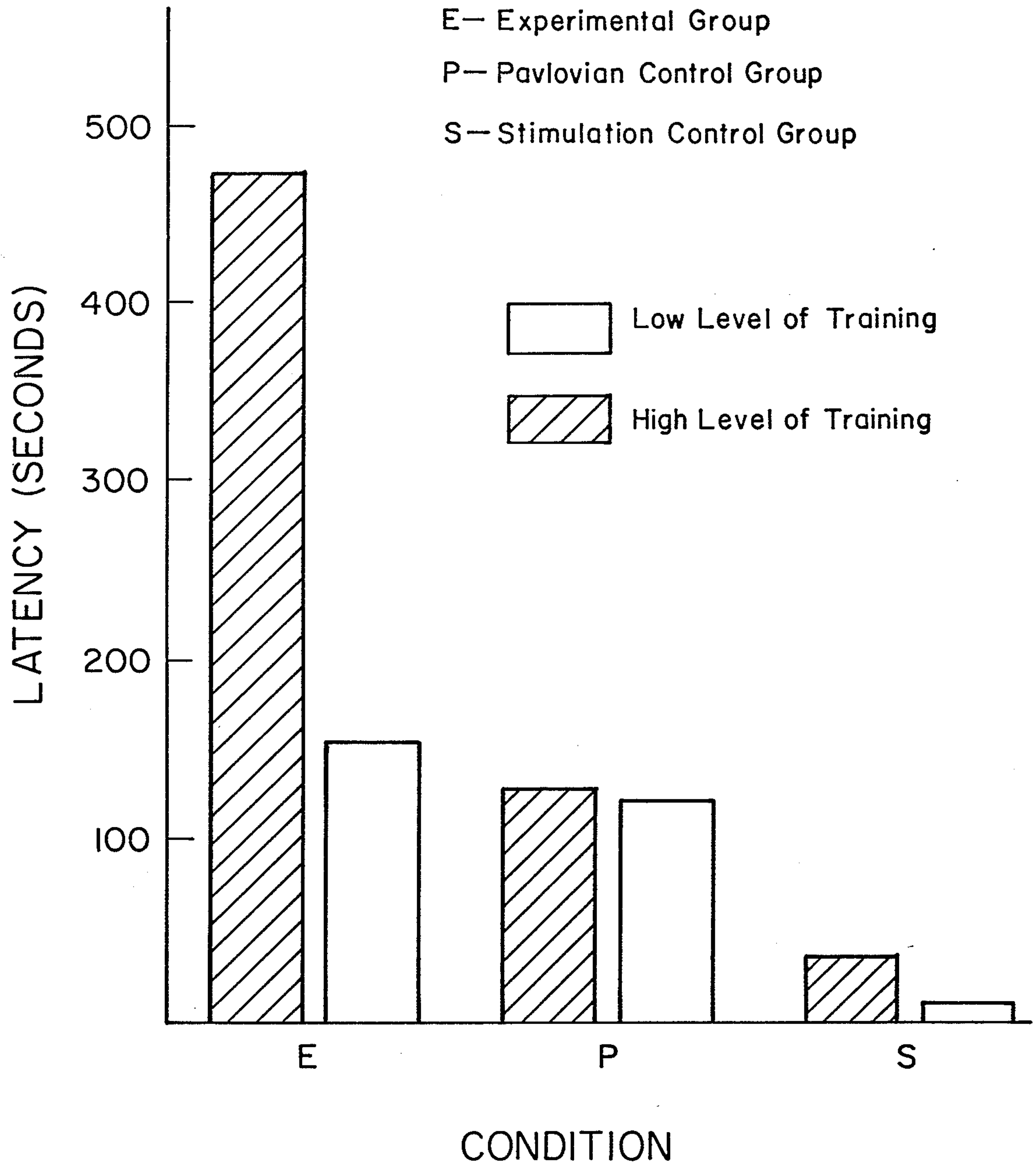
Acquisition Results

Acquisition was measured by the crossover latencies, in seconds, on the first extinction trial. A factorial analysis of variance, containing the factors of age (young and adult), level of training (one acquisition trial and two acquisition trials), and treatment condition (experimental, Pavlovian control, and stimulation control) was employed and is summarized in Table B.2 in Appendix B on p. 69.

No significant main effect of age was found; as well, age did not interact significantly with any other factor or combination of factors (see Table B.2). Thus, acquisition of the passive avoidance response as measured by crossover latencies on the first extinction trial was equivalent for young and adult animals in each of the three treatment conditions (see Figure C.1 in Appendix C, on p. 73 for the distribution of acquisition scores in the two age groups).

Figure 2 shows the latencies in seconds for movement into the shock compartment on the first extinction trial for each treatment condition at both levels of training. Inspection of Figure 2 suggests that subjects in the experimental conditions had longer latencies than subjects in the Pavlovian or stimulation control groups. This result indicates

Figure 2. Mean latencies on the first extinction trial in the three treatment conditions at the low and high levels of training.


E— Experimental Group
P— Pavlovian Control Group
S— Stimulation Control Group
Low Level of Training
High Level of Training
LATENCY (SECONDS)
500
400
300
200
100
E
P
S
CONDITION

that, in general, a higher level of acquisition was attained by subjects in the experimental group than in the control groups. As well, subjects in the Pavlovian control group appeared to have had longer latencies than subjects in the stimulation control group. In corroboration, there was a significant main effect for condition (F (2, 60) = 11.03, $p < .01$). The main effect for condition was further probed by means of the Tukey correction procedure for post hoc comparisons. This analysis yielded a significant effect for the comparison between the experimental and the Pavlovian (q (3, 60) = 7.58, $p < .05$) and the stimulation (q (3, 60) = 11.30, $p < .05$) control groups. As well, the comparison between the Pavlovian and the stimulation control conditions was significant (q (3, 60) = 3.72, $p < .05$).

Inspection of Figure 2 also suggests that animals in the high level of training condition had longer crossover latencies than animals in the low level of training condition. In support, the analysis revealed a significant main effect for level of training (F (1, 60) = 5.02, $p < .05$).

Further inspection of Figure 2 suggests that the increased crossover latencies after two acquisition trials in comparison to the latencies after one acquisition trial occurred primarily in the experimental group rather than in the Pavlovian and stimulation control groups. This was corroborated by the overall analysis. A significant level of training x treatment condition interaction (F (2, 60) = 4.09, $p < .05$) was found.

Simple main effects tests were employed to investigate further the nature of the interaction. The effect of level of training was examined within the respective treatment conditions. The results of the simple main effects tests indicated a significant level of training effect in the experimental treatment condition (F (1, 60) = 13.57, $p < .01$) but not in the Pavlovian (F (1, 60) = .00, $p > .05$) or stimulation control groups (F (1, 60) = .05, $p > .05$). As well, the effect of different treatment conditions at each level of training was examined. The results indicated that the groups differed from each other at the high level of training (F (2, 60) = 13.92, $p < .001$) but not at the low level of training (F (2, 60) = 1.26, $p > .05$). Tukey post hoc analyses were employed to explore the nature of the effect at the high level of training. The latencies of experimental animals were significantly longer than the latencies of Pavlovian control (q (3, 60) = 13.81, $p < .05$) and stimulation control (q (3, 60) = 17.20, $p < .05$) animals. A tendency for the latencies of Pavlovian control subjects to be longer than those of stimulation control subjects (q (3, 60) = 3.38, $p < .10$) was found.

The significant interaction of the level of training and treatment condition clarifies the nature of the significant main effects for acquisition of the passive avoidance response described earlier. Subjects in the high level of training experimental condition had a much higher level of acquisition than subjects in the low level of training experimental condition. The latencies of the Pavlovian control groups and the stimulation control groups at each level of training did not differ. The acquisition latencies of the three treatment conditions differed significantly in the high level of training condition but not in the low level of training condition.

Extinction Results

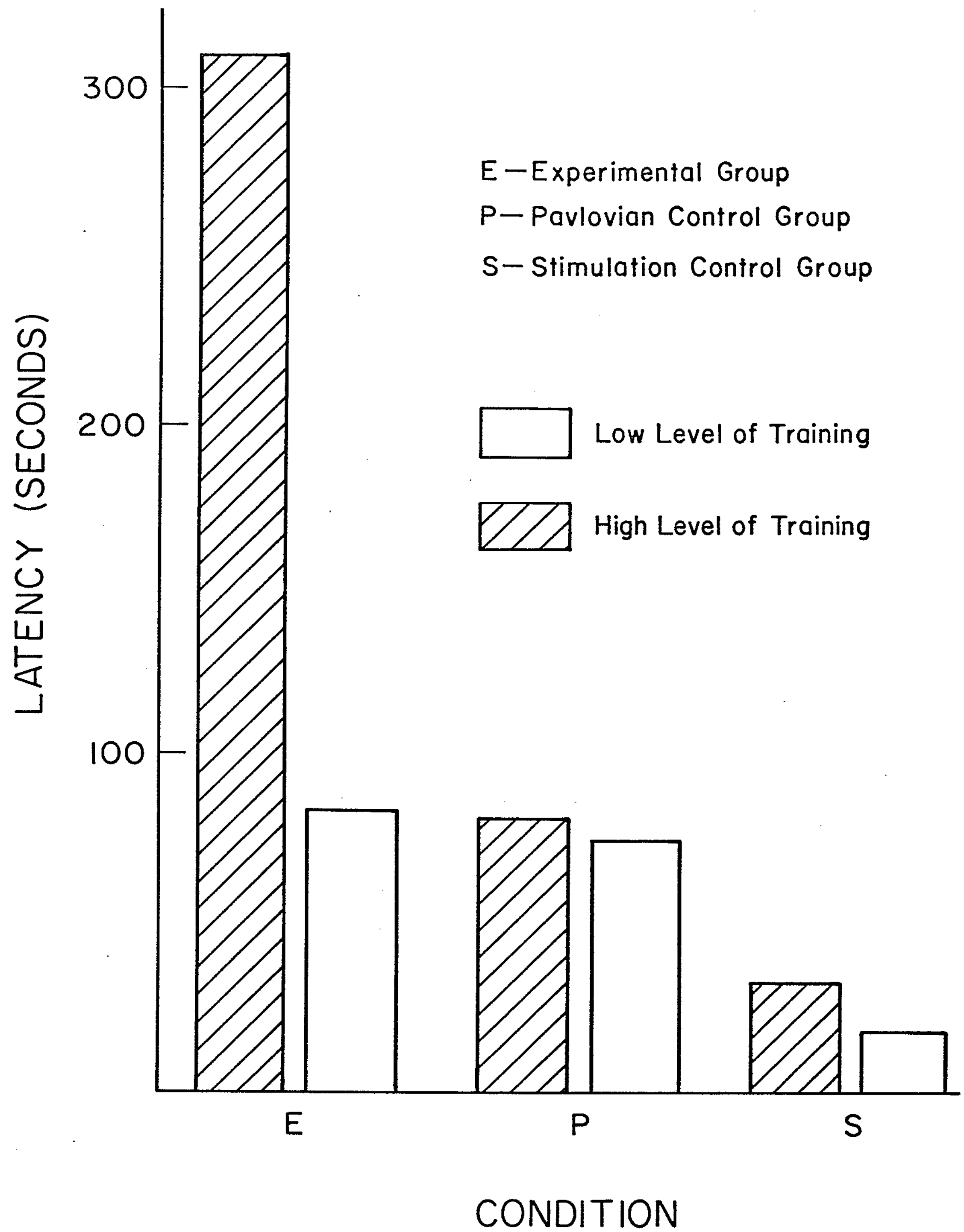
Extinction was measured by the latencies in seconds to cross from the safe to the shock side of the apparatus in each of four extinction trials. The data were analyzed by the application of a mixed design repeated measures analysis of variance, containing the between subject factors of age (young and adult), level of training (low and high), and treatment condition (experimental, Pavlovian control, and stimulation control), and the repeated measure of four crossover latencies on each extinction trial. The extinction results are summarized in Table B.3 in Appendix B on p. 70. In order to present the results clearly, they are presented in the present section first as a function of the latencies cumulated over trials as a measure of general performance, and second as a function of the latencies across each of the four trials as a measure of rate.

General Performance Level

No age effects, either main or interacting with level of training and/or treatment conditions, were found to be significant (see Table B.3). That is, young and adult animals did not differ in their crossover latencies at either the high or low levels of training, in the experimental, Pavlovian control, or stimulation control groups, or overall.

Figure 3 shows the crossover latencies in seconds cumulated over the four extinction trials for the three treatment conditions at the high and low levels of training. Inspection of Figure 3 suggests that the experimental groups had longer crossover latencies than the Pavlovian and stimulation control groups, and the Pavlovian control groups had longer crossover latencies than the stimulation control groups. These results were supported by the overall analysis. The main effect of treatment condition was significant (F (2, 60) = 9.29, $p < .001$). In order to ex-

Figure 3. Mean latencies during extinction for the three treatment conditions at the low and high levels of training.


E — Experimental Group
P — Pavlovian Control Group
S — Stimulation Control Group
Low Level of Training
High Level of Training
LATENCY (SECONDS)
300
200
100
E
P
S
CONDITION

plore the nature of the effect, Tukey *post hoc* analyses were conducted. The analyses only partially corroborated the results suggested by inspection of Figure 3. The experimental subjects did have significantly longer crossover latencies than the Pavlovian (q (3, 60) = 3.48, $p < .05$) and the stimulation control subjects (q (3, 60) = 5.21, $p < .05$). However, the Pavlovian control subjects did not have significantly longer crossover latencies than the stimulation control subjects (q)3, 60) = 1.73, $p > .05$).

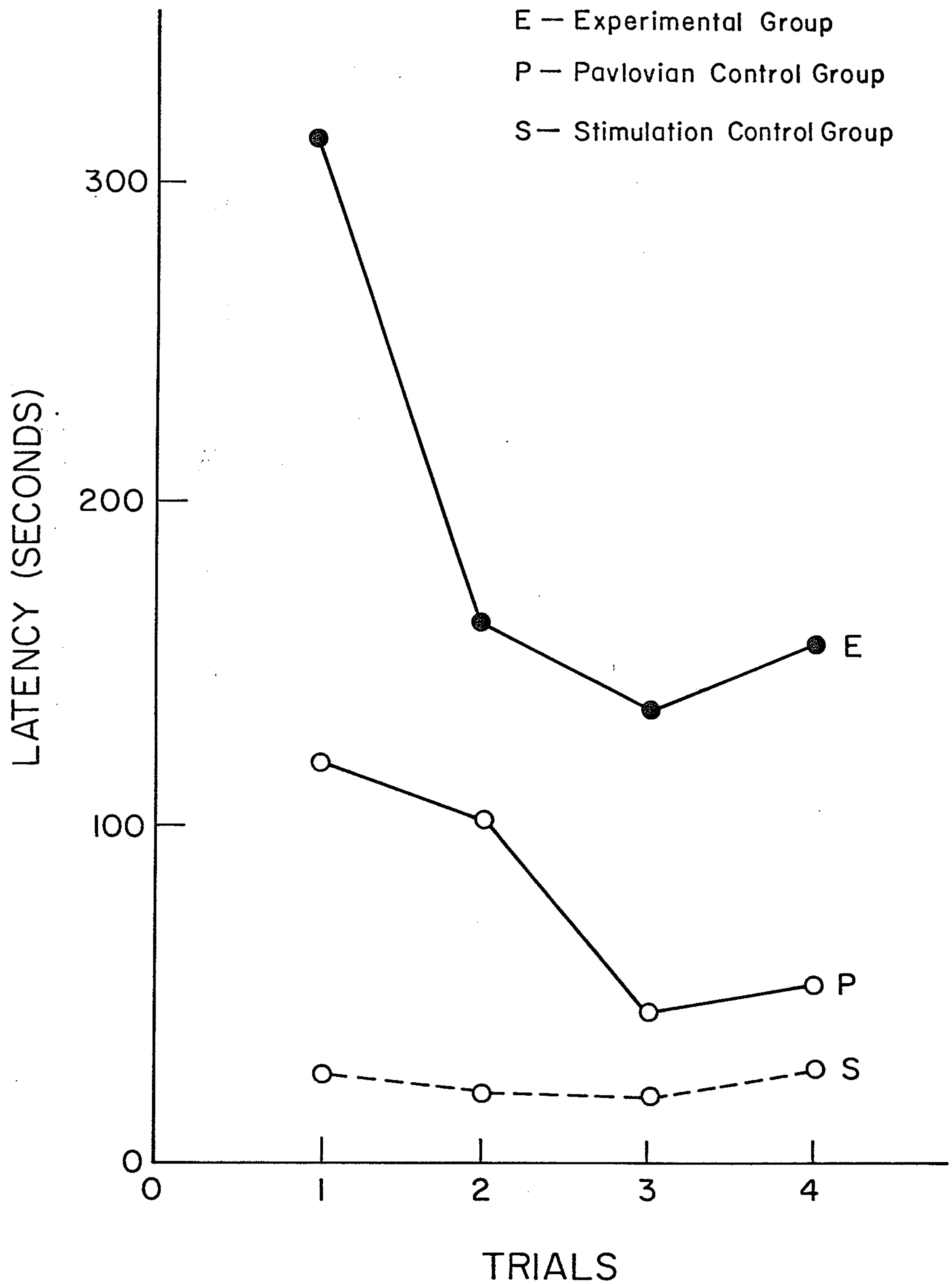
Inspection of Figure 3 also suggests that animals in the high level of training condition had longer crossover latencies than animals in the low level of training conditions. In corroboration, the analysis revealed a significant main effect for level of training (F (1, 60) = 5.42, $p < .05$). Further inspection of Figure 3 suggests that rats in the experimental condition at the high level of training had much longer latencies than rats in the experimental condition at the low level of training. The latencies of the Pavlovian control groups and the stimulation control groups at the two levels of training did not appear to differ. In support, the overall analysis revealed that the interaction for level of training and treatment condition was significant (F (2, 60) = 4.67, $p < .05$). Simple main effects tests were employed to investigate the nature of the interaction. The level of training effect was significant in the experimental condition (F (1, 60) = 55.91), $p < .01$) but not in the Pavlovian (F (1, 60) = .04, $p > .05$) or stimulation control groups (F (1, 60) = .19, $p > .05$). The latencies of each of the three treatment conditions differed significantly at the high level of training (F (2, 60) = 50.36, $p < .001$). Tukey *post hoc* analyses were employed to further explore the effects. The experimental treatment animals had significantly longer latencies than the Pavlovian (q (3, 60) = 6.84, $p < .05$) and stimulation (q (3, 60) = 8.36, $p < .05$) treatment animals. The latencies of the subjects in the Pavlovian and stimulation control groups did not differ significantly (q (3, 60) = 1.52, $p > .05$). Although the results of the simple main effects tests indicated that the latencies in each of the three treatment conditions differed significantly at the low level of training (F (2, 60) = 3.43, $p < .05$), none of the pairwise treatment comparisons were found to be significant when Tukey *post hoc* analyses were employed to explore the effect further. That is, no treatment at the low level of training produced significantly longer crossover latencies than any other group even though the treatment groups differed significantly overall at the low level of training.

Latencies Across Four Extinction Trials

Young and adult subjects behaved similarly over the course of extinction. That is, no age differences in the rate of extinction across the four extinction trials were found (see Table B.3, Appendix B, p. 70 for the analysis of variance summary, and Table A.3, Appendix A, p. 66 for the means of each treatment, age, and level of training group for each extinction trial). As well, no significant interaction between age and level of training and/or treatment condition was found across the four trials (see Table B).

Figure 4 shows the crossover latencies, in seconds, of the treatment groups, pooled across level of training, for each of the four extinction trials. Inspection of Figure 4 indicates that overall crossover latencies decreased over trials. In corroboration, a significant main effect

Figure 4. Mean latencies of response on each extinction trial for the three treatment conditions.



E — Experimental Group
P — Pavlovian Control Group
S — Stimulation Control Group
LATENCY (SECONDS)
300
200
100
0
0
1
2
3
4
TRIALS
E
P
S

for trials ($\underline{F}$ (3, 180) = 7.86, $\underline{p} < .001$) was found. In addition, inspection of Figure 4 suggests that the latency decrease was found in the experimental and Pavlovian control groups but not in the stimulation control groups. In support, a significant interaction effect for trials and treatment condition ($\underline{F}$ (6, 180) = 3.16, $\underline{p} < .01$) was found.

A trend analysis was used in order to examine further the trials x treatment condition interaction. Inspection of Figure 4 suggests that both linear and quadratic components were present. The analysis yielded supportive evidence. A significant linear trend ($\underline{F}$ (1. 60) = 8.92, $\underline{p} <$ .005) and a significant quadratic trend ($\underline{F}$ (1, 60) = 12.51, $\underline{p} < .001$) were found. As well, inspection of Figure 4 suggests that the rate of extinction in the experimental and Pavlovian control groups were not different from each other, whereas the rate of extinction in the experimental and Pavlovian control groups combined was different from that in the stimulation control group. These results were supported by the overall trend analysis. A significant linear trend x treatment condition interaction ($\underline{F}$ (2, 60) = 3.06, $\underline{p}$ = .05) and a significant quadratic trend x treatment condition interaction ($\underline{F}$ (2, 60) = 5.62, $\underline{p} < .01$) were found. _Post hoc_ comparisons were employed in order to explore the nature of the interaction, using the rate of extinction as measured by overall trend. In the first comparison, trends for the experimental versus Pavlovian control groups were examined. In the second comparison, the rate of extinction of the experimental and Pavlovian control groups combined was compared with the rate of extinction of the stimulation control group. The overall trend in the experimental condition was not significantly different from the overall trend in the Pavlovian control condition

(F (3, 180) = 2.16, $p > .05$). The overall trend of the experimental and Pavlovian control groups combined was significantly different from the overall trend of the stimulation control group (F (3, 180) = 3.50, $p <$ .01). In other words, rate of extinction in the experimental group and in the Pavlovian control group were not significantly different from each other. Rate of extinction of the combined experimental and Pavlovian groups was different than rate of extinction of the stimulation control group.

In summary, the results revealed the following: no systematic age differences were evident before treatment; only an interaction between age and treatment condition, which did not appear to affect acquisition level, was found. No age differences were found either during acquisition or in the rate of extinction. In general, subjects in the high level of training condition had a higher level of acquisition than subjects in the low level of training condition. At the high level of training, rats in the experimental condition had a higher level of acquisition than rats in either control group, and rats in the Pavlovian control group had a tendency toward a higher level of acquisition than rats in the stimulation control group. At the low level of training, no acquisition differences among the three treatment conditions were found. The rate of extinction was the same for the experimental and Pavlovian groups but different from the stimulation group.

CHAPTER FIVE: DISCUSSION

The present chapter is divided into two major sections in order to facilitate discussion of the results. The two sections concern (1) age effects in passive avoidance responding, and some possible explanations for the absence of a significant age difference in the present study; and (2) the nature of the passive avoidance results in general.

Age Effects

No systematic age differences, or interactions between age and the other factors of level of training and treatment condition were found in either acquisition level or extinction rate. Because the age effects may have been the result of different causes in acquisition and extinction phases of the experiment, age effects in acquisition and extinction will be discussed separately.

Acquisition

The results of the present thesis are in contradiction to previously reported age differences in acquisition of a passive avoidance response (Brunner, 1969; Egger & Livesey, 1972; Feigley, 1974; Feigley & Spear, 1970; Riccio & Marrazo, 1972; Riccio et al., 1968; Riccio & Schulenburg, 1969; Schulenburg et al., 1971). The major difference between the acquisition phase of the present study and that of many of the previous studies was the use of an apparatus which was scaled to the size of the animal. Therefore, apparatus size will be evaluated in terms of its contribution to the age effect.

Brunner (1969), Feigley and Spear (1970), Riccio and Marrazo (1972), Riccio et al. (1968), and Schulenburg et al. (1971) have all reported slower acquisition of a passive avoidance response by young rats than by adult rats with the use of unscaled apparatus. Age differences found by these investigators may have been due to (1) age differences in activity level; or (2) age differences in ability to perceive cues and their significance. The former does not seem likely as the cause of a lack of an age difference in the present thesis. If young animals are more active than adult animals (e.g., Candland & Campbell, 1962), then in a smaller apparatus the young animals would have a greater probability of moving onto the shock grid.

The results of the present thesis imply that the size of the apparatus in comparison to the size of the animal is an important variable because of an increase in cue salience in an appropriately sized apparatus. As Feigley and Spear (1970) noted in their discussion, task variables may not be as conspicuous to small animals placed in a large apparatus as they are to large animals in the same apparatus. As well, adult rats may be able to attend to less prominent cues than young rats even in a scaled apparatus, although in the present instance this does not appear to be the case since no age differences were found. Age differences in learning a simple passive avoidance response may not occur when easily discernible cues are present. Thus, significant age differences in the present thesis may not have been found because the task was so easy for the young animals to learn that age differences in inhibitory control would not have influenced performance and thus no real age differences occurred. In order to investigate the hypothesis that apparatus size is an important contributing variable to passive avoidance learning, a parametric study of the effects of apparatus size on both young and adult animals is suggested.

However, four investigators have previously reported the use of an apparatus which was scaled to the size of the subject in a study of passive avoidance (Egger & Livesey, 1972; Feigley, 1974; Feigley & Spear, 1970; Riccio & Schulenburg, 1969), and some have found that young rats acquire the response more slowly than adult rats (Egger & Livesey, 1972; Feigley, 1974; Riccio & Schulenburg, 1969). Egger and Livesey (1972) found that young rats did not acquire passive avoidance responding as quickly as adults. However, their study is difficult to compare to the present study, since in that study rats were trained on active avoidance responding and then tested for passive avoidance. Age differences in active avoidance acquisition, or in the ability to transfer learning in one task to performance in another could have contributed to the passive avoidance age effect.

Feigley (1974) found age differences in the effect of scopolamine, a cholinergic blocking agent, on passive avoidance behaviour. He reported that the drug had no effect on passive avoidance learning in rats of 16 days of age but significantly impaired passive avoidance learning in rats of 20 days of age. Because of procedural difficulties, the effects of the drug were compared only between rats which were 16 days of age and adults, and not between rats which were 20 days of age and adults. Even though one can only conjecture, it is possible that with the use of the scaled apparatus, no age differences between the 20 day old rats and adults would have been found.

Feigley and Spear (1970) found no significant age differences in the acquisition of a passive avoidance response in an apparatus which was scaled to the size of the animals. However, they also found that young rats acquired the response significantly more slowly than adult rats in an apparatus which was the same size for all animals. The results which were found by Feigley and Spear (1970) with the use of scaled apparatus were similar to those in the present thesis.

Riccio and Schulenburg (1969) reported statistically significant poorer acquisition of a passive avoidance response in 20 day old animals than in 100 day old animals. They noted that "acquisition of the 180 sec criterion typically occurred after one shock in adults and only slightly more slowly in the 30- and 20-day-old subjects" (Riccio & Schulenburg, 1969, p. 431). With such a slight difference in performance, a small amount of intragroup variability in the age groups would be necessary in order to attain a significant difference in the results. It is interesting to note that the results obtained by Riccio and Schulenburg versus those obtained in the present thesis and by Feigley and Spear (1970) may reflect differences in type of shock used. Riccio and Schulenburg (1969) used a matched impedance shock source while a constant current shock source was used in the present thesis. It might be that the type of shock affects the amount of intragroup variability. A great deal of variability was found in both young and adult subjects in the present study. As well, Feigley and Spear (1970), who were the only other investigators to report no age differences in acquisition of a passive avoidance response, employed the same type of shock source (i.e., constant current) as in the present thesis. Of course a closer examination of the effects of shock on the variability of behaviour would be necessary in order to determine whether the type of shock source employed would significantly affect results of a learning task.

To recapitulate, it appears that the size of the apparatus in con-

conjunction with the type of shock source employed has contributed to the lack of an age effect in acquisition of a simple passive avoidance response.

Extinction

The lack of an age difference in rate of extinction may have been due to (1) equivalent levels of acquisition; or (2) similar types of learning (i.e., instrumental or Pavlovian conditioning) in the two age groups.

It is doubtful, for two reasons, that equivalent levels of acquisition alone could account for the lack of an age effect in extinction rate. First, rate of extinction was not found to vary as a function of acquisition level, since the rate of extinction was the same in the two levels of training conditions. If rate of extinction does not vary as a function of acquisition level, then it would be difficult to propose that acquisition level contributed to the age effect in extinction in the present thesis. Second, even given equivalent acquisition levels, the type of learning which had occurred would influence rate of extinction. An instrumental response would extinguish more quickly than a Pavlovian response (Church, 1963). It appears, therefore, that extinction rate was similar in the two age groups because both young and adult animals were attending to the same aspects of the learning task. As in the acquisition phase of the study, the lack of an age effect appears to be the result of similar processes in young and adult learning.

As alluded to in Chapter One in the section concerning the necessity of a Pavlovian conditioning control group (see p. 9), predictions based on certain theoretical models of early experience effects (Bronson, 1965;

Razran, 1961; Thompson, 1966) would lead to the following expectation: young animals would attend mainly to the Pavlovian cues in the task whereas adult animals would attend mainly to the instrumental cues in the task. Since no age differences in the type of learning were found, no comments on the theories can be made.

To recapitulate, the lack of an age difference in the acquisition and extinction of a simple passive avoidance response has been discussed. It seems reasonable to infer that no actual age differences in acquisition occurred because the task was easy to learn for both the young and adult rats. Acquisition in the infant age group was probably facilitated by the use of apparatus which was scaled to the size of the animal. Easily discernible cues in the small apparatus may readily have been associated with shock, thus eliminating the influence of age differences in inhibitory control on acquisition performance. The rate of extinction across age appeared to be independent of the level of acquisition, and dependent on the type of learning (i.e., instrumental or Pavlovian conditioning). Therefore, since both the young and adult animals appeared to attend to the same cues on the learning task, their rates of extinction were similar. Because of this similarity, it also seems reasonable to assume that no actual age differences in extinction rate occurred.

Passive Avoidance Learning

The passive avoidance results of the present thesis, irrespective of the age variables, are consistent with those of Blanchard and Blanchard (1970). The latter authors reported that the experimental and yoked shock control animals behaved similarly. On the basis of this evidence, Blanchard and Blanchard concluded that passive avoidance behaviour was determined by fear conditioning. In the present thesis, no significant differences in the rate of extinction of the experimental and Pavlovian control condition animals were found. The mean rate of extinction of the experimental and Pavlovian control groups combined was significantly faster than that of the stimulation control group. The stimulation control group, in turn, showed no evidence of change in crossover latencies over the four extinction trials. Such results seem to indicate that animals in the experimental condition attended more to the Pavlovian than to the instrumental components of the task, since the experimental animals behaved in a manner similar to the Pavlovian control group. By procedural definition, the Pavlovian control group could only have reacted to the Pavlovian components of the task situation.

Randall and Riccio (1969) found evidence of both Pavlovian and instrumental learning in a passive avoidance situation. In the present investigation, it might be argued, the significantly greater acquisition level of the experimental group than the Pavlovian group in the high level of training condition was due to instrumental conditioning in the experimental group. However, as noted above, on the basis of extinction rate results, extinction behaviour for the most part appeared to be under the influence of Pavlovian cues. Thus, the greater acquisition level of the experimental group is likely better attributed to factors other than instrumental conditioning. Perhaps Pavlovian conditioning to a compound stimulus occurred in the experimental group in the high level of training condition.

Summary

The purpose of the present investigation was to determine whether age differences in the rate of extinction of a passive avoidance response was due to an inhibitory deficit in young rats, the level of acquisition, or a combination of the two factors. A comparison of rates of extinction in young and adult animals at two levels of training was employed in order to investigate the possibilities. Neither inhibitory control nor level of training appeared to influence the rate of extinction. In fact, no age differences in acquisition level or rate of extinction were evident. The lack of an age difference in the acquisition level of the response was attributed to scaled apparatus. Presumably, more easily discernible cues in the small apparatus facilitated acquisition in the young group of rats, thus eliminating any age differences. Although the constant current shock source may have contributed to the lack of an age effect, the nature of the contribution is uncertain. Since Pavlovian fear conditioning seemed to occur in both the young and adult groups, the rate of extinction was similar in the two age groups. A parametric investigation of the effects of apparatus size and type of shock source on the learning behaviour of both young and adult rats was suggested. Passive avoidance responding, irrespective of age, appeared to be controlled on the whole by Pavlovian rather than instrumental factors.

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APPENDIX A

Table A.1

Mean Crossover Latencies For Each

Condition Before Treatment

Young Subjects

Group	Mean Latency (in seconds)
Low Level of Training	
Experimental	12
Pavlovian Control	13
Stimulation Control	22
High Level of Training	
Experimental	14
Pavlovian Control	5
Stimulation Control	17

Adult Subjects

Group	Mean Latency (in seconds)
Low Level of Training	
Experimental	12
Pavlovian Control	14
Stimulation Control	5
High Level of Training	
Experimental	10
Pavlovian Control	13
Stimulation Control	13

Table A.2

Mean Crossover Latencies For Each Condition

On The First Extinction Trial

Young Subjects

Group	Mean Latency (in seconds)
Low Level of Training	
Experimental	48
Pavlovian Control	63
Stimulation Control	23
High Level of Training	
Experimental	542
Pavlovian Control	36
Stimulation Control	39

Adult Subjects

Group	Mean Latency (in seconds)
Low Level of Training	
Experimental	261
Pavlovian Control	177
Stimulation Control	10
High Level of Training	
Experimental	410
Pavlovian Control	209
Stimulation Control	33

Table A.3

Mean Crossover Latencies for Each Condition

On Each Of The Four Extinction Trials

Young Subjects

Group	Mean Latency (in seconds) Trials 1	2	3	4
Low Level of Training				
Experimental	48.0	32.3	38.5	35.2
Pavlovian Control	62.8	68.8	40.3	38.2
Stimulation Control	22.7	20.5	13.7	19.3
High Level of Training				
Experimental	542.0	298.5	296.0	271.8
Pavlovian Control	36.2	13.8	15.8	20.5
Stimulation Control	39.0	17.7	18.0	16.7

Adult Subjects

Group	Mean Latency (in seconds) Trials 1	2	3	4
Low Level of Training				
Experimental	260.7	123.3	71.8	71.8
Pavlovian Control	176.8	108.3	35.7	117.8
Stimulation Control	9.7	16.3	23.3	11.8
High Level of Training				
Experimental	410.3	216.5	140.2	269.2
Pavlovian Control	209.3	212.8	80.7	50.2
Stimulation Control	33.0	25.3	21.5	66.3

APPENDIX B

Table B.1

Summary of The Analysis of Variance Of The

Pretreatment Crossover Latencies

Source	*df*	*SS*	*MS*	*F*
Level of Training (T)	1	21.16	21.16	.31
Condition (C)	2	99.66	49.83	.74
Age (A)	1	141.66	141.66	2.10
T x C	2	121.54	60.54	.90
T x A	1	125.34	125.34	1.85
C x A	2	701.42	350.71	5.19**
T x C x A	2	272.67	136.34	2.27
Within Cell	60	4054.21	67.57	
Total	71	5537.66		

** $p < .01$

Table B.2

Summary Of The Analysis of Variance Of The

Crossover Latencies On The First

Extinction Trial

Source	df	SS	MS	F
Level of Training (T)	1	237475.28	237475.28	5.02*
Condition (C)	2	1042414.59	521207.29	11.03**
Age (A)	1	60958.69	60958.69	1.30
T x C	2	386396.01	193198.01	4.09*
T x A	1	38688.41	38688.41	.82
C x A	2	73121.30	36560.65	.77
T x C x A	2	144484.40	72242.20	1.53
Within Cell	60	2834349.20	47239.10	
Total	71	4817887.88		

* $p < .05$
** $p < .01$

Table B.3

Summary Of The Analysis of Variance Of The

Crossover Latencies On Each Of The

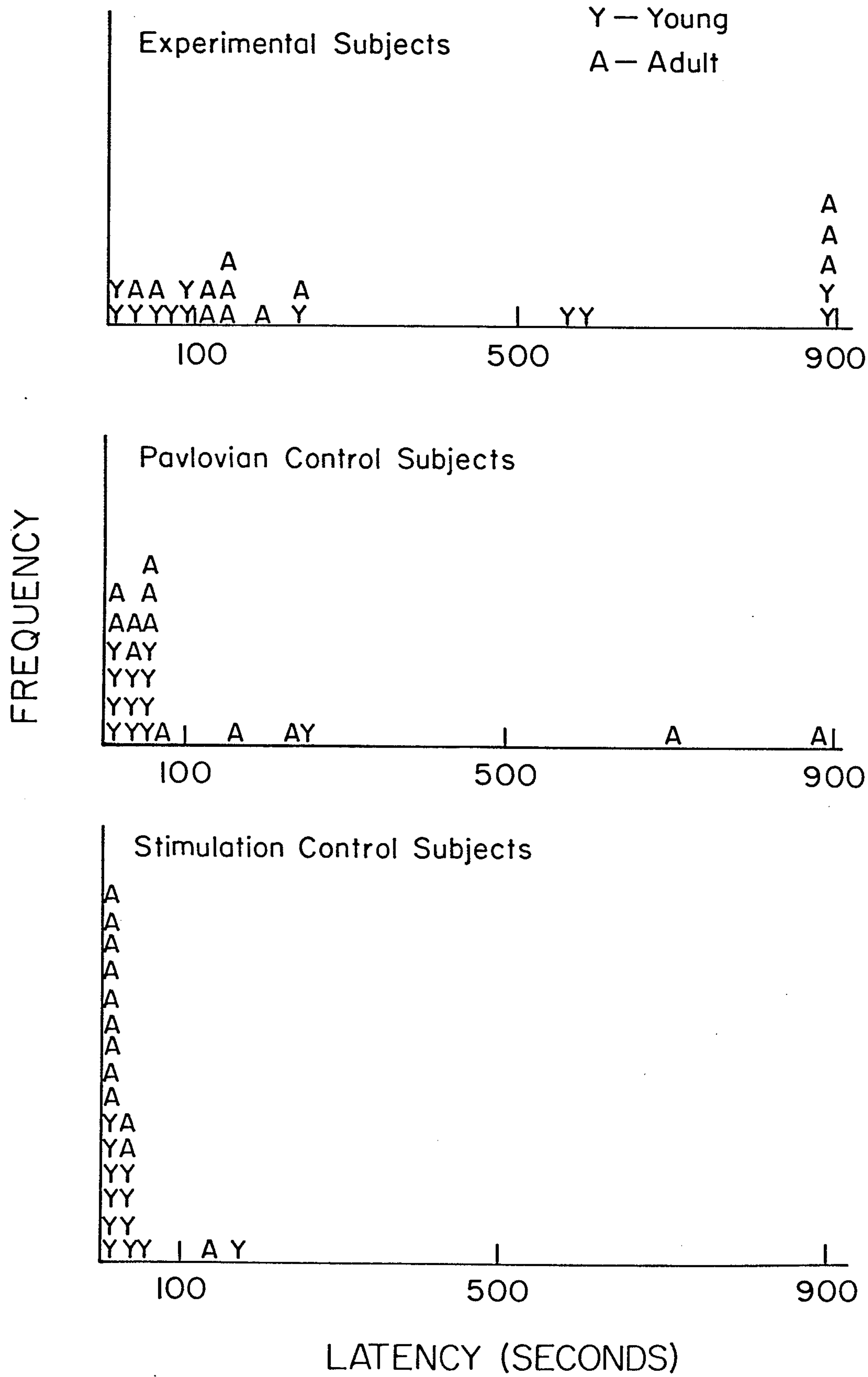
Four Extinction Trials

Source	df	SS	MS	F
Level of Training (T)	1	429423.00	429423.00	5.42*
Condition (C)	2	1472753.00	736376.50	9.30**
Age (A)	1	67803.00	67803.00	.86
T x C	2	739693.00	369846.50	4.67*
T x A	1	23961.00	23961.00	.30
C x A	2	114011.00	57005.50	.72
T x C x A	2	207731.00	103865.50	1.31
Within Cell	60	4751465.00	69191.16	
Trials (R)	3	316705.00	105568.31	7.86**
R x L	3	35196.00	11732.00	.87
R x C	6	254831.00	42471.83	3.16*
R x A	3	43067.00	14355.66	1.06
R x T x C	6	74321.00	12386.83	.92
R x T x A	3	23160.00	7720.00	.57
R x C x A	6	45185.00	7530.83	.56
R x T x C x A	6	83522.00	13920.33	1.03
Within Cell	180	2418440.00	13535.77	

* $p < .05$
** $p < .01$

APPENDIX C

Figure C.1. Distribution of the acquisition scores for young and adult subjects in the three treatment conditions.


Experimental Subjects
Y — Young
A — Adult
Pavlovian Control Subjects
Stimulation Control Subjects
FREQUENCY
100
500
900
LATENCY (SECONDS)