EFFECTS OF DIFFERENTIAL FOOD DEPRIVATION ON PARTIAL REINFORCEMENT IN TWO SELECTIVELY BRED STRAINS OF RATS

MICHAEL TIMGREN

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Abstract

The effects of three levels of food deprivation, and shift in reinforcement patterns were investigated in selectively bred high-(RHA/Lu) and low-(RLA/Lu) avoidance strains. The high-avoidance strain responded to the appetitive drive to a greater extent than the low-avoidance strain whereas the low-avoidance strain responded to change in reinforcement pattern more strongly than the high-avoidance strain. The males and females of both the RHA/Lu and RLA/Lu strain responded differently to the change in food deprivation pattern. The RHA/Lu females and the RLA/Lu males yielded an inverted U-shaped function over the three food deprivation levels.

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Research into the Roman high and low avoidance strains has been limited to investigations into activity, avoidance behaviour, emotionality, and drugs. The present study is an attempt to expand the Roman high and low avoidance strain research into the field of partial reinforcement. As a background to the present study, partial reinforcement literature is reviewed from the following perspectives: historical development, the frustration effect and food deprivation. Since the Roman high and low avoidance strains are used as subjects, research which used these strains is also reviewed.

In the early 1950's, researchers began paying increased attention to partial reinforcement. The procedure, however, was recognized early in the century as a variation in conditioning experiments. Systematic investigations of partial reinforcement were not undertaken until the late 1930's. An early attempt at a definition was presented by Jenkins and Stanley (1950). "Partial reinforcement refers to the reinforcement given at least once but omitted on one or more of the trials or after one or more of the responses in a series." (p. 194). A more recent restatement has been offered by Amsel (1967). "A response is said to be partially or intermittantly reinforced if it is rewarded according to some probability less than one and according to any of a variety of patterns" (p. 2).

Historical Perspective of Partial Reinforcement Effect

An early reference to reinforcement of less than 100% was made by Razran (1934). He cites a thesis experiment by Platinov in 1912 in which an avoidance conditioned response was maintained by only reinforcing the initial trial each day.

Partial reinforcement was recognized by Pavlov (1927). He referred to three preliminary experiments in which variations were made in the pattern of reinforcement. The results indicated that the pattern of reinforcement influenced the number of trials required for the subject to be conditioned.

A major contributor to the early study of partial reinforcement was Humphreys. A number of techniques including conditioning, free response and verbal expectancies was used by him to study partial reinforcement. Humphreys (1939a) applied partial reinforcement to human eye-lid conditioning. On the reinforcement trials the subjects were conditioned to a light followed by a puff of air to the cornea. The nonreinforced trials consisted of light but no puff of air. The results did not indicate significant differences in acquisition between the two groups in frequency or magnitude of punishment in eye-lid conditioning. A greater resistance to extinction in both the frequency and magnitude of punishment was obtained by the partial reinforcement subjects than the continuous reinforcement group. Humphreys (1939b) applied partial reinforcement to verbal expectancy. The results were consistent with eye-lid conditioning in that the resistance to extinction was found to be significantly greater in the partial reinforcement group than the continuous reinforcement group. In the study of psychogalvanic response, Humphreys (1940) found that the continuous and partial reinforcement subjects were about equal in acquisition whereas the partial reinforcement subjects were superior in the resistance to extinction.

One of the early issues of partial reinforcement investigated was scheduling. Two distinct techniques emerged, namely, free-response and trial situations. Free-response refers to the technique whereby the inter response time is controlled by the subject, whereas in the trial situation it is controlled by the experimenter. As early as the 1930's Skinner (1933) was investigating free-response scheduling. Initially, he conceived the idea of reinforcing the subject only after a specific amount of time had elapsed. The behavior of the subject between the reinforcements was of no consequence. This procedure he termed periodic reconditioning; more recently it has been termed periodic reinforcement. A new approach to scheduling emerged when Skinner (1936) introduced reinforcement at a fixed ratio. The reward in this approach was dependent upon the number of responses emitted by the subject.

Although the trial situation was used in the early 1930's in acquisition studies (Anderson, 1933, and Hall, 1934), it was not applied to partial reinforcement until the early 1940's.

Finger (1942) described the effect of various conditions of reinforcement upon the acquisition and extinction of the running response of the rat. The results suggest that the greater the amount of food as reinforcement the faster is the response after acquisition and the more rapid is the extinction.

The effect of distribution of reward on partial reinforcement was investigated by Sheffield (1949). Using the running response, the results of her study indicated that massed and spaced training trials yielded a significant performance discrepancy between 100% and 50% reinforcement. The massed training was found to have a significantly greater effect on extinction on the 50% than the 100% reinforcement group.

Jenkins and Stanley (1950) in their comprehensive review of the early partial reinforcement literature concluded that "acquisition proceeds somewhat more rapidly and reaches a higher final training level under continuous reinforcement than under partial reinforcement" (p.209) and "all other things equal, resistance to extinction after partial reinforcement is greater than that after continuous reinforcement." (p. 222).

A number of the early investigators noted that failure to reinforce a response that had been previously reinforced sets up an emotional response. Miller and Stephenson (1936) in a runway study with rats found reliable individual differences in agitation during nonreinforcement of a response that had previously been reinforced. They concluded that nonreward had some energizing effect following reward. Similarly Hull (1943) observed that cessation of previous reinforcements resulted in a slight initial rise in motor reaction (p. 262).

Rohrer (1947) demonstrated that nonreward had motivational properties. In his 1949 study, he attributed the characteristics of the motivational state of nonreward to frustration. He used the term "frustration" to account for the reduction in strength of the bar pressing response.

At the same time, Sheffield (1949, 1950), from her runway studies, related partial reinforcement effects to the spacing of trials. She suggested that the partial reinforcement effect was due to frustration produced by nonreinforcement, thereby attributing motivational properties to nonreward. Other studies attributing motivational properties to nonreward have been published by Denny and Dunham (1951), Brown and Farber (1951) and Seward (1951).

Amsel (1958, 1962, 1967) has formulated findings from studies of motivational properties of nonreward into a Frustration Theory. Hull (1943) had postulated a two-factor Inhibition Theory consisting of reward and punishment. Amsel proposed to introduce a third factor, namely, frustrative events resulting from nonreward. Amsel and Roussel (1952) found that the strength of the performance on the nonreinforcement trials exceeded that exhibited on the preliminary and the reward test trials. From these results Amsel concluded that nonreward trials have motivational properties. These active properties are defined as frustrative. "Frustration is a state which results from the nonreinforcement of an instrumental response which previously was consistently reinforced." (Amsel and Roussel, 1952, p. 363).

The principles of frustration theory were elaborated by Amsel (1958, 1962, 1967). The essential features of the theory will be summarized. Once a hungry rat has completed a number of rewarded trials, the stimulus cues in the goal box become conditioned to and elicit components of the goal response. By means of conditioning and generalization the expectancy of reward is elicited earlier and earlier in the response sequence. Once the reward expectancy is established, the appearance of nonreward produces an aversive emotional state called "frustration" which results in an increased drive level. The heightened vigour in the frustration state has been termed "frustration effect" (FE) by Amsel (1958).

Anticipatory frustration develops similarly to the anticipated goal response and provides increased vigour in the earlier portions of an instrumental response. The organism is placed in a temporary conflict since the response stimuli accompanying the anticipatory goal and frustration responses elicit incompatible approach and avoidance tendencies. The organism resolves the conflict by moving away from the frustrated environment toward the goal and in this rewarded state finds the response was worth the effort. Hence the frustration stimuli eventually become conditioned to the approach response. In this line of reasoning one is able to account for the higher acquisition performance of the partially rewarded group compared to that which was continuously rewarded.

The increased interest and investigation of partial reinforcement has continued from the early days of Skinner. In fact four major lines of experimental situations have been developed in partial reinforcement research:

a) Classical conditioning
b) Discreet-trial instrumental learning
c) Free responding
d) Verbal expectancy

The present study is a runway experiment, and consequently, the discreet trial instrumental learning studies, will be reviewed, particularly as they relate to the frustration effect (FE).

Partial Reinforcement and the Frustration Effect

Ever since Amsel (1958, 1962) proposed a theoretical framework (frustration theory) to account for the results of his and related partial reinforcement research, investigators have produced evidence to support or reject his postulates. A number of issues which are related to the frustration effect will be reviewed: magnitude of reward, prior training, incomplete incentive reduction and delay of reward.

Since the frustration effect (FE) is dependent on the omission of an expected reward, frustration theory predicts that the amount of the frustration is directly related to the strength of the reward. Consequently, a number of studies have altered the magnitude of the reward to determine the effect of varying the strength of reward on the FE. The between-group and within-subject design have been used to study the magnitude of reward effect on the FE. The between-group studies in which different groups of rats have been run with different amounts of intermittent reward, have shown a direct relationship between the increase in the magnitude of reward and the FE (Barrett, Peyser and McHose, 1965; Daly, 1968). However, McHose, (1969), Gavelek and McHose, (1970), Peckham and Amsel, (1967) have shown that significant FE was found with large reward but not with small reward. The within-subject experiments in which the same subjects have been run with different amounts of intermittent reward, have shown a direct relationship between the magnitude of reward and the FE.

Frustration theory predicts that increasing the reward magnitude on the reward trial should have the effect of increasing the speed on the nonreward trials because the goal response has been strengthened. Inconsistent results have been found, with Krippner, Endsley and Tacker (1967), Peckham and Amsel (1964) supporting the frustration theory but others such as Barrett, Peyser and McHose, (1965), Daly, (1968), McHose, (1969) not finding the expected results. Since the inconsistent results are not explicable in terms of frustration theory, Krippner et al. (1967) explained the results in a three-factor interpretation. They suggested that the increase in reward magnitude enhances the reward value of the first goal box which produces a tendency for the subject to retrace. Consequently, the subject is in conflict among the desire to retrace, effects of frustration and reward from the second goal box. These conflicts result in the inconsistent results.

The strength of the expectancy of reward can be manipulated by different types of training. Hence varied training procedures have been used to study the FE. Usually continuous reinforcement is given from the outset to establish an expectancy of reward (Savage, 1960, McHose, 1963, Patten and Myers, 1970) which results in an immediate FE upon the shift to partial reinforcement. Wagner (1959) has demonstrated an immediate frustration effect following 76 reward trials. Amsel (1958) has pointed out that frustration effect is a function of the number of reward trials prior to nonreward and found that less than 60 reward trials delayed the appearance of a significant FE until later nonreinforced trials. Amsel and Ward (1965) gave partial reinforcement from the outset and found that the FE increased with training. Partial reinforcement has also been given after a few reward trials which resulted in the FE being an increasing function of the number of prior trials (Hug, 1970; Yalen, 1969).

Incomplete incentive reduction is analogous to FE produced by nonreward and has constantly been shown to increase the response in the second runway (Barrett et al, 1965; Bower, 1959; Daly, 1968; Patten and Myers, 1970). However, using a control group to ensure that reduction in the amount of reward is the variable affecting the FE and not hunger drive has not produced evidence for FE produced by incomplete reward magnitude reduction (Barrett et al., 1965; Daly, 1968). However, Hall and Marr (1969) trained subjects on differential magnitude reward and revised the magnitude of reward for test trials. The results indicated that FE is a function of reduction of reward even when motivational level due to hunger is held constant.

Investigations into the delay of reward have found slower speeds in the second runway following delay of reward as compared to immediate reward (McHose, 1966; Sgro, Glotfelty and Moore, 1970). A delay of reward combined with a reduction in the magnitude of reward had yielded an FE (McHose, 1966, 1968).

Application of Drive to Partial Reinforcement Effect

The earliest application of drive level to partial reinforcement was by Linton and Miller (1951). The drive level was manipulated by having the animals either satiated or without food for 22 hours before the trials. The animals were tested under 100% or 50% reinforcement. The extinction results indicated that under satiation the 50% reinforcement animals ran faster than the 100% reinforcement group, although the difference did not reach statistical significance. The 22 hour food deprived rats ran significantly faster than the satiated group under 100% reinforcement. The results indicate that drive level does effect partial reinforcement behavior. A study by Lewis and Cotton (1957) obtained negative results. Food deprivation of 1, 6 and 23 hours was used as drive levels under 100% and 50% reinforcement. The interaction between the drive levels and the two reinforcement variables did not reach significance. Badia (1955) studied partial reinforcement under 3 levels of food deprivation (2½, 11½, 22½ hours). A cross over effect was noted whereby running was faster for the 100% reinforcement group during the early acquisition levels but the 50% reinforced group ran faster during the later trials. It was found that the subjects ran faster asymptotically under medium and high deprivation than low, both in 100% and 50% reinforcement conditions. The results showed a cross over effect as the subjects at each of the 3 deprivation levels ran faster under 50% than the 100% reinforcement. McHose and Ludvigson (1964) studied the effect of prior level of drive produced by food deprivation on the frustration effect. The subjects were placed on a feeding schedule to keep their weight at 80% of the initial body weight for the high drive group and 90% of their body weight for the low drive group. The results showed that the FE was apparent for both drive conditions and that the effect was more pronounced for those in the high drive group. Haas, Shessel, Willner and Rescorla (1970) studied the effect of satiation following partial reinforcement. The results indicate that the group under partial reinforcement had greater resistance to the decremental effect of satiation than did the animals under continuous reinforcement.

In frustration theory, the FE is attributed to a temporary increase in the drive level. Considerable evidence is available to show that FE indeed does represent an increase in motivation. Several studies have measured FE in terms of activity following reward and nonreward trials (Dunlap and Dackowski, 1970; Gallup and Altomari, 1969).

It has been shown that partial reinforced subjects are more active in the goal box than the continuous reinforced subjects. Goodrich (1959) found that the partial reinforced subjects on reinforced trials spent a longer time at the goal box than the continuous reinforced subjects. Tacker and Way (1968) replaced the goal box with an open field. The subjects were found to be more active following nonreinforced trials than reinforced trials. Gallup and Hare (1969) compared partial and continuous reinforced subjects in the open-field. The results indicated that the partial reinforcement subjects were more active than the continuous ones.

The measure of activity has not been limited to the goal box. Goodrich (1959) found that the subjects under partial reinforcement stopped more often early in training than did the continuous reinforced subjects.

McCoy and Marx (1965) found that the partial reinforcement subjects reversed direction and stopped more often than continuous reinforcement subjects early in training. However, when asymptote was reached the competing responses were infrequent in both groups. Mikulka and Pavlik (1966) found that partial reinforcement subjects made more competing responses at various deprivation levels except for the satiated condition where the results were reversed. Allison (1967) found that the partial reinforcement subjects retraced faster during acquisition than continuous. However, the failure to find this effect has also been recorded (Allison 1967, Robbins, Chait, and Weinstock, 1968). These studies lend support to the motivational properties of the FE.

A few studies have been devoted to the effect of brain lesions on partial reinforcement. Bloom (1971) compared a group of hippocampal lesioned rats with a group of normal rats. The lesion group was slower following reward trials than the normal group but the nonreward trials yielded no significant difference. Bloom suggested that the hippocampal lesion interferes with the normal response to reinforcement. Hence the lesioned subjects do not respond to the reward trial because the value of the food has been decreased. Franchina and Brown (1971) found that hippocampal lesioned rats do not respond to a shift in the reward magnitude. Their findings appear to support Bloom's (1971) interpretation.

In recent years a great deal of research has been devoted to the study of drugs. However, relatively few of these studies have been applied to partial reinforcement.

Wagner (1963) found that sodium amytol produced a general reduction in the running response. The sodium amytol depressed the running response of the partial reinforcement group compared to the saline control group. In contrast, Nelson and Wollen (1965) with a similar design as Wagner (1963) found amobarbital to have little effect on the activating properties of nonreward. Gray (1969) in his study with amobarbital found evidence to support Nelson and Wollen's (1965) findings that the effect of the drug did not alter the FE. However he did find that amobarbital depressed the running response of the partial reinforcement group in the acquisition phase.

Hence research into the effects of drugs and lesions on the various variables in the FE paradigm remains incomplete.

The Development of the Roman Low and High Avoidance Strains

The search for genetic bases for behavioral differences has occupied the interest of researchers for several decades. The early studies used ill defined populations or did not report the selection methods. However, the recent appearance of standardized strains of rats has led to an heightened interest in the genetic analysis of many phenotypes including learning. Broadhurst (1960) suggests two main approaches to genetic determinants of behavior, namely, selection and analysis of characteristics displayed by different pure strains. The purpose of the selection procedures is to provide a base from which genetic analysis can begin. Tryon (1940) had the most successful early selection study. His investigation which selected for high and low error scores on a 17 unit maze showed clear differentiation between the maze bright and dull strains. Most of the early selection studies were designed to test genetic involvements in learning. Other phenotypes have been examined such as the Maudsley strains selected by Broadhurst (1960) for high and low emotional defecation in the open-field test.

From the results of Bignami's (1965) research, the Roman high and low avoidance strains were selected on the basis of high or low rate of conditioned avoidance response (CAR) acquisition during the first two sessions in an escape-avoidance conditioning apparatus (shuttle box) of standard type. The other selection criterion was the high or low (CAR) retention from one session to the next. Originally the rats were obtained from an Italian commercial dealer. Each generation up to and including the fifth generation of selection were given 5 daily sessions of 50 trials. The conditioned stimulus (CS) was light and the unconditioned stimulus (UCS) which developed escape and later avoidance responses, was moderately painful shock to the feet. Both the total number of avoidance responses produced and the number of trials required to reach learning and retention criteria from one session to the next were the basis for selection of parents for the successive generation. Environmental conditions were rigorously controlled. Tests showed very little effect of environmental factors. The results after 5 generations showed that the Roman high avoidance (RHA) strain were constantly superior in the conditioned avoidance response compared to both the Roman low avoidance strain (RLA) and the unselected population. The RHA line showed a steady upward progression of avoidance response from a common parental mean value of 105 avoidances out of 250 to a mean of 171 for the fifth generation. The RLA strain showed a gradual decrease to a mean value of 51 by the fifth generation. The Roman strains were moved to Birmingham, England following the fifth generation at which time they were retested to guard against environmental differences related to the transfer. The parental stock of each succeeding generation was based on avoidance scores following a series of 25 conditioning trials in a shuttle box. The investigation by Broadhurst and Bignami (1965) found that the RHA strain was lighter and more active than the RLA. Generally, the sex differences were not significant between the strains. Bignami (1965) concluded that the results were a clear demonstration of the strong genetic component in the rate of acquisition of the conditioned avoidance response by the rat.

Research into the Roman Strains

Broadhurst and Bignami (1965) investigated the response of the Roman strains to determine their correlation with phenotypes other than those for which they were selected. Consequently, the Roman strains were subjected to the "open-field test." The results indicated that the Roman strains were not characterized by marked differences in emotional responsiveness as determined by the open-field test of emotional elimination. However, the ambulation scores showed the RHA strain to be significantly more active in exploratory ambulation than the RLA strain.

Holland and Gupta (1966) used the 8th generation RHA and RLA strains to investigate differences in general activity and emotionality. Rearing behavior and the activity cage were the methods used to measure the general activity of the animals. Lat (1963) suggested that rearing behavior is an indicator of the central nervous system excitability whereas Berlyne (1961) indicated that it determines the exploratory directed level of arousal. The activity cage measured the activity or the arousal mechanism. The open-field test was used to measure the animals' emotional response. The strains were found to differ in activity but not emotionality. The RHA scored significantly higher on the factors related to activation than did the RLA strain. The results were consistent with the findings of Broadhurst and Bignami (1965) who found that Roman strains were not characteristically differentiated by defecation but found that the RHA strain was significantly more active in exploratory ambulation than the RLA strain.

Gupta and Holland (1969) in general found the RHA strain to be more active than the RLA strain and made some theoretical comments to account for the results. They suggest that the RLA strain, which are poorer conditioners than the RHA strain due to their low level of excitation, will condition even more poorly under low level of emotionality. In contrast, the RHA who have a high level of arousal will condition easily and the conditionability will increase to a greater extent under high degree of emotionality. Hence the acquisition of the CAR may be the result of individual differences in the ease of arousal in the central nervous system and the level of drive. "In other words avoidance behavior may be the outcome of an interaction between genetically determined central excitation or emotionality (or both) and the environmentally determined reinforcers". (p. 95).

Satinder and Hill (1974) researched the effects of genotype and postnatal experience of the Roman strains. The Roman High Avoidance strain (RHA/Lu) showed significantly higher avoidance response than the Roman Low Avoidance strains (RLA/Lu), consistent with the findings of Bignami (1965) and Broadhurst and Bignami (1965). Holland and Gupta (1966) noted that the main difference between the Roman strains was the activity level. Satinder and Hill (1974) qualified Holland and Gupta's (1966) findings by concluding that the strain difference in activity was restricted to the avoidance paradigm. Their findings also agreed with Broadhurst and Bignami (1965) who found no significant "open-field" defecation differences and a negative correlation between escape-avoidance and the open-field defecation measures.

Imada (1972) studied emotional reactivity and conditionability of the Roman strains. The measure of emotionality was the extent to which drinking behavior was suppressed by administering brief unsignalled shock repeatedly during drinking situations. The strains were then matched on basal emotional level (BEL) obtained from the measure of suppressed drinking behavior by adjusting the shock level so that the average degree of suppression was equal for the strains. Half of the subjects received a signal prior to the shock while the others did not. The difference between the drinking curves for the two groups in each strain was the measure of conditionability. The results indicated an emotionality response difference between the Roman strains. The RLA strain was found to be more emotional than the RHA. This finding contradicts the results reported by Broadhurst and Bignami (1965) who found no significant difference in emotionality between the Roman high and low avoidance strains as measured by the open-field test. Imada (1972) concluded that the RLA strain is more emotional than the RHA strain but the open-field test of emotionality was not sensitive enough to make the discrimination. Imada's (1972) results indicated that the RHA strain was more active and had better conditionability for a conditioned avoidance response than the RLA strain which is consistent with the findings of Broadhurst and Bignami (1965) and Holland and Gupta (1966).

In a recent study by Wilcock (1972) the male RHA strain showed a faster water escape latency as well as conditionability to water escape than the RLA male. This is consistent with previous aversive conditioning studies which have shown the RHA to be more responsive to aversive conditioning than the RLA (Broadhurst and Bignami, 1965; Holland and Gupta, 1966; Satinder and Petryshyn, 1974).

Drug Studies on the Roman Strains

The establishment of stable avoidance conditioning behaviour permitted these animals to be used in a number of pharmacological investigations.

Gregory (1967) studied rearing following avoidance learning in a two-way shuttle-box and the effect of the tranquilizing drug methylpentynol carbamate on post training stress. The results indicated that rearing was suppressed following participation in the shuttle-box. However the difference between the strains was not significant. Methylpentynol carbamate does not appear to affect rearing or its suppression following escape avoidance training. However, the drug was found to increase the rearing of the RLA strain while decreasing the RHA strain, hence reducing the general activity difference between the strains.

The 12th generation Roman high avoidance animals were used by Gregory (1968) to study the effect of reserpine and premylamine (depressant drugs) on rearing behaviour and avoidance learning in a two-way shuttle-box. The effect of the drugs on rearing and aversive learning performance was similar for both sexes and was found to be most effective at the highest dose level used. The drugs depressed the conditioned avoidance response (CAR) and Gregory (1968) suggests that the depressant drugs may either reduce the fear which in turn suppresses the motivational factor or acts as a sedative to disrupt the motor performance. The latter was considered to be the more plausible alternative. The RHA strain was characterized by greater activity. The findings indicate that the difference in activity level is responsible for the variability between the sexes of the RHA strain in CAR performance.

Garg and Holland (1969) studied the Maudsley and Roman strains to determine the effect of nicotine on maze learning. The results indicated that post trial administration of nicotine increased certain aspects of the learning process such as consolidation. On the 8th generation, the drug had a greater effect on the RHA than the RLA. The authors suggest that the difference in conditionability was due to a difference in transmission of sensory information. The females were found to be generally superior in learning than the males.

Garg (1969) studied the effect of nicotine on rearing frequency in four strains of rats including the Roman strains. The RHA strain was found to be higher in activity (number of sections crossed) than the RLA strain. Garg also found that the rearing frequency was increased by administration of nicotine. The RHA strain was found to be extremely sensitive to nicotine; however, the drug did not appear to produce any effect on the RLA strain. The females were found to be superior to the males in exploratory behaviour and affected more by nicotine.

The two Roman strains were included in the research by Satinder (1971) regarding the effects of d-amphetamine sulphate and caffeine on the escape-avoidance conditioning. The results showed that the drugs facilitated avoidance behaviour in the RLA/Lu but not the RHA/Lu strain. The tendency was for the drug to minimize the marked strain difference found on avoidance and escape latency under pre-drug conditions. He suggests that the different response to the drugs may be due to the underlying genetic mechanism responsible for the behaviour or possibly the brain mechansim underlying escape avoidance behaviour may interact differently with the drugs.

Satinder (1972) followed up his previous study (Satinder, 1971) by investigating the relationship between avoidance and intertrial activity by punishing or permitting intertrial crossing (ITC) with and without dosages of d-amphetamine sulphate. The RHA/Lu strain showed no effect of the ITC punishment on avoidance but a suppression of activity was produced. The drug inhibited avoidance under both the ITC-punishment and the ITC-permissible trials. However the drug increased intertrial activity only under the ITC-permissible condition. Satinder (1972) suggests that the results indicate that "intertrial crossing punishment can produce strain dependent dissociation between avoidance and intertrial responses" (p. 293). The dissociations are affected by d-amphetamine sulphate.

Satinder and Petryshyn (1974) investigated the interaction among genotype, unconditioned stimulus, d-amphetamine and one-way avoidance behaviour. The difference between the RHA/Lu and the RLA/Lu strains was reduced in the one-way compared to the two-way avoidance learning, which was taken to indicate that the complexity of the learning task influences the rate of learning. Since strain difference was found in both the one-way and two-way avoidance learning, it is an indication that avoidance learning is generalizable from the two-way to the one-way avoidance learning paradigm. Motivational differences in shock sensitivity did not account for the total variation in learning rates. D-amphetamine reduced the variation between the strains in one-way active avoidance learning. The authors suggest that the results indicate a higher level of arousal for the RHA/Lu compared to the RLA/Lu strain.

It is of interest to determine whether or not the motivational component is generalizable to the partial reinforcement paradigm. The motivational component of the RHA/Lu and the RLA/Lu strains has been investigated in relation to shock levels in the avoidance learning paradigm (Satinder and Hill, 1974; Satinder and Petryshyn, 1974).

Since most researchers are interested in learning on the broad scale rather than on specific learning tasks, it is important to determine whether differences generalize to other learning paradigms. The

Roman strains have been tested in two-way avoidance learning by Bignami (1965), and one-way avoidance learning by Satinder and Petryshyn (1974). Because further investigation into other learning tasks is desirable this study investigated the strain differences in the partial reinforcement paradigm.

Hunger was used as the "motivator" in this study as in most of the partial reinforcement studies (Amsel and Roussel, 1952; Savage, 1960; and many others).

Sex differences in learning and consolidation between the RHA and RLA strains have been demonstrated by Garg and Holland (1969). Studies, with the Maudsley strain, support the Garg and Holland results. The generalizability of sex differences to the partial reinforcement paradigm was also investigated in the present experiment.

METHOD

Experimental Design

The experimental design consisted of six variables. The two between variables were strain and sex. The within variables were deprivation schedule consisting of three levels, days, trials, and the shift from 100% to 50% reinforcement.

Subjects

Thirty-two experimentally naive rats, 16 from each strain, RHA/Lu:S_{22} and RLA/Lu:S_{22} were used as subjects. Each strain had equal representation from each sex. All animals were bred and reared in the laboratory and were 150 days of age at the beginning of the experiment. Before the experiment the subjects were housed in groups of two or three with their own strain and sex. During the experiment they were housed in individual cages and were code numbered. The temperature was controlled between $72^\circ \pm 2^\circ$ F and the humidity level was 40%. The fluorescent lights were on and off on 12 hour cycles automatically.

Apparatus

The apparatus designed by Satinder in 1968 was used. It is similar to the one employed by Amsel and Roussel (1952) consisting of a start box, followed by 2 runways and goal boxes set up in series. The dimensions of the start and goal boxes and runways were 12" x 3 1/2" x 5" and 36" x 3 1/2" x 5" respectively (see Figure 1). The running times were obtained in runway 1 when the subjects interrupted a photo cell beam 10" from the start box thereby activating an electric timer. The timer was stopped by the breaking of the photo cell beam 2" from goal box 1. In runway 2 a separate timer was activated when the photo cell beam which was 10" into the runway was interrupted. The breaking of the photo cell beam 2" from goal box 2 stopped the timer. Time interval taken to traverse the 24" distance between the photo cell beams in runway 2 constituted the latency score.

Procedure

The procedure consisted of 4 phases: restricted feeding, pretraining, acquisition and testing.

Restrictive feeding was gradually introduced over 5 days to lower the animal's body weight. The animals were weighed daily to ensure that the body weight remained between 80 - 85% of their free-feeding body weight. Water was available to the animals at all times.

The pretraining phase consisted of 10 minutes of exploration of the apparatus for 2 consecutive days. This was followed by a 5 minute exploration time in the apparatus with food available in each goal box on 3 consecutive days. The sixth day was like the 3 previous days except that the apparatus was in operation in order to give the animals opportunity to adapt. A background noise of 65 dbs. was used to mask external sounds, similar to the procedure used by Satinder (1971). (Sound intensities were averages at the floor level above the standard reference level of .0002 μ bar, measured by General Radio Sound level meter, Type 1551-c). The reward in each goal box consisted of 3 45mg Noyes precision food pellets.

The acquisition phase consisted of 10 100% reinforcement trials per day run on alternative days for a total of 120 trials per animal.

The testing phase consisted of 3 sets of 10 daily trials over a 7 day period, one set for each of 3 deprivation schedules (for a total of 21 days). Each trial consisted of either a reward or nonreward (selected randomly) in goal box 1 and a reward trial in goal box 2. Hence each animal was exposed to 35 reward and 35 nonreward trials in goal box 1 and 70 reward trials in goal box 2 over each 7 day testing period. The animals were tested on 3 drive levels consisting of 23, 11 and 3 hours of food deprivation. The subjects were run in 3 groups consisting of 8, 12, and 12 animals. The first 8 animals were tested on the three deprivation levels (23, 11, and 3 hours) in serial order. The remaining 24 animals were partitioned into 6 groups of 4 animals and each group was exposed to the three deprivation conditions in a different order. (Table 1).

TABLE 1

Procedure

Partitioning of Groups and Training Sessions Under Three Food Deprivation Levels

A. 24 animals - consisting of:

RHA/Lu	Females	- 6
	Males	- 6
RLA/Lu	Females	- 6
	Males	- 6

B. 24 animals partitioned into 6 groups of 4 animals

Each of the 6 groups consisted of:

RHA/Lu Females - 1
Males - 1

RLA/Lu Females - 1
Males - 1

C. Combinations of Testing Sessions For The Six Groups Under Three Food Deprivation Conditions:

1 2 3
2 3 1
3 1 2
1 3 2
2 1 3
3 2 1

The testing continued until each team had been tested on each of the three food deprivation levels.

During the course of the experiment 2 animals died and were replaced.

RESULTS

The latency response was obtained by measuring the time interval required by each subject to traverse the second runway. The analysis of variance was used to analyze the latency and percentage change data. Table 2 shows the analysis of variance of the total latency data. (p. 43).

The variables of interest in the analysis were strains (the Roman high and low avoidance), 3 food deprivation levels (23, 11, and 3 hours), reinforcement pattern (100% or 50%), sexes, trials and days.

No significant difference in the latency or percentage change data was obtained among the 8 animals who ran in serial order at each of the three food deprivation levels and the other 2 groups of 12 animals each who were exposed to all combinations of orders at each of the 3 deprivation levels which permitted the data to be pooled.

Food Deprivation Levels

100% Reinforcement:

The analysis of variance of the latency data for the 100% reinforcement pattern indicates that the RHA/Lu strain responds differently at each of the food deprivation levels ($\underline{F} = 6.61$, $\underline{df} = 2/56$, $\underline{p} < .01$). The mean latency for the RHA/Lu strain was .651, .684 and .716 sec. for 23, 11 and 3 hours food deprivation, respectively. The results indicate that the RHA/Lu strain mean latencies are in inverse relation to the number of hours of food deprivation. However, the RLA/Lu strain mean latencies of .700, .701 and .717 sec. for 23, 11 and 3 hours of food deprivation respectively, did not reach significance. Under 100% reinforcement the RHA/Lu strain yielded a significantly ($\underline{F} = 8.16$, $\underline{df} = 1/28$, $\underline{p} < .01$) lower latency than the RLA/Lu strain under 23 hours of food deprivation. Latency differences of significant magnitude were not found under 11 and 3 hours of food deprivation between the strains. The results showed that under 100% reinforcement the difference in latencies between the RHA/Lu and RLA/Lu strains are reduced as the number of hours of food deprivation is decreased (Figure 2).

50% Reinforcement

Under 50% reinforcement pattern the RHA/Lu strain yielded significant ($\underline{F} = 6.96$, $\underline{df} = 2/56$, $\underline{p} < .01$) food deprivation variation indicating that the RHA/Lu strain responds differently to the 3 food deprivation levels. The RHA/Lu strain mean latencies of .574, .608, and .636 for 23, 11 and 3 hours of food deprivation, respectively, indicated that the mean latencies are an inverse function of the number of hours of food deprivation. The RLA/Lu strain did not yield significant variation at the 3 food deprivation levels. The RHA/Lu and the RLA/Lu strains, under 50% reinforcement, yielded a significant ($\underline{F} = 3.98$, $\underline{df} = 1/28$, $\underline{p} < .025$) difference in the mean latency under 3 hours of food deprivation. However, these 2 strains did not show significant variation under 11 hours and 23 hours of food deprivation under 50% reinforcement.

The results indicate that the change from 100% to 50% reinforcement pattern has the effect of reducing the strain difference in latency for the 23 hour food deprivation level, increasing the strain latency difference under 3 hours of food deprivation and reversing the relative position of strain mean latencies under 11 hours of food deprivation.

Change in Reinforcement Pattern

The analysis of variance indicated that both the high and low avoidance strains yielded a significant latency variation in the change in the reinforcement pattern from 100% to 50% reinforcement. This change yielded a significant (*F* = 845.86, *df* = 1/28, $p < .001$) latency variability for the RHA/Lu strain and (*F* = 859.76, *df* = 1/28, $p < .001$) for the RLA/Lu strain. The low avoidance strain produced mean latencies of .706 and .595 sec. and the high avoidance strain .684 and .600 sec. for 100% and 50% reinforcement respectively. Hence the low avoidance strain had a longer mean latency under 100% reinforcement trials and yielded a lower latency score on the 50% reinforcement trials than the high avoidance strain. These results indicate that the low avoidance strain responded to the change from 100% to 50% reinforcement more than the high avoidance strain. The difference between the mean latency for the 100% and 50% reinforcement trials was also calculated and the percentage change measure was obtained by the formula:

$$\text{Percentage change} = \frac{\text{100\% reinf. latency} - \text{50\% reinf. latency} \times 100}{\text{100\% reinf. latency}}$$

The percentage change data which showed the amount of the shift from 100% to 50% reinforcement, yielded a significant (*F* = 20.21, *df* = 1/28, $p < .01$) variability between the strains. The RLA/Lu and RHA/Lu strain ran 15.77% and 11.61% faster during the 50% reinforcement trials than 100% respectively, indicating that the RLA/Lu strain responded a greater extent to the change in reinforcement pattern than the RHA/Lu strain. The faster running response to nonreward was referred to as the frustration effect (FE) by Amsel and Roussel (1952). The change from 100% to 50% reinforcement is significantly different for the strains at 3 and 11 hours of food deprivation. The 3 hour food deprivation level yielded a significant (*F* = 9.47, *df* = 2/56, $p < .01$) strain variation on the percentage change data. In percentage form, the RLA/Lu and RHA/Lu strains ran 16.28% and 11.51% faster respectively on the 50% reinforced trials than on the 100% which is a demonstration of the frustration effect for both strains. However, the RLA/Lu strain responds significantly more to the change from 100% to 50% reinforcement, than the RHA/Lu strain. Similar findings are produced at the 11 hour food deprivation level, where a significant ($\underline{F} = 9.20$, $\underline{df} = 1/28$, $\underline{p} < .01$) strain variation was yielded in the change from 100% to 50% reinforcement. In percentage form, the RLA/Lu strain responded with a 15.89% faster latency response under 50% reinforcement than the 100% reinforcement trials compared to 11.44% for the RHA/Lu strain under similar conditions. These results indicate that under 11 hours of food deprivation both the RLA/Lu and RHA/Lu strains yielded significant frustration effects (FE) and the RLA/Lu strain responded to a greater extent to the change from 100% to 50% reinforcement. However, at the 23 hour food deprivation level, the RLA/Lu and RHA/Lu strains did not yield a significant strain variation in the shift from 100% to 50% reinforcement. The results indicate in percentage form that both the RLA/Lu and RHA/Lu strains respond to a greater degree under 50% than 100% reinforcement under the 23 hour food deprivation level. The RLA/Lu and the RHA/Lu strains ran 15.13% and 11.89% faster respectively on the 50% reinforced trials compared to the 100% indicating that the FE is produced in both strains but the FE does not differ between the strains significantly at the 23 hour food deprivation level.

Sex Difference

The analysis of variance of the latency data yielded a significant sex difference in the RHA/Lu strain under both the 100% and 50% reinforcement trials. The 100% reinforcement trials for the RHA/Lu strain produced a significant ($F = 6.39$, $df = 1/14$, $p < .025$) sex variability. The results indicated that under 100% reinforcement the high avoidance females yielded a significantly lower latency .665 sec. than the males .702 sec. However, the RLA/Lu strain yielded latencies of .708 and .704 sec. for females and males, respectively, which did not produce a significant sex difference. Hence the RHA/Lu females' mean latency is faster than the RHA/Lu males' and both sexes of the RLA/Lu strain.

The 50% reinforcement pattern yielded a significant ($F = 4.48$, $df = 1/14$, $p < .05$) mean latency sex difference in the RHA/Lu strain whereas in the RLA/Lu no significant differences were found. The latencies were .592 and .621 sec. for the females and males, respectively. The RHA/Lu strain for 50% reinforcement trials did not yield significant sex differences. Comparing the sexes of the 2 strains, the only significant difference between the latencies on the 50% reinforcement trials is slower performance of the RHA/Lu males than the rest. The results also indicated that the change from 100% to 50% reinforcement reduced the sex difference in the RHA/Lu strain whereas the minimal sex differences in the RLA/Lu strain remained constant. (Figure 2).

The analysis of variance of the latency data yielded a significant ($F = 7.76$, $df = 2/56$, $P < .01$) food deprivation, sex and strain interaction.

The sexes of both the RHA/Lu and the RLA/Lu strains responded differently to the 3 reinforcement levels (Figure 2). At 23, 11, and 3 hours of food deprivation significant sex and strain interactions of ($F = 8.95$, $df = 2/56$, $p < .01$), ($F = 4.68$, $df = 2/56$, $p < .05$), and ($F = 5.50$, $df = 2/56$, $p < .025$) were found. The sexes within each strain yielded reciprocal U-shaped patterns in the mean latency response over the 3 food deprivation levels (Figure 2).

The results also indicated that the females of the 2 strains yielded reciprocal U-shaped mean latency functions for the 3 levels of food deprivation. For 23, 11 and 3 hours of food deprivation the females of RHA/Lu and RLA/Lu strain yielded mean latencies of .626, .691, .679 sec. and .727, .674, .723 sec., respectively. The difference between the females of the strains was significant ($F = 12.83$, $df = 1/14$, $p < .01$) only at the 23 hours of food deprivation level. The RHA/Lu females yielded lower mean latencies at 23 and 3 hours of food deprivation than the RLA/Lu females and the relative positions were reversed at 11 hours of food deprivation (Figure 2). The males yielded similar U-shaped functions to the females under the 3 deprivation levels. The RHA/Lu and the RLA/Lu males yielded mean latencies of .677, .676, .753 sec. and .674, .728, .711 sec. respectively for 23, 11 and 3 hours of food deprivation. Only at the 11 hours of food deprivation was a significant ($F = 4.86$, $df = 1/14$, $p < .05$) difference obtained. The RHA/Lu males yielded a lower mean latency at the 11 hour food deprivation than the RLA/Lu but the relative positions were reversed at 23 and 3 hour food deprivation levels.

The shift from 100% to 50% reinforcement produced some minor effects on the sex variables. At the 23 hour food deprivation the difference between the latencies of the females of RHA/Lu and RLA/Lu strains were reduced ($\underline{F} = 5.53$, $\underline{df} = 1/14$, $\underline{p} < .05$), as was the difference between the males at the 11 hour food deprivation. However, the difference between the mean latencies of the males at the 3 hour food deprivation was increased to a significant level ($\underline{F} = 15.65$, $\underline{df} = 1/14$, $\underline{p} = < .01$). The RLA/Lu males' mean latency of .586 sec. was significantly lower than the .664 sec. obtained by the RHA/Lu males.

Hence the significant difference between the 2 strains in the change from 100% to 50% reinforcement at the various food deprivation levels can be attributed largely to the low mean latency yielded by the RHA/Lu females under 23 hours of food deprivation and the high mean latency response yielded by the RHA/Lu strain males under 3 hours of food deprivation (Figure 2).

Trial Effect

The analysis of variance yielded significant trial variation ($\underline{F} = 77.31$, $\underline{df} = 4/112$, $\underline{p} < .001$). The latency data indicated that the animals decreased their mean latency after each subsequent trial.

A significant ($\underline{F} = 5.64$, $\underline{df} = 4/112$, $\underline{p} < .01$) interaction between the trials and the change from 100% to 50% reinforcement indicated that the 100% and 50% reinforcement patterns had a differential effect on the trials.

Days Effect

The analysis of variance of the latency data indicated that the subjects only exhibited minimal variation from day to day indicating that the running of the animals over a 7 day period for each deprivation level did not affect the results.

DISCUSSION

Amsel and Roussel (1952) termed the increased drive state following the omission of an expected reward the frustration effect (FE). The results of the present study support the findings of Amsel and Roussel (1952) who found the shift from 100% to 50% reinforcement yielded an FE. Both the RHA/Lu and RLA/Lu strains responded with an FE following the shift in the reinforcement pattern.

Gupta and Holland (1966) suggested that the conditioned avoidance response (CAR) is in part due to either differences in emotionality which are related to the autonomic nervous system or arousal which is related to differences in the central nervous systems. It is generally accepted that the FE is an emotional response (Amsel, 1958; and Savage, 1960) and hence related to the autonomic nervous system. Although both strains showed a significantly faster latency following 50% reinforcement than the 100% reinforcement, the RLA/Lu strain yielded a significantly larger FE than the RHA/Lu strain which indicates that the former strain manifests a higher emotional response to the change in reinforcement pattern than the latter. Hence, the present study lends support to the study by Imada (1972) who found the RLA strain to be more emotional than the RHA strain as measured by suppression of drinking by unsignalled shock. The results support Imada's (1972) conclusion that motivation based techniques may be a more sensitive measure of emotionality than open-field measures.

The RHA/Lu and RLA/Lu strains produced an immediate FE following the shift from 100% to 50% reinforcement which is consistent with the findings of Wagner (1959) and Savage (1960) who found an immediate FE following 76 and 80 reward training trials respectively. Amsel (1958) suggested that less than 60 reward trials delayed the FE until later trials. The present study used 120 training trials and indicated that with both the RHA/Lu and RLA/Lu strains, 120 training trials are sufficient to elicit an immediate FE. Further investigation is required to determine whether or not the RHA/Lu and RLA/Lu strains produce an FE which is a function of the number of prior reward trials.

The FE was not found to be significantly different on any of the testing days (consisting of 5 reward and 5 nonreward trials each) following the 120 training trials indicating that the 120 training trials are sufficient to produce asymptotic latency levels.

The results of the present study are consistent with several explanations for the FE. Bower (1962) proposed that the anticipated goal response (r_G) is aroused by stimuli in the first runway and is reduced by the reward in the first goal box. In the nonreward trials, the anticipated goal response (r_G) in runway 1 combines with the anticipated goal response (r_G) of the reward in the second goal box to yield a faster latency. Staddon (1970) suggested that the FE may be due to generalization decrement. He argues that after continuous reward, the after-effects of reward should have a conditional inhibiting effect on the latency because of association with the slow response early in the chain. The nonreward trials remove the cue for slow running and produce an increase in the response rate. These theoretical positions, along with others, have all been used to account for the FE. However, they are unable to explain the larger FE produced by the RLA/Lu than the RHA/Lu strains.

The more vigorous response to the shift in reinforcement pattern produced by the RLA/Lu strain compared to the RHA/Lu strain was unexpected, since the latter has been shown to respond to a greater degree in most situations including conditionability, (Bignami, 1965); activity, (Broadhurst and Bignami, 1965); and conditioned avoidance response, (Satinder, 1971, 1972a; Satinder and Petryshyn, 1974). According to Scull (1973), the amount of the FE should be directly related to the strength of the anticipated goal response (r_G) in Spence's (1956) formulation. Hence, the RLA/Lu strain with the larger FE forms a stronger anticipated goal response than the RHA/Lu strain. The strain difference in response to the shift in reinforcement pattern cannot be accounted for by the theoretical position proposed by Amsel, (1958, 1962 and 1967); Bower (1962); or Staddon (1970). However the cognitive dissonance theory has been applied to the behaviour of the rat in the runway by Lawrence and

Festinger (1962) and may give a reasonable explanation to the FE variation between the high and low avoidance strains. By way of elaboration, nonreinforced trials yield dissonance because effort has been expanded by the rat to reach the goal box in anticipation of food and no reinforcement is received. The presence of dissonance gives rise to a motivational state which causes the animal to respond with increased vigor in order to reduce the dissonance. The magnitude of the dissonance depends on the value of the reward to the organism. It is generally accepted that the RHA strain is more active than the RLA strain (Holland and Gupta, 1966; Satinder and Petryshyn, 1974; and others). Hence the less active RLA strain may consider the food more rewarding because of the effort exerted in order to obtain the reward than the more active RHA strain which finds the food less rewarding because less effort has been expended for the reward. Consequently, the RLA strain with the strong dissonance responds to the change from 100% to 50% reinforcement with more vigor in order to reduce the dissonance than the RHA strain.

The change in food deprivation levels, in the present study, did not yield a statistically significant FE variation within the strains. However, both the RHA/Lu and RLA/Lu yielded an inverse relationship between the FE and the number of hours of food deprivation. On the other hand, McHose and Ludvigson (1964) found the FE to be a function of the prior drive level. The difference in the results may in part be due to procedural variations, as the McHose and Ludvigson (1964) study used percentage of loss in body weight as the measure of prior drive magnitude whereas the present study used the more common food deprivation levels as the measure of the motivational variable.

The results indicate that the 2 strains selectively bred for high and low rates of shock avoidance behaviour also respond differently to appetitive motivation. Consistent and convincing evidence has been reported to indicate that an increase in motivation improves learning and performance (Collier and Willis, 1961; Pavlik and Reynolds, 1963; Bitterman and Schoel, 1970; and others). Since it is generally accepted that increased food deprivation improves performance, the RHA/Lu strain behaved in the expected direction as the increase in food deprivation resulted in a subsequent shorter latency. However, the RLA/Lu strain did not respond significantly to the change in food deprivation levels. Hence, an appetitive motivational difference may exist between the high and low avoidance strain with the former being more sensitive to appetitive motivational factors than the latter. Differences in shock avoidance behaviour have in part been attributed to variability in motivation between RHA and RLA strains (Satinder and Petryshyn, 1974). They found that the RLA/Lu strain yielded noticeable differences in the learning rates during training whereas the RHA/Lu strain did not yield a functional relationship between avoidance learning and shock intensity.

The variability in response to the motivational factors by the 2 strains may be due to the different nature of the drive. The RHA/Lu strain may respond to the different levels of appetitive motivation to a greater extent than the RLA/Lu strain whereas the RLA/Lu strain may respond more to the different levels of aversive motivation.

A study by Broadhurst and Bignami (1965) indicated that the sexes within the RHA and RLA strains responded differently to active avoidance conditioning. The RHA males were found to escape faster from the aversive stimulus than the females and in the RLA strain the relative positions of the sexes were reversed. The present results indicate that the sexes within the 2 strains responded in similar fashion to 11 hours of food deprivation as to the Broadhurst and Bignami (1965) study of active avoidance conditioning. However, the change in food deprivation to either 3 or 23 hours resulted in a reversal of the relative positions as the RHA/Lu females responded faster than the males and the RLA/Lu males faster than the females. Variation within and between the RHA/Lu and RLA/Lu strains have also been demonstrated by Satinder and Hill (1974) and Satinder and Petryshyn (1974). The former found the RHA/Lu females to yield more avoidance response than the males whereas in the RLA/Lu the relative positions were reversed. The flinch threshold showed the females of both strains to yield lower scores than the males. The males were found to perform poorer on cross over, and rearing and grooming measures. Satinder and Petryshyn (1974) found the RHA/Lu females suppressed 1-way avoidance behaviour under 4.0 mg/kg dosage level. These sex variations within and between the RHA/Lu and RLA/Lu strains must be taken into account in the study of appetitive and aversive motivation.

The results of the present study indicated that both the rewarded and nonrewarded trials showed a gradual decrease in performance over each ensuing trial each day. These results support the findings of Seward, Pereboom, Butler and Jones (1957) who found that consumption of food resulted in poorer subsequent performance. This decline was attributed to the loss of the hunger drive.

In summary, the results of this study suggest the following conclusions:

(a) The RHA/Lu strain responds to the appetitive drive to a greater extent than the RLA/Lu strain.

(b) The RLA/Lu strain responds to change in reinforcement pattern (FE) more strongly than the RHA/Lu strain.

(c) The sexes within each strain show reciprocal U-shaped functions to changes in food deprivation schedules.

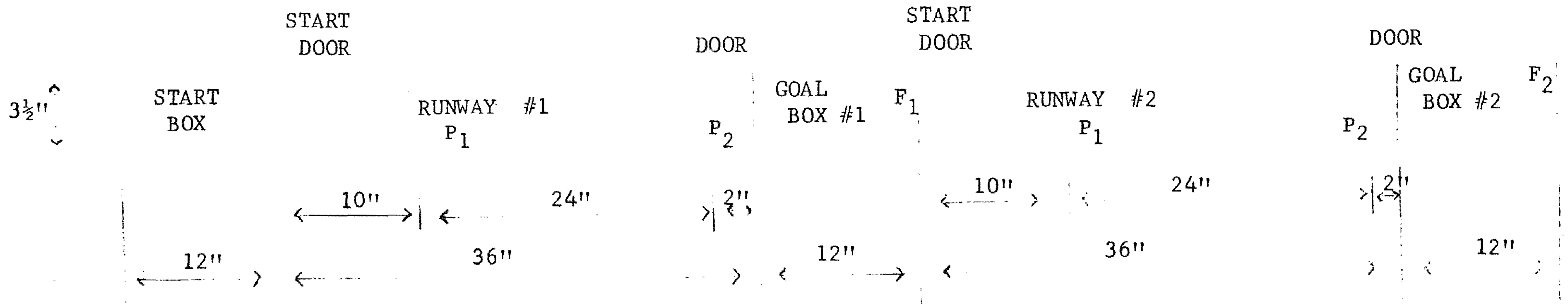

Figure 1. Floor plan of the apparatus. The walls of the apparatus were 5" high. P_1 and P_2 in each runway represent the two photo cells which were located 2" above the runway floor. F_1 and F_2 represent the food reward receptacles in each of the goal boxes. The apparatus was constructed from transparent plexiglass. The clocks and photo cells controlled the opening and closing of doors.

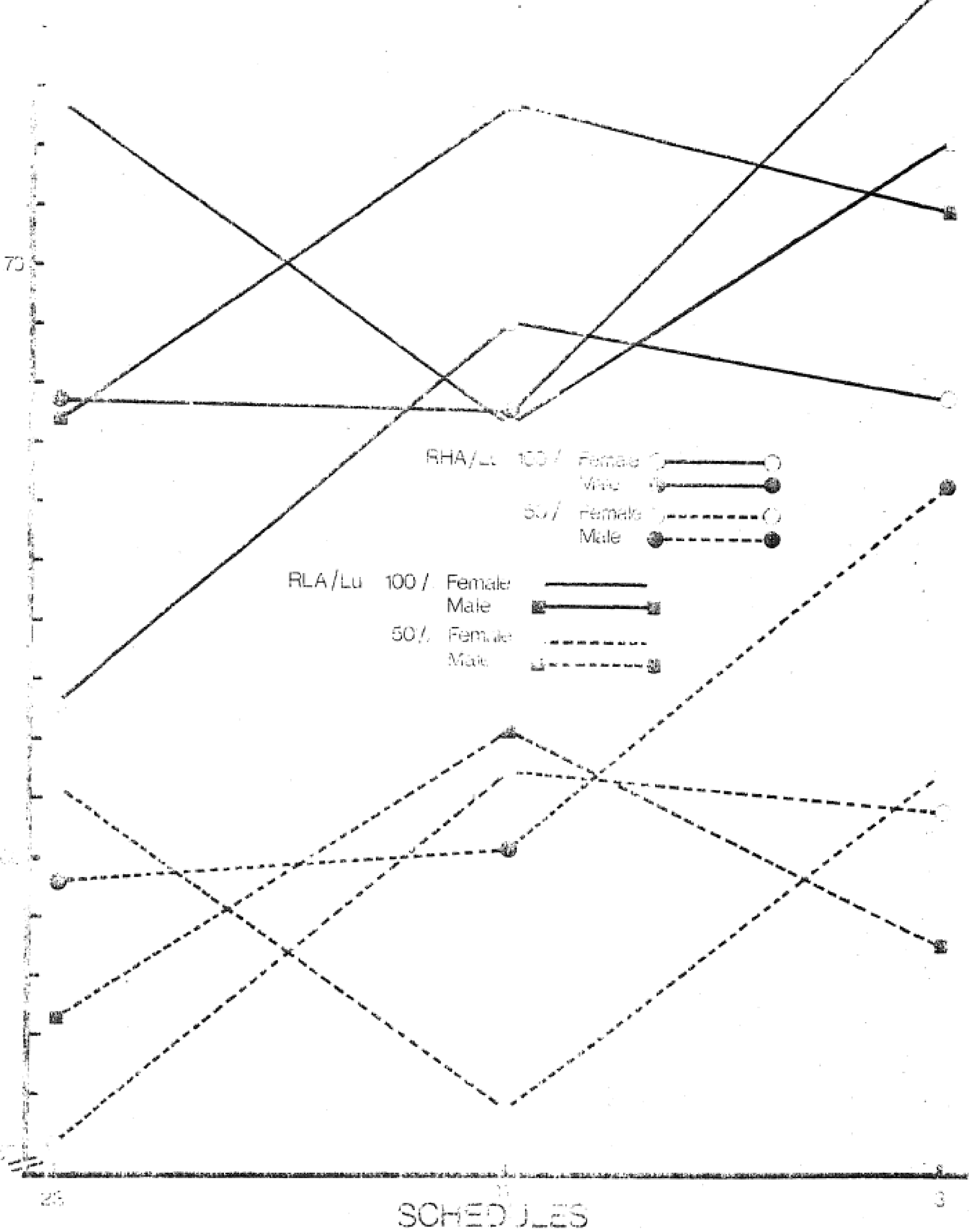

Figure 2. Mean latency in seconds for both males and females of the RHA/Lu and RLA/Lu strains under 23, 11 and 3 hours of food deprivation and 100% and 50% reinforcement pattern.

TABLE 2

Analysis of Variance of Latency Data

	df	ms	f	p
Strain	1	0.05	0.02	.89
Sex	1	0.38	0.15	.69
Strain x Sex	1	0.53	0.20	.65
Error - Strain x Sex	28	2.52		
Schedule	2	0.81	5.31	.01
Schedule x Strain	2	0.38	2.52	.08
Schedule x Sex	2	0.09	0.56	.57
Schedule x Strain x Sex	2	1.24	8.13	.001
Error - Schedule x Strain x Sex	56	0.15		
Days	6	0.05	1.43	.20
Days x Strain	6	0.04	1.29	.26
Days x Sex	6	0.03	0.89	.49
Days x Strain x Sex	6	0.03	0.85	.52
Error - Days x Strain x Sex	168	0.03		

	df	ms	f	p
100% to 50%	1	15.01	462.01	.001
100% To 50% x Strain	1	0.48	14.83	.001
100% To 50% x Sex	1	0.00	0.11	.73
100% To 50% x Strain x Sex	1	0.01	0.28	.59
Error - 100% To 50% x Strain x Sex	28	0.03		
Trial	4	0.42	36.94	.001
Trial x Strain	4	0.01	0.53	.71
Trial x Sex	4	0.04	3.55	.001
Trial x Strain x Sex	4	0.00	0.38	.81
Error - Trial x Strain x Sex	112	0.01		
Schedule x Days	12	0.03	1.16	.30
Schedule x Days x Strain	12	0.04	1.25	.24
Schedule x Days x Sex	12	0.03	0.88	.56
Schedule x Days x Strain x Sex	12	0.04	1.26	.23
Error - Schedule x Days x Strain x Sex	336	0.03		
Schedule x 100% To 50%	2	0.00	0.38	.67
Schedule x 100% To 50% x Strain	2	0.00	0.15	.85
Schedule x 100% To 50% x Sex	2	0.02	1.80	.17
Schedule x 100% To 50% x Strain x Sex	2	0.00	0.22	.80
Error - Schedule x 100% To 50% x Strain x Sex	56	0.01		

	df	ms	f	p
Schedule x Trial	8	0.01	1.58	.13
Schedule x Trial x Strain	8	0.01	1.48	.16
Schedule x Trial x Sex	8	0.01	0.95	.47
Schedule x Trial x Strain x Sex	8	0.00	0.20	.98
Error - Schedule x Trial x Strain x Sex	56	0.01		
Days x 100% To 50%	6	0.01	0.78	.58
Days x 100% To 50% x Strain	6	0.01	1.31	.25
Days x 100% To 50% x Sex	6	0.00	0.55	.76
Days x 100% To 50% x Strain x Sex	6	0.01	1.34	.23
Error - Days x 100% To 50% x Strain x Sex	168	0.01		
Days x Trial	24	0.01	1.39	.10
Days x Trial x Strain	24	0.00	0.81	.71
Days x Trial x Sex	24	0.01	1.05	.38
Days x Trial x Strain x Sex	24	0.00	0.81	.72
Error - Days x Trial x Strain x Sex	672	0.01		
100% To 50% x Trial	4	0.03	4.87	.001
100% To 50% x Trial x Strain	4	0.01	2.15	.07
100% To 50% x Trial x Sex	4	0.00	0.53	.71
100% To 50% x Trial x Strain x Sex	4	0.00	0.24	.91
Error - 100% To 50% x Trial x Strain x Sex	112	0.01		

	df	ms	f	p
Schedule x Days x 100% To 50%	12	0.00	0.66	.78
Schedule x Days x 100% To 50% x Strain	12	0.01	0.75	.69
Schedule x Days x 100% To 50% x Sex	12	0.01	0.03	.41
Schedule x Days x 100% To 50% x Strain x Sex	12	0.00	0.67	.77
Error - Schedule x Days x 100% To 50% x Strain x Sex	336	0.01		
Schedule x Days x Trial	48	0.01	1.08	.32
Schedule x Days x Trial x Strain	48	0.01	1.32	.06
Schedule x Days x Trial x Sex	48	0.01	1.32	.06
Schedule x Days x Trial x Strain x Sex	48	0.01	1.18	.18
Error - Schedule x Days x Trial x Strain x Sex	1344	0.00		
Schedule x 100% To 50% x Trial	8	0.01	1.34	.22
Schedule x 100% To 50% x Trial x Strain	8	0.00	0.73	.65
Schedule x 100% To 50% x Trial x Sex	8	0.01	1.02	.41
Schedule x 100% To 50% x Trial x Strain x Sex	8	0.00	0.42	.90
Error - Schedule x 100% To 50% x Trial x Strain x Sex	224	0.01		
Days x 100% To 50% x Trial	24	0.00	0.96	.51
Days x 100% To 50% x Trial x Strain	24	0.01	1.12	.31
Days x 100% To 50% x Trial x Sex	24	0.00	0.89	.60
Days x 100% To 50% x Trial x Strain x Sex	24	0.00	1.00	.46
Error - Days x 100% To 50% x Trial x Strain x Sex	672	0.00		

	df	ms	f	p
Schedule x Days x 100% To 50% x Trial	48	0.01	0.97	.52
Schedule x Days x 100% To 50% x Trial x Strain	48	0.01	1.40	.03
Schedule x Days x 100% To 50% x Trial x Sex	48	0.01	0.98	.49
Schedule x Days x 100% To 50% x Trial x Strain x Sex	48	0.00	0.84	.76
Error - Schedule x Days x 100% To 50% x Trial x Strain x Sex	1344	0.01		

REFERENCES

Allison, J. Time spent in the goal box: Effects of frequency and schedule of reinforcement. Psychonomic Science, 1967, 7, 165-166.

Amsel, A. The role of frustrative nonreward in noncontinuous reward situations. Psychological Bulletin, 1958, 55, 102-119.

Amsel, A. Frustrative nonreward in partial reinforcement and discrimination learning: Some recent history and theoretical extensions. Psychological Review, 1962, 69, 306-328.

Amsel, A. Partial reinforcement effects on vigor and persistence. In Spencer, K.W. and Spencer, J.T., (Ed.). Psychology of learning and motivation: Advances in research and theory. Volume 1. New York: Academic Press, 1967.

Amsel, A., and Roussel, J. Motivational properties of frustration: I. Effect on a running response of the addition of frustration to the motivational complex. Journal of Experimental Psychology, 1952, 43, 363-368.

Amsel, A., and Ward, J.S. Frustration and persistence: Resistance to discrimination following prior experience with discriminanda. Psychological Monographs, 1965, 79, (Whole #597).

Anderson, A.C. Running time and the goal gradient. Journal of Experimental Psychology, 1933, 16, 423-428.

Badia, P. Effects of drive, reinforcement schedule and change of schedule on performance. Journal of Experimental Psychology, 1965, 69, 292-297.

Barrett, R.J., Peyser, C.S., & McHose, J.H. Effects of complete and incomplete reward reducation on a subsequent response. Psychonomic Science, 1965, 3, 277-278.

Berlyne, D.E. Conflict, arousal & curiosity, New York: McGraw Hill, 1960.

Bignami, G. Selection for high rates and low rates of avoidance conditioning in the rat. Animal Behaviour, 1965, 13, 221-227.

Bitterman, M.E. and Schoel, W.M. Instrumental learning in animals: Parameters of reinforcement. Annual Review of Psychology, 1970, 21, 367-436.

Bloom, J.M. and McFarlain, R.A. Hippocampal lesions and the partial reinforcement effect. Psychological Reports, 1971, 29, 831-837.

Bower, G.H. Escape learning as a function of amount of shock reduction. Journal of Experimental Psychology, 1959, 58, 482-484.

Bower, G.H. The influences of graded reductions in reward and prior frustrating events upon the magnitude of frustration effect. Journal of Comparative and Physiological Psychology, 1962, 55, 582-587.

Broadhurst, P.L. Experiments in psychogenetics: Application of biometrical genetics to behavior. In Eysenck, H.J. (Ed.) Experiments in personality. Volume 1, Psychogenetics and psychopharmacology. London: Routledge, Kegon, and Paul. 1960.

Broadhurst, P.L. and Bignami, G. Correlative effects of psychogenetic selection: A study of Roman high and low avoidance strains of rats. Behavior Research and Therapy, 1965, 2, 273-280.

Brown, J.S., and Farber, I.E. Emotions conceptualized as intervening variables with suggestions toward a theory of frustration. Psychological Bulletin, 1951, 48, 465-495.

Collier, G. and Willis, F.N. Deprivation and reinforcement. Journal of Experimental Psychology, 1961, 62, 377-384.

Daly, H.B. Excitory and inhibitory effects of complete and incomplete reward reduction in the double runway. Journal of Experimental Psychology, 1968, 76, 430-438.

Denny, M.R. and Dunham, M.D. The effect of differential nonreinforcement of the incorrect response on the learning of the correct response in the simple T-maze. Journal of Experimental Psychology, 1951, 41, 382-389.

Dunlap, W.P. & Dachowski, L. Effects of drive and partial reinforcement on extinction both between and within daily sessions. Psychological Reports, 1970, 27, 875-885.

Finger, F.W. The effect of varying conditions of reinforcement upon a simple running response. Journal of Experimental Psychology, 1942, 30, 53-68.

Franchina, J.J. & Brown, T.S. Reward magnitude shift effects in rats with hippocampal lesions. Journal of Comparative and Physiological Psychology, 1971, 76, 365-370.

Gallup, G.G., Jr., & Altomari, J.S. Activity as a post situation measure of frustrative nonreward. Journal of Comparative and Physiological Psychology, 1969, 68, 382-384.

Gallup, G.G., Hare, G.K. Activity following partially reinforced trials: Evidence for a residual frustration effect due to conditioned frustration effect. Psychonomic Science, 1969, 16, 41-42.

Garg, M. Variation in the effects of nicotine in four strains of rats. Psychopharmacologia, 1969, 14, 432-438.

Garg, M., & Holland, H.C. Consolidation and maze learning: A study of some strain/ Drug interactions. Psychopharmacologia, 1969, 14, 426-431.

Gavelek, J.R. & McHose, J.H. Contrast effects in differential delay of reward conditioning. Journal of Experimental Psychology, 1970, 86, 454-457.

Goodrich, K.P. Performance in different segments of an instrumental response chain as a function of reinforcement schedule. Journal of Experimental Psychology, 1959, 57, 57-63.

Gray, J.A. Sodium amobarbital and effects of frustrative nonreward. Journal of Comparative and Physiological Psychology, 1969, 69, 55-64.

Gregory, K. A note on the action of methylpentynol carbamate in strains of rats bred for differential conditioning ability. Psycholpharmacologia, 1967, 317-319.

Gregory, K. The action of the drug prenylamine on exploratory activity and aversive learning in a selected strain of rats. Psychopharmacologia, 1968, 13, 22-28.

Gupta, B.D., & Holland, H.C. An examination of the effects of stimulant and depressant drugs on escape of avoidance conditioning in strains of rats selectively bred for emotionality / nonemotionality. Psychopharmacologia, 1969, 14, 95-105.

Haas, R.B., Shessel, F.M., Willner, H.S., & Rescorla, R.A. The effect of satiation following partial reinforcement. Psychonomic Science, 1970, 18, 296-297.

Hall, C.S. Emotional behavior in the rat: Defecation and urination as measures of individual differences in emotionality. Journal of Comparative Psychology, 1934, 18, 385-403.

Hall, L.A. & Marr, J.N. Incomplete reduction of reward and the frustration effect with hunger constant. Journal of Experimental Psychology, 1969, 80, 493-497.

Holland, H.C. & Gupta, B.D. Some correlated measures of activity and reactivity in two strains of rats selectively bred for differences in the acquisition of a conditioned avoidance response. Animal Behavior, 1966, 14, 574-580.

Hug, J.J. Frustration effects after varied numbers of partial and continuous reinforcement: Incentive differences as a function of reinforcement percentages. Psychonomic Science, 1970, 21 57-59.

Hull, C.L. Principles of behavior, New York: Appeton - Century - Crofts, 1943.

Humphreys, L.G. The effect of random alternation of reinforcement on the acquisition and extinction of conditioned eyelid reactions. Journal of Experimental Psychology, 1939, 25, 141-158 (a).

Humphreys, L.G. Acquisition and extinction of verbal expectation in a situation analogous to conditioning. Journal of Experimental Psychology, 1939, 25, 294-301 (b).

Humphreys, L.G. Extinction of conditioned psycho-galvanic responses following two conditions of reinforcement. Journal of Experimental Psychology, 1940, 27, 71-75.

Imada, H. Emotionality and conditionality in rats. Journal of Comparative and Physiological Psychology, 1972, 79, 481-487.

Jenkins, W.D. & Stanley, J.C., Jr. Partial reinforcement: A review and critique. Psychological Bulletin, 1950, 47, 193-234.

Krippner, R.A., Endsley, R.C., & Tacker, R.S. Magnitude of G_1 reward and the frustration effect in a between subjects design. Psychonomic Science, 1967, 9, 385-386.

Lat, J. The spontaneous exploritory reactions as a tool for psychopharmacological studies. Proceedings of the 2nd. International Pharmacological Meeting, Prague, 1963.

Lawrence, D.H. & Festinger, L. Deterrents and reinforcement: The psychology of insufficient reward. Stanford, California: Stanford University Press, 1962.

Lewis, D.J., & Cotton, J.W. Learning and performance as a function of drive strength during acquisition and extinction. Journal of Comparative and Physiological Psychology, 1957, 50, 189 - 194.

Linton, H.B., & Miller, N.E. The effect of partial reinforcement on behavior during satiation. Journal of Comparative and Physiological Psychology, 1951, 44, 142-148

McCay, D.F., & Marx, M.H. Competing responses and the partial reinforcement effect. Journal of Experimental Psychology, 1965, 70, 352-356.

McDonald, S.G., Porter, J.J., & Madison, H.L. Changes following asymptotic instrumental performance as a function of shifts in drive. Psychonomic Science, 1970, 19, 33-34.

McHose, J.H. Effect of continued nonreinforcement on the frustration effect. Journal of Experimental Psychology, 1963, 65, 444-450.

McHose, J.H. Incentive reduction: Simultaneous delay increase and magnitude reduction and subsequent responding. Psychonomic Science, 1966, 5, 215-216.

McHose, J.H. Incentive reduction: Varied simultaneous reductions and subsequent responding. Psychonomic Science, 1968, 11, 313-314.

McHose, J.H. Role of frustration in the development in relative and absolute S-discrimination contrast effects. Journal of Experimental Psychology, 1969, 81, 256-260.

McHose, J.H., & Ludvigson, H.W. Frustration effect as a function of drive. Psychological Reports, 1964, 14, 371-374.

McHose, J.H., & Ludvigson, H.W. Role of reward magnitude and incomplete reduction of reward magnitude in the frustration effect. Journal of Experimental Psychology, 1965, 70, 490-495.

Mikulka, P.J., & Pavlik, W.B. Deprivation level, competing responses and the PRE. Psychological Reports, 1966, 18, 95-102.

Miller, N.E., & Stevenson, S.S. Agitated behavior of rats during experimental extinction and a curve of spontaneous recovery. Journal of Comparative Psychology, 1936, 21, 205.

Nelson, P.B., & Wollen, K.A. Effects of ethanol and partial reinforcement upon runway acquisition. Psychonomic Science, 1965, 3, 135-136.

Patten, R.L., & Myers, D.B. Number of training trials and frustration effects of nonzero reward reduction in the double alley. Psychonomic Science, 1970, 18, 291-292.

Pavlik, W.B., & Reynolds, W.F. Effects of deprivation schedule and reward magnitude on acquisition and extinction performance. Journal of Comparative and Physiological Psychology, 1963, 56, 452-455.

Pavlov, J.P. Conditioned reflexes (Translated by G.V. Anrep) London: Oxford University Press, 1927.

Peckham, R.J., & Amsel, A. Magnitude of reward and frustration effect in a within-subject design. Psychonomic Science, 1964, 1, 285.

Peckham, R.J., & Amsel, A. Within subject demonstration of a relationship between frustration and magnitude of reward in a differential magnitude of reward discrimination. Journal of Experimental Psychology, 1967, 73, 187.

Razran, G.H.S. Conditioned withdrawal of response. Psychological Bulletin, 1934, 31, 111-143.

Robbins, D., Chait, H., & Weinstock, S. Effects of nonreinforcement on running behavior during acquisition, extinction, and reacquisition. Journal of Comparative and Physiological Psychology, 1968, 66, 699-706.

Rohrer, J.H. Experimental extinction as a function of the distribution of extinction trials and response strength. Journal of Experimental Psychology, 1947, 37, 473-493.

Rohrer, J.H. A motivational state resulting from nonreward. Journal of Comparative and Physiological Psychology, 1949, 42, 476-485.

Satinder, K.P. Genotype dependent effects of d-amphetamine sulphate and caffeine on escape-avoidance behavior of rats. Journal of Comparative and Physiological Psychology, 1971, 76, 359-364.

Satinder, K.P. Effects of intertrial crossing punishment and d-amphetamine sulphate on avoidance and activity in four selectively bred strains. Psychonomic Science, 1972, 29, 291-293.

Satinder, K.P., & Hill, K.D. Effects of genotype and postnatal experience on activity, avoidance, shock threshold, and open-field behavior of rats. Journal of Comparative and Physiological Psychology, 1974, 86, 363-374.

Satinder, K.P., & Petryshyn, W.R. Interaction among genotype, unconditioned stimulus, d-amphetamine and one-way avoidance behavior of rats. Journal of Comparative and Physiological Psychology, 1974, 86, 1059-1073.

Savage, R.D. Constitutional determinants of emotionality in the rats: An experimental investigation of fear, frustration and conflict. Ph. D. Thesis, University of London, 1960.

Scull, J.W. The Amsel frustration effect: Interpretations and research. Psychological Bulletin, 1973, 79, 352-361.

Seward, J.P. Experimental evidence for the motivating function of reward. Psychological Bulletin, 1951, 48, 130-149.

Seward, J.P., Pereboom, A.C., Butler, B., & Jones, R.B. The role of pre-feeding in an apparent frustration effect. Journal of Experimental Psychology, 1957, 54, 445-450.

Sgro, J.A., Glotfelty, R.A., & Moore, B.D. Delay of reward in the double alleyway: A within-subjects versus between-groups comparison. Journal of Experimental Psychology, 1970, 84, 82-87.

Sheffield, V.F. Extinction as a function of partial reinforcement and distribution of practice. Journal of Experimental Psychology, 1949, 39, 511-526.

Sheffield, V.F. Resistance to extinction as a function of the distribution of extinction trials. Journal of Experimental Psychology, 1950, 40, 305-313.

Skinner, B.F. The rate of establishment of a discrimination. Journal of Genetic Psychology, 1933, 9, 302-350.

Skinner, B.F. The extinction and its modification by a temporal discrimination. Psychological Bulletin, 1936, 33, 784.

Spence, K.W. Behavior theory and conditioning. New Haven: Yale University Press, 1956.

Staddon, J.E. Temporal effects of reinforcement: A negative frustration effect. Learning and Motivation, 1970, 1, 227-247.

Tacker, R.S., & Way, J. Motivational properties of nonreward. Psychonomic Science, 1968, 10, 103-104.

Tryon, R.C. Genetic differences in maze learning ability in rats. Yearbook of National Society of Studies in Education, 1940, 39, 111-119.

Wagner, A.R. The role of reinforcement and nonreinforcement in an "apparent frustration effect". Journal of Experimental Psychology, 1959, 57, 130-136.

Wagner, A.R. Sodium amytal and partial reinforced runway performance. Journal of Experimental Psychology, 1963, 65, 474-477.

Wilcock, J. Comparative psychology lives on under an assumed name - Psychogenetics ! American Psychologist, 1972, 27, 531-538.

Yalen, D. Magnitude of the frustration effect and number of training trials. Psychonomic Science, 1969, 15, 137-138.