Effects of Food-Deprivation on Free-Operant Avoidance Behavior

By

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A DISSERTATION PRESENTED TO THE GRADUATE COUNCIL OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA
1971

Dedicated to my Mother and Father,
Wife and Son.

ACKNOWLEDGEMENTS

I gratefully thank Dr. E. F. Malagodi for his guidance during my graduate school career and for the direction, support, and facilities to conduct the research in this dissertation.

I also express my appreciation to Dr. Robert L. King, Dr. Henry S. Pennypacker, Dr. Charles J. Vierck, and Dr. Richard D. Willis for being my teachers and for serving on my committee.

I would also like to thank many others who have contributed immeasurably to my education and professional development. These people include Dr. Merle E. Meyer, Dr. Louis Lippman, Dr. Donald A. Dewsbury, Dr. Michael A. Milan, Thomas Waddell, and my wife, Kathleen.

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Graduate Council of the University of Florida in Partial Fulfillment
of the Requirements for the Degree of Doctor of Philosophy

EFFECTS OF FOOD-DEPRIVATION ON FREE-OPERANT
AVOIDANCE BEHAVIOR

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August, 1971

Chairman: E. F. Malagodi
Major Department: Psychology

In Exp. 1, lever pressing was maintained by Sidman's shock-postponement procedure under conditions of free-feed and food deprivation with rats. In Exp. 2, responding was maintained conjointly by Sidman's shock-postponement procedure and by response-dependent time-out from the avoidance contingencies under the same food conditions as Exp. 1. In Exp. 3, the effects of food deprivation were determined for responding maintained by Herrnstein and Hineline's shock-frequency-reduction procedure. Exps. 1-3 used rats as the experimental animals. In order to extend the species generality of the food-deprivation effect, lever pressing by hamsters was maintained with Sidman's shock-postponement procedure under conditions of free-feeding and food deprivation in Exp. 4. In all 4 experiments, food deprivation resulted in a decrease in the rate of lever pressing to avoid electric shock. Reinstatement of free-feeding conditions resulted in a gain in body weight and an increase in response rates. This food-deprivation effect was not dependent upon any particular free-operant avoidance procedure and occurred with both rats and hamsters as experimental animals.

INTRODUCTION

Since the advent of Sidman's (1953) free-operant avoidance paradigm, there have been several studies using this procedure under conditions necessitating food deprivation. One example is the multiple schedule procedure employed by Herrnstein and Brady (1958). During the first stimulus condition, food was presented on a 5 min fixed-interval schedule (FI 5). During the third 5 min stimulus condition, responses initially postponed shock for 20 sec (Sidman avoidance). The second and fourth stimulus conditions were Time-Out (TO) conditions and responses had no programmed consequences. Varying the shock-postponement interval produced changes in the response rates of both rats during the avoidance and the two TO conditions. As the shock-postponement interval was shortened, response rates in these three components increased. The rate of responding during the FI 5 condition decreased for one rat and remained unchanged for the other. Another example is the concurrent food-presentation and shock-avoidance procedure (Hearst, 1962; Catania, Deegan, & Cook, 1966). In Hearst's experiment, chain pulling by a Rhesus monkey was reinforced on a variable-interval 2 min schedule of food reinforcement and lever pressing postponed shock for 10 sec. Hearst found that stimulus generalization prior to discrimination training was greater for the shock-avoidance-maintained response than for the food-maintained response. After extensive discrimination training the gradients could be made virtually identical. In the experiment by Catania et al., a press on one lever postponed shock and a press on a different lever resulted in food presentation on a fixed-ratio schedule. Catania et al. reported that the overall response rates maintained by each schedule were not systematically affected when one or the other schedule was removed. Thus the two concurrent behaviors were maintained relatively independent of each other.

Both the multiple avoidance-appetitive and the concurrent avoidance-appetitive schedules require food deprivation as a necessary setting-condition for the maintenance of behavior by response-dependent food. This use of food deprivation suggests that it may be an important variable to manipulate during chronically-maintained avoidance behavior.

Some theoreticians (Hull, 1943; Kendler, 1965) have suggested that food deprivation should facilitate shock escape-avoidance behavior. Hull's (1943) drive summation hypothesis predicts that the "appetitional drive" summates with the "drive" arising from the shock, and that this increase in the sum of "drives" should facilitate escape-avoidance behavior. Amsel (1950) conducted an experiment to test this prediction. Rats were confined in a starting box at one end of a five-foot alley with an electrifiable grid floor. A light was turned on for 3 sec, and then, simultaneously with opening of the start box door, the floors of the start box and alley were electrified. Opening the door allowed the rat to escape to a shock-free area at the opposite end of the alley. Ten trials separated by 5 min intertrial intervals were conducted for two days. During training Amsel did not obtain a statistically reliable difference in running time between the group that had been food deprived 22 hours and the non-deprived group. When the shock was discontinued and the animals were tested in extinction, the food-deprived group ran significantly faster than the non-deprived group. Amsel concluded that the "appetitional drive" summated with a conditioned drive (anxiety) to produce this effect during extinction. Ley (1965) exposed non-deprived rats to 35 pairings of a 6 sec light illumination with 2 sec of electric shock. The light and shock were terminated simultaneously. The rats were subsequently maintained on a limited feeding schedule with free access to food and water for 1 hr daily. On day 6, the animals were tested in a hurdle-jumping task. Ten sec after being placed in the start box, the door was opened and the light was presented. The shock was never presented on these test trials. When the rat jumped the hurdle, the light was terminated. Day 7 was another test day. Only on the second day of testing (day 7) were the hurdle-jump latencies for the food-deprived group shorter than for the non-deprived group. Thus both Amsel (1950) and Ley (1965) found that food deprivation facilitated an escape-avoidance response only when tested in extinction (no-shock condition). Franchina (1966) studied the effect of 0 or 21 hrs of food deprivation combined orthogonally with 40 or 70 v of shock during a <u>single</u> shock-escape trial. The rats had to jump a hurdle to escape from the electrified start box to the shock-free compartment. On the single trial, the 21 hr food-deprived rats had shorter latencies than the non-deprived rats. Thus Amsel (1950), Ley (1965), and Franchina (1966) all report food deprivation to facilitate escape-avoidance behavior under certain conditions.

However, a recent study by Meyer, Adams, and Worthen (1969) has reported that food deprivation up to 48 hr increases shock-escape latencies. The rats were tested in an operant conditioning chamber. Upon shock onset, they could terminate the shock by depressing the lever protruding into the chamber. After the animals had acquired the escape response, the level of deprivation was manipulated. The response latencies were shortest for the 0 hr deprivation condition, and longest for the 48 hr food-deprivation condition. The latency for the 24 hr deprivation condition was intermediate between the other two values.

While investigating the effects of inescapable shock on the subsequent acquisition of a lever-press response to escape electric shock, Dinsmoor (1958) deprived half of the rats of food. He observed no effect of food deprivation on acquisition of the escape response.

Kendler (1965), with a different theoretical approach than Hull (1943), suggested that the effect of food deprivation is to lower the sensory thresholds, thus resulting in an increased effectiveness of a given shock intensity. Griffiths (1962) investigated the effect of food and water deprivation on shock tolerance. The rats were placed in the shock chamber and the DC shock voltage was increased in 2 v steps ". . . until the animals indicated by vigorous movements, vocalization, and/or excessive urination and defecation, that the shock was noxious (p. 164)." This shock value was determined 3 times per day for 5 days. The results showed that 24 hr food-deprived rats tolerated higher intensities of shock before engaging in the above behaviors than non-deprived rats. It was suggested by Blanchard and Blanchard (1966) that the result of Griffiths' study was due solely to a decreased probability of shock-elicited vocalization in the food-deprived condition. Blanchard and Blanchard repeated Griffiths' study determining the probability of shock-elicited jumping for 12 different shock intensities. The order of shock presentation was randomly varied between 0.05 ma to 2.0 ma. They found no differences between the deprived and the non-deprived groups on the flinch or jump response measures. The shock-elicited vocalization response was decreased in probability over the entire shock-stimulus range. The deprived rats emitted fewer vocalization responses at each shock intensity.

Misanin and Campbell (1969) have recently hypothesized that the effect of various motivating conditions is to alter the sensory capability of an organism to detect and react to specific stimuli. In three experiments they measured the shock-detection thresholds, shock-aversion thresholds, and the amount of activity elicited by inescapable shock under free-feeding and food-deprivation conditions. The shock-detection threshold was defined as the shock intensity that served on 50% of its presentations as an effective conditioned stimulus for avoiding a more severe shock. In the test for shock aversion, the rats were placed in a cage that pivoted on an axis, and the shock was delivered when the rat was on one side of the cage. The shock-aversion threshold was defined as the level of shock that the rat avoided 75% of the time. The same pivotal cage was used to determine reactivity to electric shock. Scrambled shock was continuously administered for 15 min and the number of cage crossings was recorded. Misanin and Campbell concluded that food deprivation had no effect on either the shock-detection threshold or the aversion threshold. There was also no difference between food-deprived and non-deprived rats in their reactivity to inescapable shock. In a fourth experiment they manipulated the degree of food deprivation during acquisition of an avoidance response. Five seconds after presentation of a light and clicker, shock was delivered until terminated by the rat's movement to the other end of the shuttle box. If the animal responded during the light and clicker, the shock was avoided and the two stimuli were terminated. The data showed that food deprivation had no effect on acquisition of the avoidance response.

A synthesis of the above literature yields three reports of negative results. The first is that food deprivation did not affect shock-detection or shock-aversion thresholds (Misanin & Campbell, 1969). The second is that food-deprivation did not modify the probability of shock-elicited activity (Misanan & Campbell, 1969), or shock-elicited flinching and jumping (Blanchard & Blanchard, 1966). The third is that food deprivation did not affect the acquisition of an escape-avoidance response (Amsel, 1950; Dinsmoor, 1958; Misanin & Campbell, 1969). The literature review also yields three reports of positive results. First is that food deprivation did decrease the probability of shock-elicited vocalization (Blanchard & Blanchard, 1966). Second, food deprivation did facilitate behavior during extinction of an avoidance response (Amsel, 1950; Ley, 1965). The third is that food deprivation of rats exhibiting chronically maintained shock-escape behavior resulted in a decrement in escape behavior (increased escape latencies) (Meyer _et al_., 1969). The purpose of this series of experiments was to assess the effects of food deprivation on free-operant avoidance responding chronically maintained by Sidman's (1953) shock-postponement paradigm and Herrnstein and Hineline's (1966) shock-frequency-reduction paradigm.

EXPERIMENT 1. FOOD-DEPRIVATION EFFECTS ON AVOIDANCE BEHAVIOR MAINTAINED BY SHOCK POSTPONEMENT IN RATS

The purpose of this experiment was to assess the effect of food deprivation on shock-avoidance behavior maintained by Sidman's (1953) free-operant shock-postponement procedure. The effect was first assessed with this procedure because this is the most commonly used avoidance procedure utilized in multiple avoidance-appetitive (Herrnstein & Brady, 1958) and concurrent avoidance-appetitive schedules (Catania, Deegan, & Cook, 1966).

Method

Subjects

Two male hooded rats, CR-3 and CR-4, approximately one year old and 450 g in body weight were used. Both rats had extensive training (230 hrs) on shock-postponement schedules prior to the start of this experiment. Water was continuously available in each animal's home cage, but unavailable during experimental sessions. Purina lab chow was continuously available in the home cage during the free-feeding conditions of the experiment, but was restricted during the deprived conditions of the experiment. The animals were fed 5.0 g per day during food deprivation until they reached the desired percentage of free-feeding body weight, at which time the daily ration of food was adjusted to maintain the desired body weight.

Apparatus

The experimental space was a Lehigh Valley Electronics rat test cage (No. 1417) housed within a sound attenuating chamber (No. 1417C). A Gerbrand's rat lever requiring 30 g of force to operate was positioned 4.2 cm off the floor and 5.5 cm to the left of the stimulus panel center. Scrambled shock was delivered by a Lehigh Valley Electronic constant-current DC shocker and scrambler (No. 1531) to the grid floor of stainless steel rods spaced 1.9 cm center-to-center. The houselight was on during each session and "white" noise was supplied to the experimental room to mask the relay programming equipment in the adjacent room.

Procedure

Sidman's (1953) shock-postponement procedure essentially involves two intervals as basic parameters. In the absence of responding, there is a fixed-time interval (the shock-shock or S-S interval) between the presentation of electric shocks. Each response postpones the impending shock for another fixed-time interval (the response-shock or R-S interval).

Experimental sessions were 4 hr long and conducted 7 days per week.

Phase 1.--The rats had an extensive history (230 hrs) with R-S and S-S intervals of 20 sec each, shocks of 2.5 ma, and an inescapable duration of 0.5 sec. The three experimental conditions for Phase 1 were ad libitum feeding (ad lib), food deprivation to body weights which were approximately 80%

of the ad lib weight (80% ad lib), and then unlimited feeding allowing recovery of body weights to approximately 90% of the ad lib weight (90% ad lib).

Phase 2.--Phase 2 was a systemtatic replication of Phase 1. The same rats were used, but two of the parameters were changed. Parameters were R-S = 20 sec, S-S = 10 sec, 2.5 ma, and 0.75 sec duration. The experimental conditions for Phase 2 were ad lib, 80% ad lib, ad lib again, and 80% ad lib again. Between the first 80% ad lib condition and the second ad lib condition, experimental sessions were not conducted in order to allow the rats to regain their ad lib weights.

Results

Phase 1

Fig. 1 and Fig. 2 show the results for rats CR-3 and CR-4 respectively. The data within the vertical lines define what in this experiment are referred to as steady-state data. The horizontal lines indicate the means of the steady-state dependent-variable values. Five sessions were used for estimating the means for CR-3, but six were used for CR-4 because of the greater variability exhibited in response rates and shock rates. For both rats, as the food-deprivation condition was instituted, response rates generally declined. Compared to the 5 days prior to food deprivation, there was increased variability of response rates during the transition from the ad lib condition to the 80% ad lib condition. Approximately 5 sessions after stabilization of body weights at 80% ad lib, the response rates for both animals stabilized. The response rates at 90% ad lib

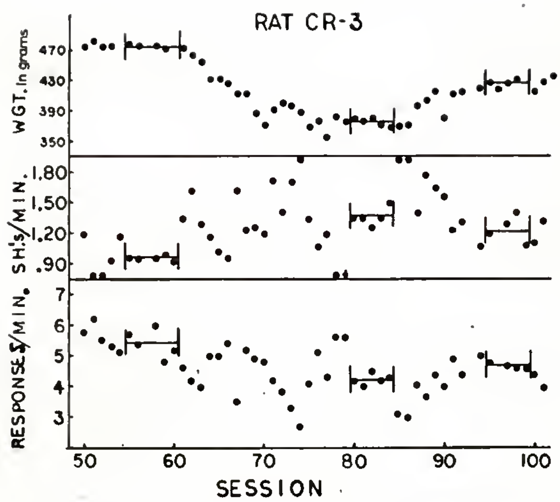

Fig. 1. Response rates, shock rates, and body weights for rat CR-3 for each session of Phase 1.

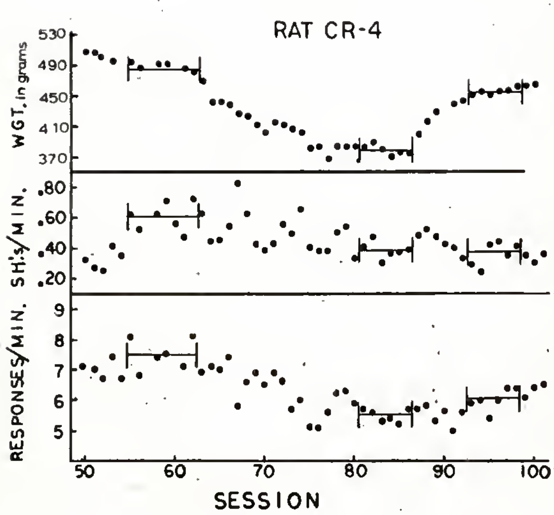

Fig. 2. Response rates, shock rates, and body weights for rat CR-4 for each session of Phase 1.

were intermediate to the ad lib rates and 80% ad lib rates. The shock rates for CR-3 roughly followed a pattern opposite to the pattern of response rates. As the body weights decreased, the shock rates increased, and then as daily weights increased to the 90% ad lib condition, shock rates decreased. Transition periods were characterized by a great deal of variability in shock rates.

A different pattern of shock rates was exhibited by CR-4. As food deprivation produced a decrease in daily weights and response rates, the shock rates also declined. This decrease in both response rates and shock rates indicates that there was a change in the temporal patterning of responses. The change to the 90% ad lib condition did not result in a change in shock rates, although the response rates did increase. Thus food deprivation resulted in a decrease in both rats' response rates with an associated shock-rate increase for rat CR-3, but decrease for rat CR-4.

In order to determine if the reduced response rates resulting from food deprivation were associated with any particular segment of the 4 hr session, the sessions were divided into half-hour intervals. The mean response rates for each half-hour interval of the steady-state sessions are plotted in Fig. 3 and Fig. 4 for CR-3 and CR-4, respectively. The vertical lines in Fig. 3 and Fig. 4 indicate the range in response rates for each mean value plotted. Fig. 3 shows that throughout the duration of the 4 hr session, the mean response rates for rat CR-3 at 80% ad lib were con-

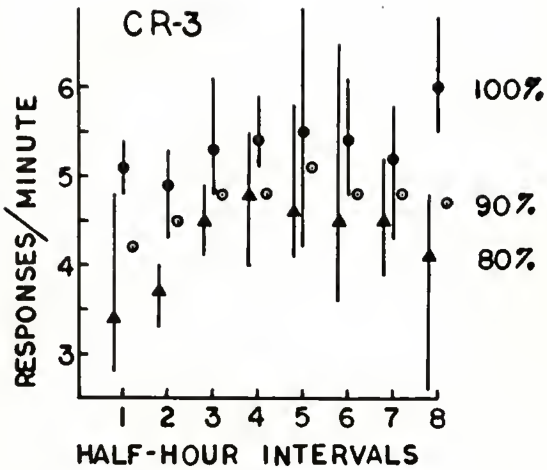

Fig. 3. Mean response rates and ranges of the 5 criteria sessions for each half-hour interval of the 4 hr session for CR-3 in Phase 1.

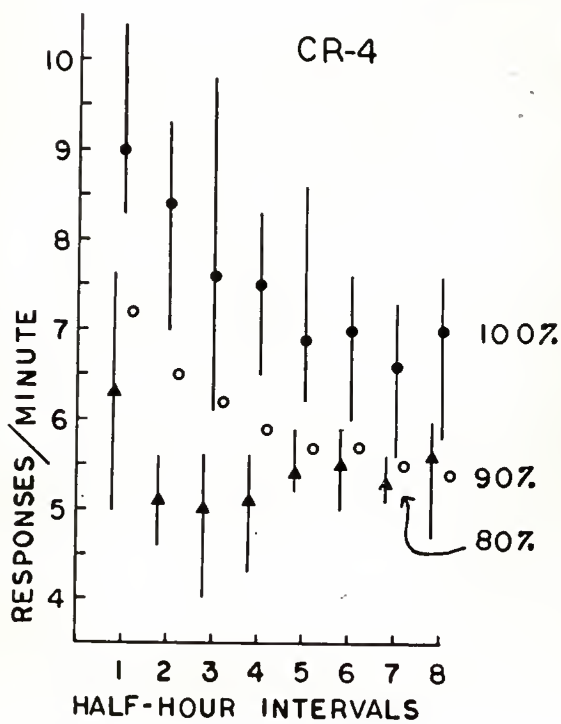

Fig. 4. Mean response rates and ranges of the 6 criteria sessions for each half-hour interval of the 4 hr sessions for CR-4 in Phase 1.

sistently below those at ad lib. The response rates at 90% ad lib were between those at the other two values. Fig. 4 shows that the mean response rates for rat CR-4 at 80% ad lib were consistently lower than at ad lib. The response rates for CR-4 obtained at 90% ad lib again occupied intermediate values between the other two.

Phase 2

Fig. 5 and Fig. 6 show the daily weights, shock rates, and response rates for CR-3 and CR-4, respectively, during Phase 2. As in Fig. 1 and Fig. 2, the horizontal lines indicate the means of the steady-state dependent-variable values within the vertical lines. The inverted V's plotted in the shock rate section of Fig. 6 indicate that the shock rates were higher than the 1 per min ceiling of the graph.

When CR-3 was food deprived for the first time in Phase 2, a decrease in response rate was not observed. Upon return to ad lib, the response rates were higher than during the initial exposure to ad lib. The second exposure to 80% ad lib resulted in a decrease in response rate. Likewise there was little change in shock rates during the first manipulation, but a reliable increase in shock rates during the second exposure to 80% ad lib.

Rat CR-4 showed a decrease in response rates and an increase in shock rates during both exposures to 80% ad lib.

Fig. 7 shows the mean response rates for each half-hour interval throughout the 4 hr session. The numbers at the end of each line indicate the order of the condition.

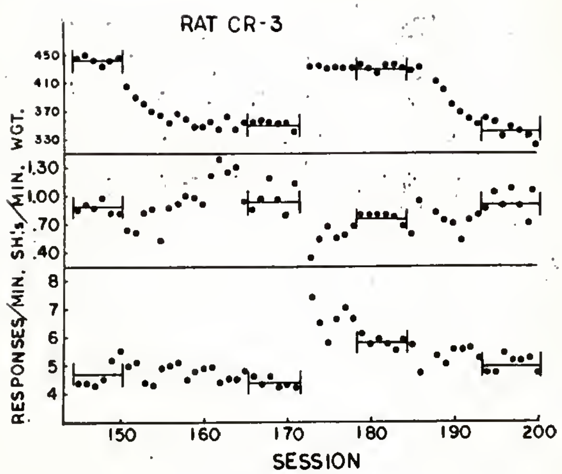

Fig. 5. Response rates, shock rates, and body weights for rat CR-3 for each session of Phase 2.

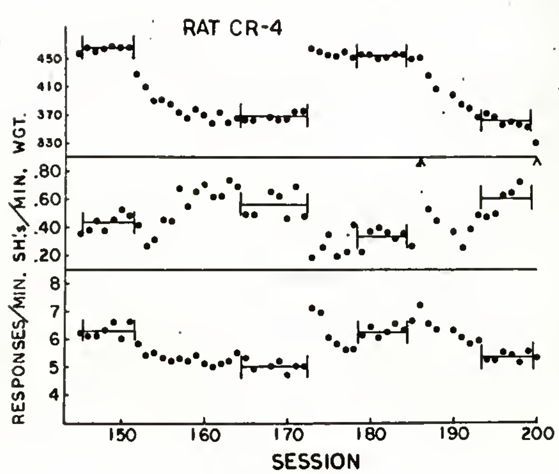

Fig. 6. Response rates, shock rates, and body weights for rat CR-4 for each session of Phase 2.

The first and third conditions for rat CR-4, the ad lib conditions, show consistently higher rates throughout the entire session than the second and fourth conditions, the 80% ad lib conditions. The rates for the first condition (ad lib) for rat CR-3 overlap with the rates for the second and fourth (deprived) conditions. Rat CR-3's response rates for the first ad lib condition were also seen in Fig. 5 to overlap the rates from both 80% ad lib conditions.

Representative cumulative records are presented in Fig. 8 and Fig. 9. Each lever press steps the pen vertically and shocks are indicated by a downward deflection of the pen. The records are divided into half-hour segments and the records shown are for the fifth, sixth, seventh, and eighth segments, going from top-to-bottom in each figure. The cumulative records for CR-3 in Fig. 8 show a perceptible decrease in response rates during food deprivation. Another result of food deprivation was an increase in the number of shocks received from the S-S interval. Instances of this occurring are indicated in the cumulative records by two or more shocks occurring close together. The cumulative records from CR-4 in Fig. 9 show decreased response rates and increased shock rates as a result of food deprivation.

Discussion

Food deprivation resulted in decreased response rates for CR-3 and CR-4 in both phases of Exp. 1, except during CR-3's first ad lib exposure during Phase 2. Two lines of evidence suggest that CR-3's response rates had not stabilized

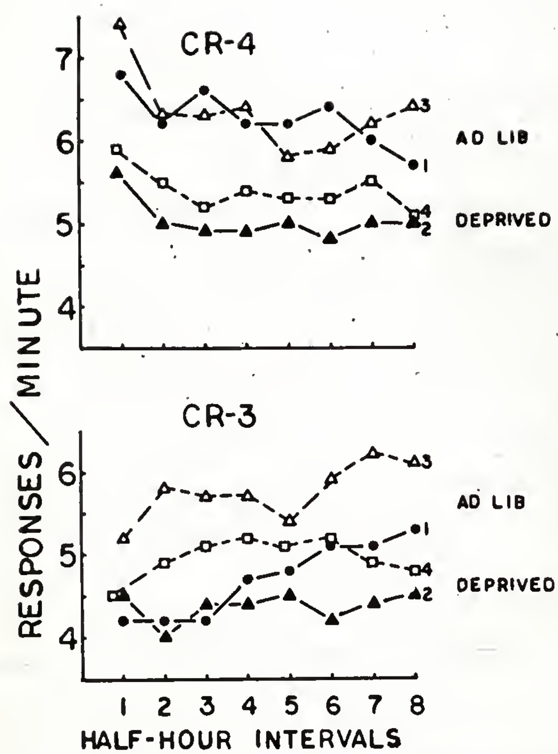

Fig. 7. Mean response rates of the criteria sessions for each half-hour interval of the 4 hr sessions of rats CR-3 and CR-4 during Phase 2.

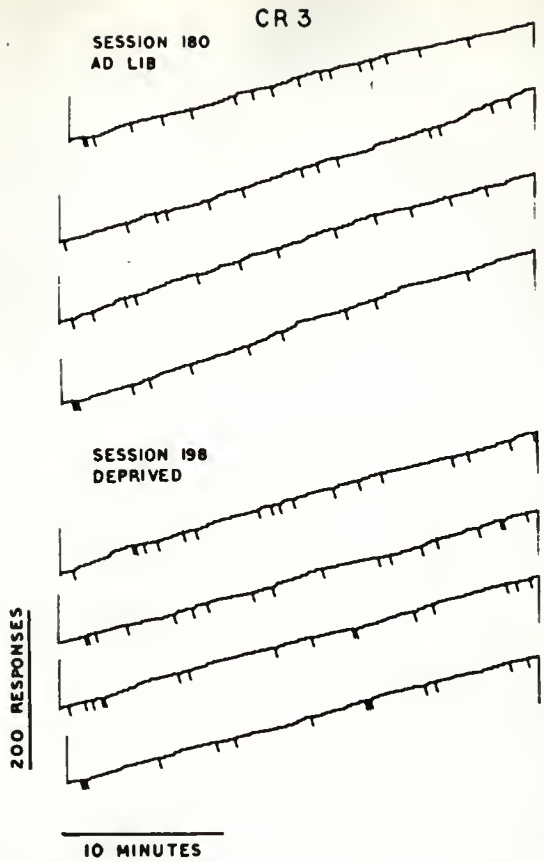

Fig. 8. Representative cumulative response records from CR-3 during ad lib and deprived conditions.

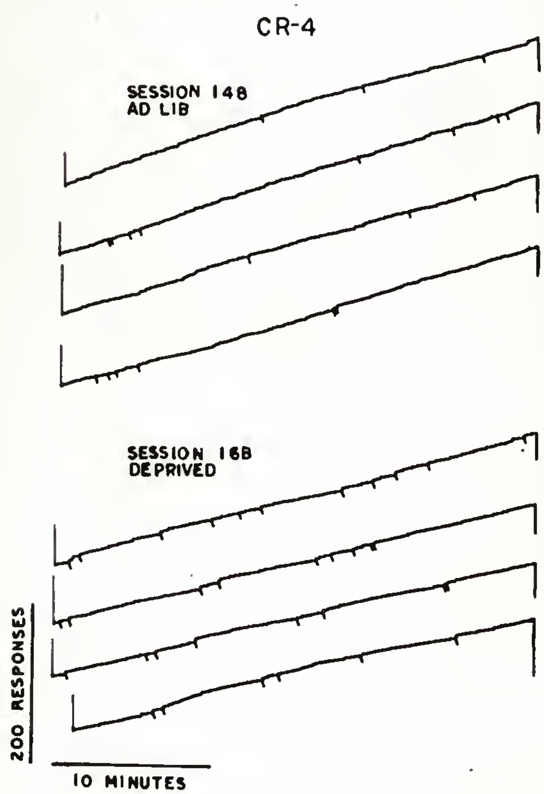

Fig. 9. Representative cumulative response records from CR-4 during ad lib and deprived conditions.

prior to the first change from ad lib to the 80% ad lib condition. One line of evidence is the fact that during the second exposure to ad lib much higher response rates were exhibited than during the first exposure to ad lib. The second line of evidence is the upward trend in response rates during the last two days of the first ad lib condition.

EXPERIMENT 2. FOOD-DEPRIVATION EFFECTS ON BEHAVIOR MAINTAINED BY A CONJOINT AVOIDANCE FIXED-INTERVAL TIME-OUT SCHEDULE

Exp. 1 demonstrated that food deprivation resulted in a decrease in the rates of responding maintained by Sidman's shock-postponement procedure. The purpose of Exp. 2 was to extend the generality of this food-deprivation effect by manipulating the level of food deprivation during behavior maintained by a Conjoint Avoidance Fixed-Interval Time-Out (Conjoint Avoidance FI TO) schedule. A conjoint schedule (Catania *et al*., 1965) maintains responding on one operandum by two or more schedules operating simultaneously. With the Conjoint Avoidance FI TO schedule each lever press postpones shock and the same response produces a Time-Out (TO) from the avoidance condition on a fixed-interval schedule.

Verhave (1962) conducted a preliminary analysis of a Conjoint Avoidance FI 15 min TO 15 min schedule. Though very little responding occurred during the TO, the FI 15 min contingency was not able to control a typical fixed-interval positively-accelerating pattern of responding (Ferster & Skinner, 1957), and the avoidance performance was not facilitated by the response-dependent TO. A response-dependent TO, when programmed on a lever separate from the avoidance lever, did maintain lever pressing but did not engender the positively-accelerating pattern of responding usually associated with fixed-interval schedules.

After manipulating the level of food deprivation during behavior maintained by the conjoint schedule, the FI TO contingency was deleted. This allowed a comparison of the food-deprivation effect with one rat in 2 different avoidance paradigms. The avoidance-alone condition also allowed an analysis of the temporal patterning of responding in terms of Anger's (1963) interresponse-time-per-opportunity (IRT/OP) measure. The IRT/OP is a conditional probability measure of interresponse-interval frequencies.

Method

Subject

One male hooded rat, T-1, approximately a year of age and 450 g in body weight was used. The animal care and apparatus was the same as in Exp. 1.

Procedure

On the Conjoint Avoidance FI TO schedule, shocks were delivered on a S-S interval, and each response during the avoidance condition postponed shock for the duration of the R-S interval. A lever press by the rat, besides postponing shock, could result in a TO from avoidance on a FI 5 min schedule. Thus the first response made after 5 min resulted in a 1 min TO from avoidance. The R-S interval was 10 sec and the S-S interval was 5 sec. Shocks were 2.5 ma DC with an inescapable duration of 0.75 sec. A houselight was on during avoidance and the experimental cage was totally dark during the TO. Responses had no effect during TO and no shocks were ever presented. Sessions were 4 hr in duration and conducted 7 days per week. Experimental manipulations with the conjoint schedule were ad lib, 80% ad lib, and 90% ad lib.

After analysis of the food-deprivation effect on the conjoint schedule, the rat was exposed to a history of avoidance alone. The parameters were R-S = 20 sec and S-S = 5 sec. Shocks were 2.0 ma AC delivered by BRS-Foringer shock generating (SG-901) and shock scrambling (SC-901) equipment with an inescapable duration of 0.50 sec. In the avoidance-alone condition, the manipulations were ad lib and 80% ad lib.

Results

The data for rat T-1 during the Conjoint Avoidance FI TO condition are presented in Fig. 10. When deprivation was instituted, there was a rapid drop in body weight to 80% ad lib, and then when feeding was increased, the body weight recovered to approximately 90% ad lib. The change in response rates paralleled the weight changes. As the weight decreased, the response rates decreased, and as the body weight increased, the response rates increased. The response rates of T-1 at 90% ad lib were intermediate between the 15-16 responses per minute exhibited at ad lib and the 11-12 responses per minute exhibited at 80% ad lib. During the early part of the deprivation condition there was a transient increase in shock rates, but the shock rates recovered to pre-deprivation levels. There was no systematic change in the low rates of responding present during the TO from avoidance. The responses that occurred during the TO were usually all within 2 sec of the initiation

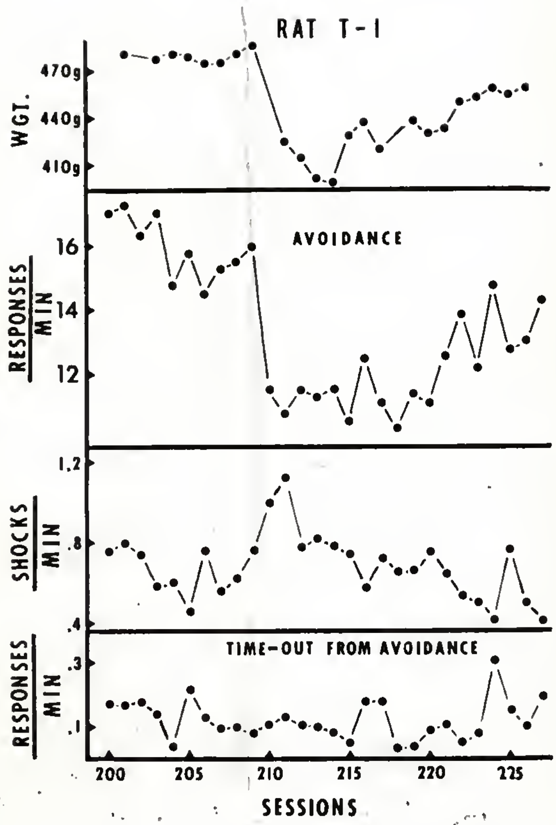

Fig. 10. Response rates, shock rates, and body weights for rat T-1 for each session of the Conjoint Avoidance FI TO schedule.

of the TO. Though the TO stimuli controlled a low rate of responding during the TO, the FI 5 TO schedule did not control a typical fixed-interval positively-accelerating pattern of responding.

Fig. 11 shows the data from the last 5 sessions during the ad lib condition and the 80% ad lib condition in the avoidance-alone paradigm. Both a decrease in response rates and an increase in shock rates were a result of food deprivation. Fig. 12 presents an analysis of the conditional probability of responses occurring in 2 sec divisions of the R-S interval. The conditional probability of responding past the 18 sec division was not plotted in Fig. 12 since by definition it has to be 1.00. During the deprived condition, the probability of responding increased as the duration of the inter-response interval increased. Responding at the ad lib weight followed the same pattern except at the 0-2 sec division. Thus the effect of food deprivation was to decrease the probability of a response occurring within 2 sec of a previous response.

Discussion

Exp. 2 replicated the food-deprivation effect found in Exp. 1 with a permutation of Sidman's shock-postponement procedure. The relatively high rates of responding (15-16/min) were decreased markedly by food deprivation without serious disruption of the stimulus control effecting a low rate of responding during the TO. In the avoidance-alone condition decreased responding was shown not to be specific to the type

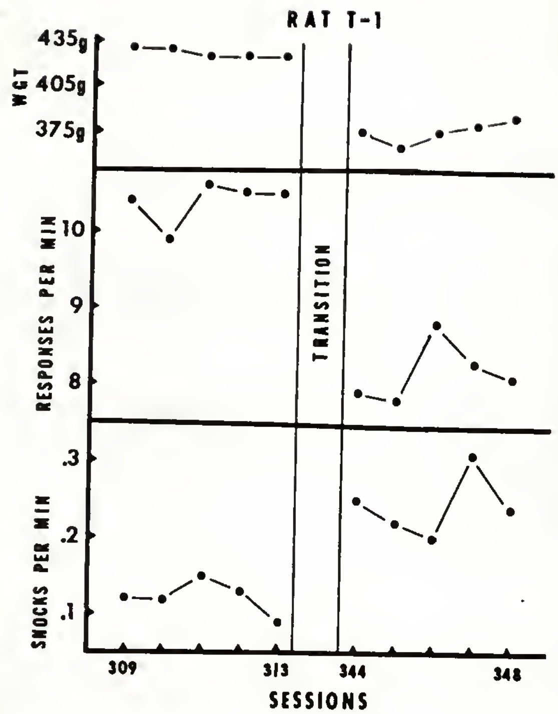

Fig. 11. Response rates, shock rates, and body weights for each of the last 5 sessions of the avoidance-alone condition for rat T-1.

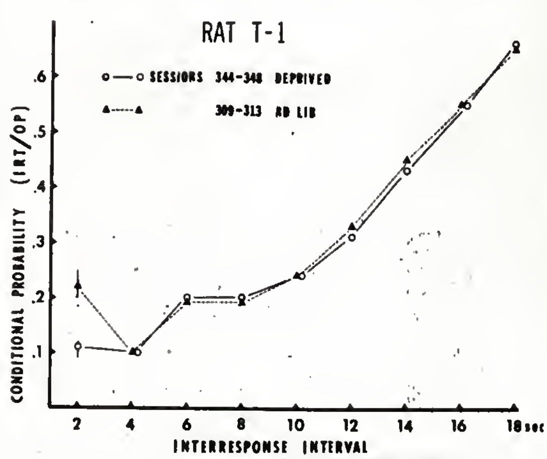

Fig. 12. Conditional probabilities of interresponse intervals for rat T-1 in the avoidance-alone condition.

of electric shock used since DC shock had been used in Exp. 1 and in the Conjoint Avoidance FI TO section of Exp. 2, while AC was used in the avoidance-alone condition of Exp. 2.

Similar to Verhave's (1962) study, the fixed-interval schedule of TO presentation did not produce the typical positively-accelerating pattern of responding associated with fixed-interval schedules. Verhave (1962) and Sidman (1962) reported that the response dependent TO only controlled schedule-appropriate patterns of responding when programmed on a separate operandum and on low fixed-ratio schedules of presentation. Thus responding was more effectively controlled by the avoidance schedule than by the fixed-interval presentation of the relatively weaker reinforcer, the TO.

EXPERIMENT 3. FOOD-DEPRIVATION EFFECTS ON AVOIDANCE BEHAVIOR MAINTAINED BY THE SHOCK-FREQUENCY-REDUCTION PROCEDURE IN RATS

Exp. 1 and Exp. 2 demonstrated that food deprivation resulted in a response-rate decrement during avoidance behavior maintained by Sidman's (1953) shock-postponement procedure and Verhave's (1962) conjoint permutation of Sidman's procedure.

Herrnstein and Hineline (1966) introduced a procedure which demonstrated that a response-dependent reduction in shock frequency was a sufficient condition to generate and maintain lever-pressing. With their procedure, responding did not postpone shocks, it only reduced the frequency of shock. In a later report summarizing this work and comparing it to Sidman's shock-postponement procedure, Herrnstein (1969) concluded that this shock-frequency-reduction paradigm was <u>no</u> <u>less</u> effective than other free-operant avoidance procedures in generating lever-pressing in the rat.

The purpose of Exp. 3 was to assess the effect of food deprivation on avoidance behavior maintained by the shock-frequency-reduction procedure of Herrnstein and Hineline (1966).

Method

Subjects

Two male hooded rats, R-65 and R-66, with an extensive history of avoidance behavior maintained by the shock-frequency-reduction procedure were used. The animal housing conditions were the same as in Exp. 1.

Apparatus

The apparatus was the same as in Exp. 1 except that the shock was AC delivered from BRS-Foringer shock generating (SG-901) and scrambling (SC-901) units.

Procedure

Herrnstein and Hineline's (1966) shock-frequency-reduction procedure essentially involved two separate distributions of shock delivery. One distribution, the high-probability-shock distribution, was in effect as long as the animal failed to depress the lever. A tape reader was stepped every 2 sec, and the pattern of shock was varied randomly but with a specified probability of 0.3 for every 2 sec. Thus if no responding occurred, the rat received a Normal distribution of shocks with an average rate of 9/min. The other distribution, the low-probability-shock distribution, was in effect dependent upon a lever response by the animal. The low-probability-shock distribution had a shock probability of 0.1 for every 2 sec period. Upon a lever depression the low-probability-shock distribution was in effect until a shock was delivered, at which time the high-probability-shock distribution was reinstated. Thus the lowest possible shock rate was approximately 3/min. The first response after a shock changed the probability of shock per 2 sec period from 0.3 to 0.1.

After stable responding was achieved under ad lib, the rats were deprived to 80% ad lib. The deprived weights were reached by absolute food deprivation for the first week, and then 5 g of food per day until the desired weight was attained. During deprivation conditions, the rats were fed enough food after the daily sessions to maintain the desired body weight. After stable response rates occurred at 80% ad lib, the ad lib condition was reinstated, and then was followed by deprivation to 70% ad lib. Thus experimental conditions were ad lib, 80% ad lib, ad lib, and 70% ad lib.

Sessions were 100 min in duration conducted 6 days per week. The houselight was on for the entire session and each response produced an audible "click" from a feedback relay. Shocks were 0.8 ma AC with an inescapable duration of 0.3 sec.

Results

Fig. 13 presents the results for rat R-65. The horizontal lines indicate the mean dependent-variable values for the last 10 sessions (steady-state sessions) in each feeding condition. Upon initiation of the 80% ad lib condition, there was a steady decrease in response rates along with an increase in shock rates. The second ad lib condition resulted in an increase in response rates and a decrease in shock rates. Subsequent food deprivation to 70% ad lib and then reinstatement of ad lib conditions resulted in similar changes in response rates and shock rates. The response rates during 70% ad lib were lower than the rates during 80% ad lib. Conversely, the shock rates were higher during the 70% ad lib condition, than during the 80% ad lib condition. There was increased variability in both response rates and shock rates during the deprivation conditions.

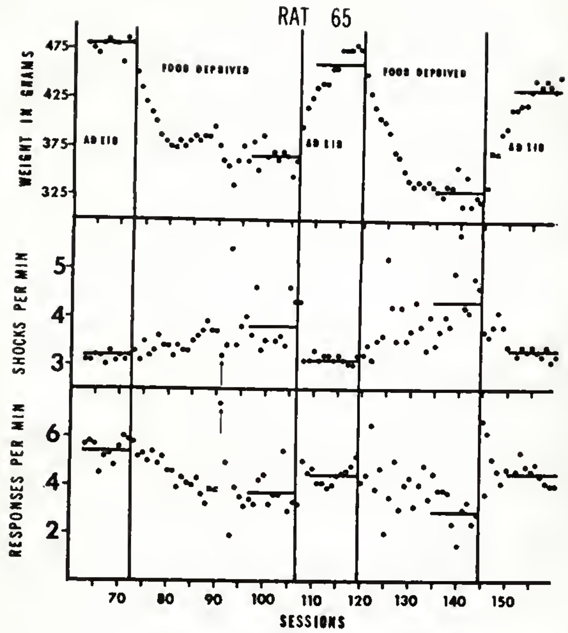

Fig. 13. Response rates, shock rates, and body weights for rat R-65 for each session.

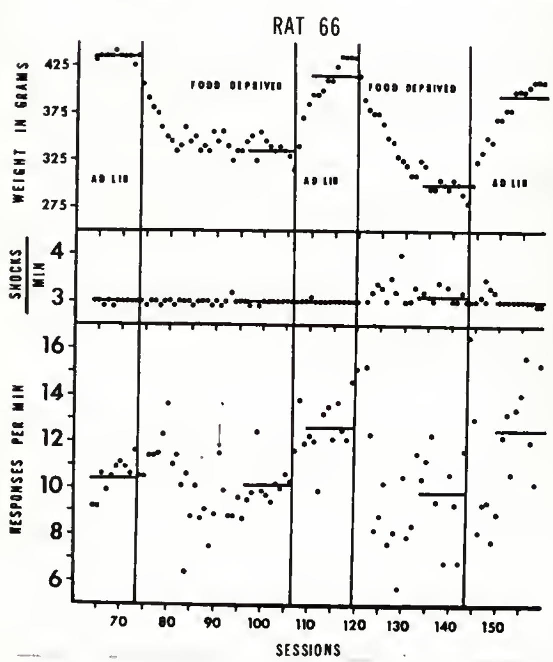

Fig. 14. Response rates, shock rates, and body weights for rat R-66 for each session.

Fig. 14 shows the data for rat R-66. Throughout the entire experiment, R-66 exhibited more variability in response rates than R-65. The first change from the ad lib to the 80% ad lib condition did not result in a decrease in response rates. Resumption of the ad lib condition resulted in an increase in response rates compared to the rates exhibited during the 80% ad lib condition. Food deprivation to 70% ad lib resulted in a decrease in response rates and then an increase in rates upon reinstatement of the ad lib condition. Shock rates for R-66 were maintained at the minimum possible except during deprivation to 70% ad lib.

Fig. 15 shows representative cumulative records for rat R-65 during ad lib conditions and the 70% ad lib condition. Oblique pips on the response pen indicate shock presentations while the event pen indicates which shock distribution was in effect at any given point in time. When the event pen was down (post-shock), the high-probability shock distribution was in effect and when it was up (post-response), the low-probability shock distribution was in effect. Inspection of the cumulative records shows that for R-65 there was an increase in the amount of time spent in contact with the high-probability shock distribution during the 70% ad lib condition.

Fig. 16 presents representative cumulative records for rat R-66. Recording specifications are the same as in Fig. 16. In contrast to R-65's records in Fig. 15, there was no increase in the amount of time spent in contact with the

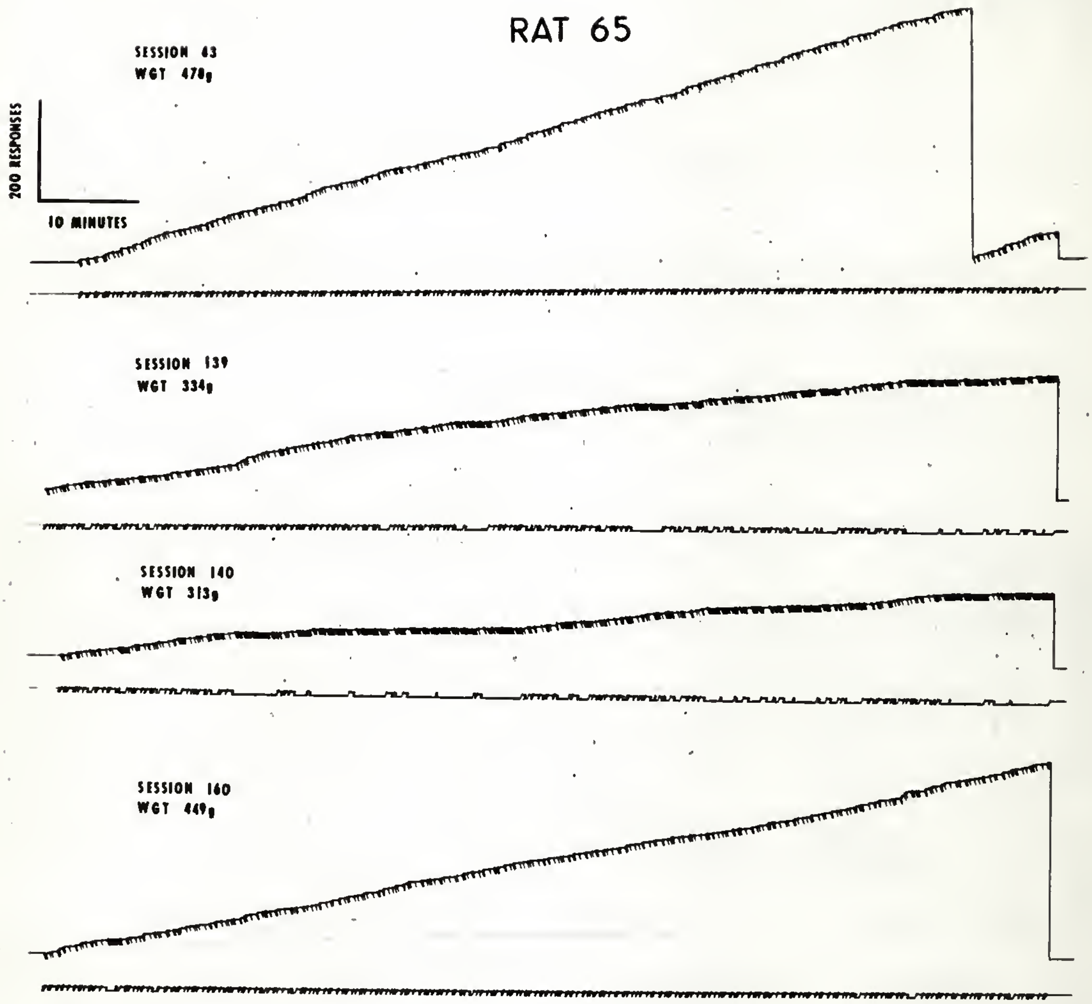

Fig. 15. Representative cumulative records for rat R-65 during ad lib and 70% ad lib conditions.

high-probability shock distribution, but there was a marked decrease in response rates during the 70% ad lib condition. Inspection of these records indicates that the main effect of food deprivation was to decrease the duration of post-shock response "bursting." Analysis of the frequencies of interresponse intervals in Fig. 17 and Fig. 18 for R-65 and R-66, respectively, substantiates this conclusion. The filled symbols in Fig. 17 and Fig. 18 are the ad lib conditions and the open symbols are the deprived conditions. Food deprivation for both animals resulted primarily in a decrease in the frequencies of responses occurring within 2 secs of a previous response.

Discussion

Exp. 3 demonstrated that the food-deprivation effect found in Exp. 1 and Exp. 2 with Sidman's shock-postponement procedure was not specific to that procedure. Thus, extension of the effect to Herrnstein and Hineline's (1966) shock-frequency-reduction procedure increases the generality of the food-deprivation effect. It also supports Herrnstein's (1969) conclusion that the shock-frequency-reduction procedure contains many functional similarities with Sidman's (1953) shock-postponement procedure.

The analysis of the frequencies of interresponse intervals indicated that deprivation effected a decreased in responses occurring within 2 sec of a previous response. This was the same conclusion that the IRT/OP analysis of T-1's responding indicated during the avoidance-alone condition

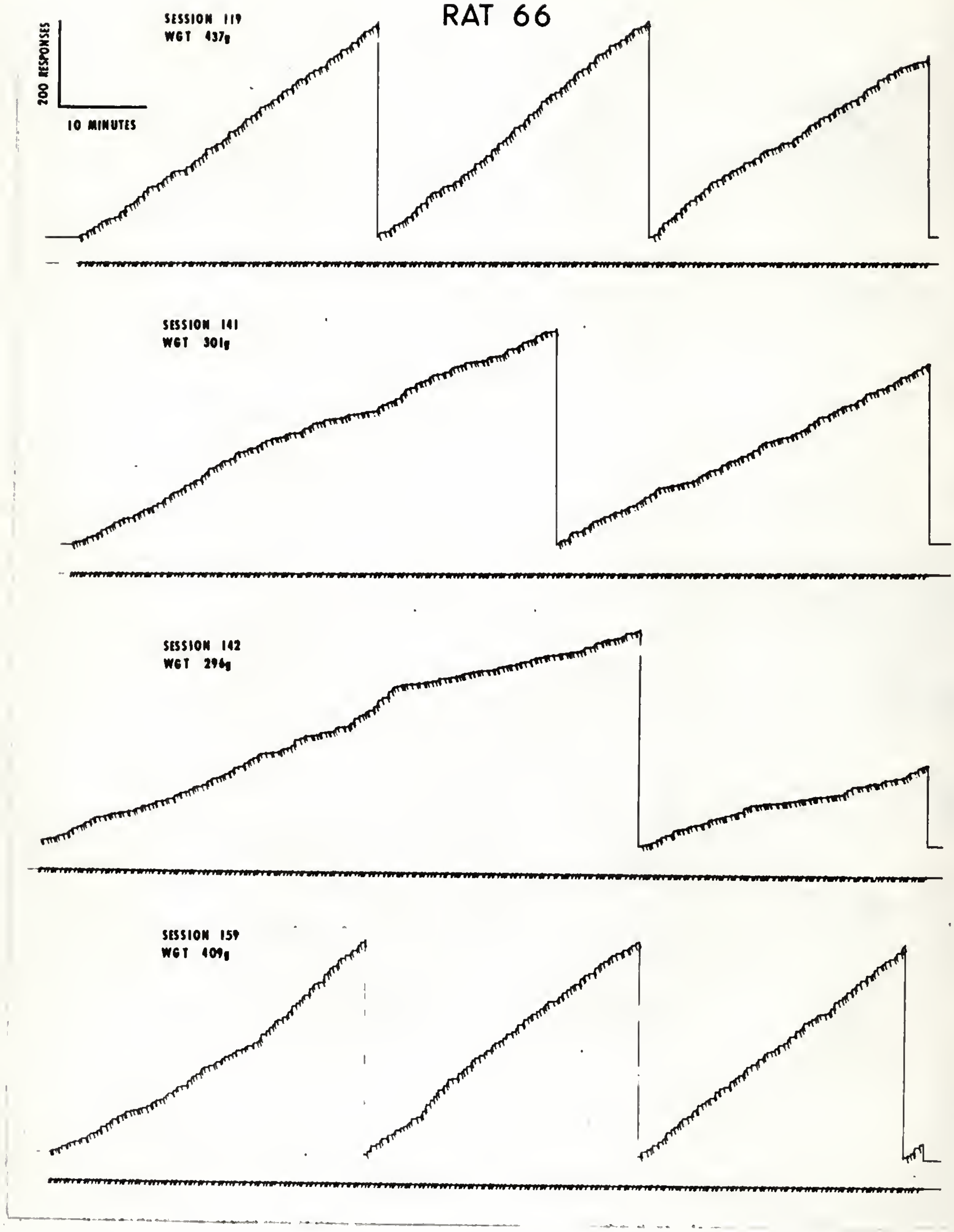

Fig. 16. Representative cumulative records for rat R-66 during ad lib and 70% ad lib conditions.

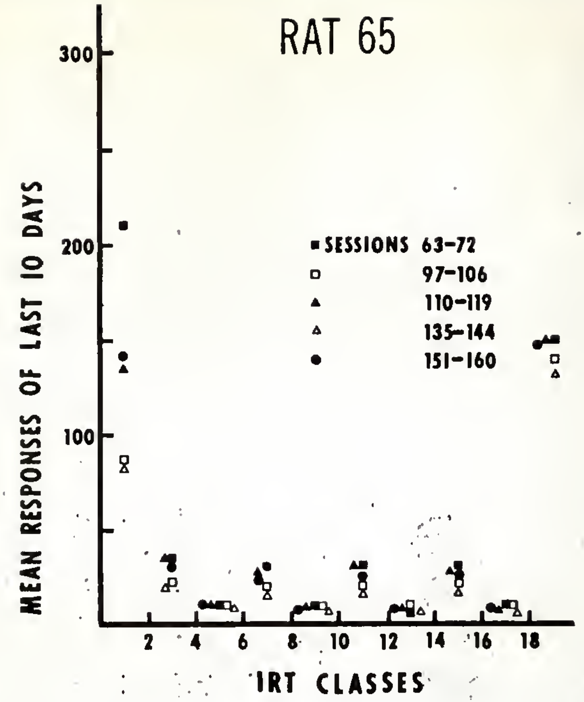

Fig. 17. Frequency of interresponse intervals for rat R-65 during ad lib and food-deprivation conditions.

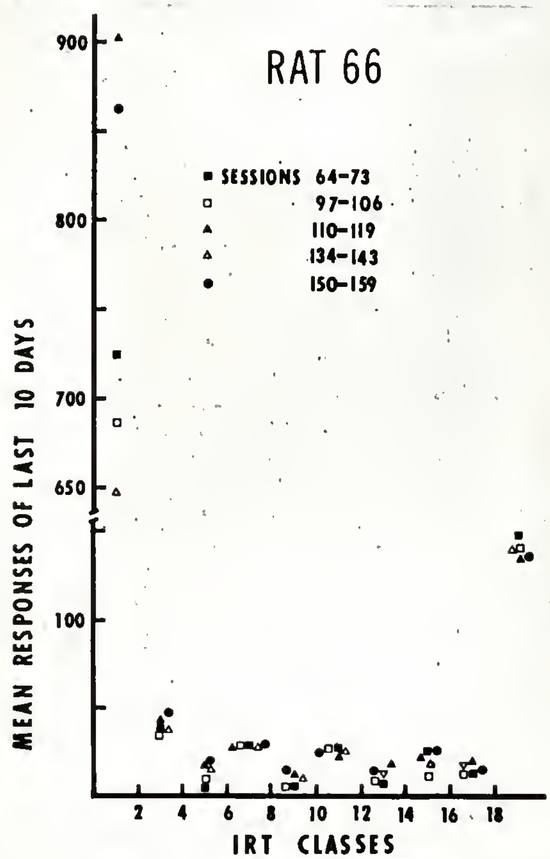

Fig. 18. Frequency of interresponse intervals for rat R-66 during ad lib and food-deprivation conditions.

of Exp. 2. Since the food-deprivation effect primarily reduced the number of responses occurring within 2 secs of a previous response, this explains why there can be large reductions from high response rates without increasing the shock rates. Both with T-1 (Exp. 2) and R-66 (Exp. 3) response rates were reduced markedly without an appreciable increase in shock rates.

EXPERIMENT 4. FOOD-DEPRIVATION EFFECTS ON AVOIDANCE BEHAVIOR MAINTAINED BY SHOCK-POSTPONEMENT IN HAMSTERS

Although Exps. 1, 2 and 3 assessed the effects of food deprivation with several different procedures, with several different parameters, and with several different rats, the following question remained unanswered. Were the effects obtained in Exps. 1, 2 and 3 specific to rats? The purpose of Exp. 4 was to assess the effect of food deprivation on avoidance behavior maintained by Sidman's (1953) shock-postponement procedure in a different rodent than rat--the hamster.

Method

Two adult male hamsters, HM-3 and HM-10, each weighing approximately 140 g were used. The same apparatus and procedures as in Exp. 1 were utilized. Experimental sessions were 60 min in duration and were conducted six days per week during the active phase of the hamster's diurnal cycle--the dark phase. Shocks were 1.0 ma AC for an inescapable duration of 0.2 sec. Schedule parameters were R-S = 20 and S-S = 5 sec. The experimental conditions were ad lib, 80% ad lib, and return to ad lib. During the deprived conditions, the hamsters were fed 5 g of food per day until the desired weight was attained.

Results and Discussion

Fig. 19 presents the data from the last 5 sessions during ad lib, 80% ad lib, and ad lib again. Response rates

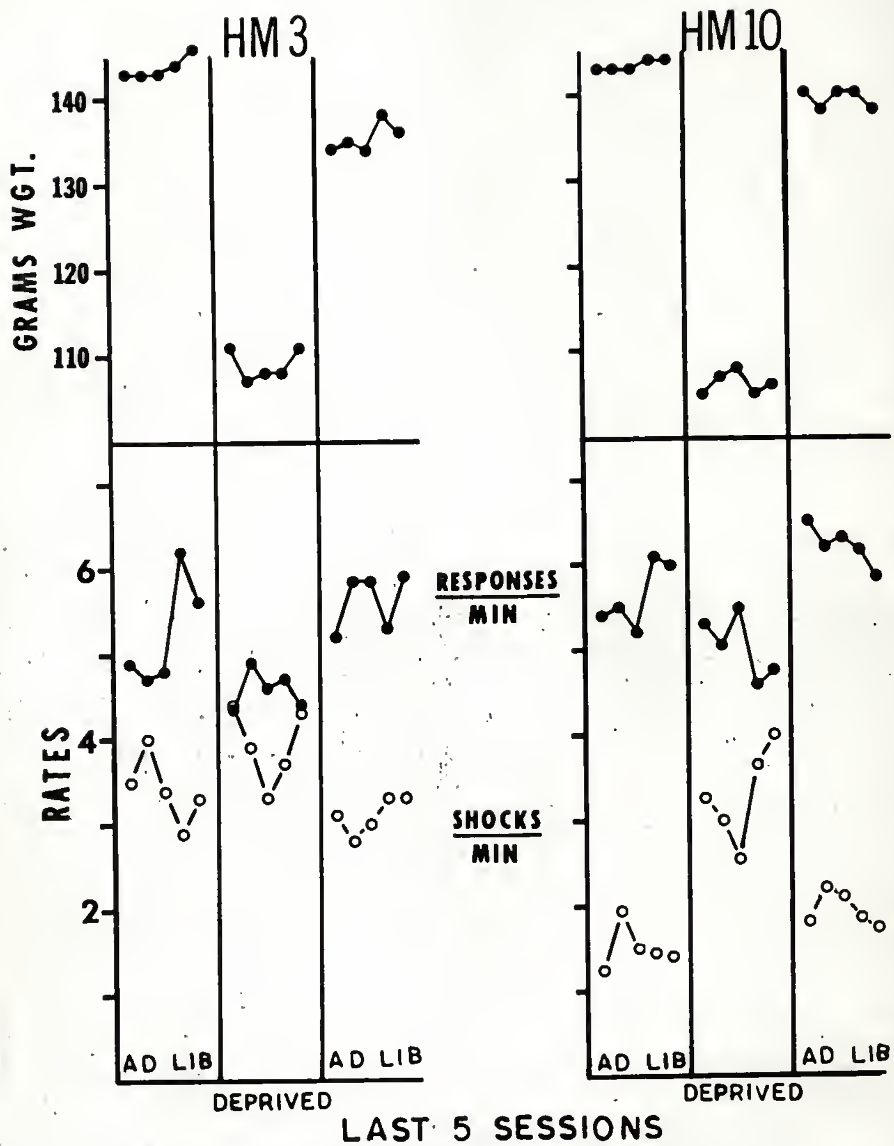

Fig. 19. Response rates, shock rates, and body weights for each of the last 5 sessions of the ad lib and the food-deprived conditions for hamsters HM-3 and HM-10.

are indicated by the filled symbols and shock rates are indicated by the open symbols. HM-3 exhibited a poor level of performance as indicated by the high shock rate during the ad lib conditions. Food deprivation resulted in a small, but reliable decrement in response rates and an increase in the already high shock rates. Subsequent reinstatement of the ad lib condition resulted in an increase in response rates and a decrease in shock rates.

Food deprivation of HM-10 resulted in a small decrease in response rates while more than doubling the shock rates. Reinstatement of the ad lib condition resulted in an increase in response rates and recovery of the pre-deprivation shock rates.

Exp. 4 replicates the previous experiments with rats and illustrates that the food-deprivation effect on free-operant avoidance behavior is not specific to rats.

GENERAL DISCUSSION

These four experiments demonstrate that food deprivation results in a decrease in the response rates of free-operant avoidance behavior. The effect was demonstrated with Herrnstein and Hineline's (1966) shock-frequency-reduction procedure and Sidman's (1953) shock-postponement procedure, and was not dependent on any particular procedure or set of parameters maintaining avoidance behavior. The species generality was also assessed by demonstrating the food-deprivation effect with both rats and hamsters. The decrement was most impressive when the rates of avoidance responding were high and response-rate decreases could occur without markedly increasing the shock rates. Rat T-1's performance during the conjoint schedule in Exp. 2 (Fig. 10) was the best example of an impressive decrease in response rates without a marked increase in shock rates. The small decrease in response rates exhibited in Exp. 4 by hamsters HM-3 and HM-10 (Fig. 19) was probably more of a result of the poor avoidance baseline during ad lib food than any species differences in susceptibility to the food-deprivation effect.

This food-deprivation effect could not be due to severe deprivation bordering on physical incapacitation because of three lines of evidence. First, with appetitively-maintained schedules, it is quite common to maintain rats at 70% of the free-feeding weight or below. For hooded rats similar to those used in Exps. 1, 2 and 3, an average running-weight for maintaining schedule performance with food would be 300-325 g. A second line of evidence is that Moskowitz (1959) has found increases in running-wheel activity, rather than decreases in activity, with deprivation to 60% of the ad lib-feeding weight. The activity levels were graded and increased as weight was decreased from 90% to 60% ad lib. The third line of evidence against an incapacitation type of explanation is the finding from these present experiments of a grading of response rates as the level of deprivation was increased. For instance, in Phase 1 of Exp. 1, for both CR-3 and CR-4, intermediate response rates were obtained at intermediate weight levels. This gradation of rates with body weight was also found with rat T-1 during the conjoint schedule and rat R-65 in the shock-frequency-reduction procedure.

In the present research, level-of-food-deprivation was defined in terms of the organism's body weight. This definition was used because it is the most common definition in studies chronically maintaining behavior by response-dependent food presentation. All of the research on food deprivation reviewed in the previous introduction used hours-since-free-access-to-food as the definition of level-of-food-deprivation. None of the studies used more than 24 hrs of food deprivation, except the Meyer et al. (1969) study which used 48 hrs. Twelve or even 24 hrs of food deprivation does not result in very deprived animals when compared to a 20% reduction in body weight. This, coupled with the inherent variability present in response-acquisition experiments, could explain the lack of positive food-deprivation results in escape-avoidance experiments (Amsel, 1950; Dinsmoor, 1958; Misanin & Campbell, 1969). The one experiment by Meyer et al. (1969) that found reliable effects of food deprivation on shock-escape behavior used 24 and 48 hrs of food deprivation. Calculations from the weight data reported show that 48 hrs of food deprivation reduced the average weight to 85% ad lib (from 285 g to 240 g). Thus the study by Meyer et al. supports the findings of the present research--food deprivation that produces a weight loss results in a decrease in escape-avoidance performance.

Catania et al. (1966) maintained their monkeys at 80% ad lib while Herrnstein and Brady (1958) maintained their rats at 60% of their 200-day weights. It can now be concluded that besides guaranteeing schedule control by the schedule of food reinforcement, the weight control prevented changes in the level-of-food-deprivation to effect changes in the free-operant avoidance performance.

The results of the present research have two important implications. The first, is that any long-term study of free-operant avoidance behavior will require the monitoring and, if necessary, controlling of the experimental organism's body weight in order to reduce food-deprivation and weight-change effects from modifying the avoidance performance.

The second implication is directed towards research with avoidance behavior and physiological interventions in the hypothalamus.

The lateral and ventral-medial areas of the hypothalamus have been shown to be very important areas for the initiation, maintenance, and cessation of feeding behavior (see Morgane & Jacobs, 1969, for a review). These two hypothalamic areas have also been demonstrated to be very important for shock-avoidance behavior. Lesions of the medial forebrain bundle of the lateral hypothalamus produce an increased sensitivity to electric shock (Harvey & Lints, 1965). Lesions in this area also interrupt feeding behavior, producing animals that for varying periods of time do not initiate feeding behavior and thus lose weight drastically (Anand & Brobeck, 1951). Lesions of the ventral-medial area of the hypothalamus have been reported to facilitate two-way shuttle-box avoidance (Grossman, 1966). These lesions also disrupt the cessation of feeding behavior and the lesioned rats become very obese (Hetherington & Ranson, 1939). Chemical and electrical stimulation studies have also implicated both feeding behaviors and avoidance behaviors with these hypothalamic areas (Carder, 1970; Grossman, 1966; Miller, 1957; Sepinwall, 1969).

This food-deprivation effect on avoidance behavior suggests that during hypothalamic investigations, the weights of the experimental animals will have to be controlled. Weight control should facilitate the determination of whether avoidance effects from hypothalamic intervention are secondary to changes in feeding behavior and weight changes, or are more primary effects of the hypothalamic interventions themselves.

The food-deprivation decrease in response rates obtained in this study does not support Hull's (1943) drive summation hypothesis or Kendler's (1965) suggestion that food deprivation lowers sensory thresholds. These data also contradict data presented by Pare (1969) concerning aversion thresholds in the rat. He defined the aversion threshold as that intensity of shock that was avoided 75% of the time in a tilt cage. He compared young and old, and male and female rats. The only measure that related to the aversion threshold was the body weight of the experimental animal. "Light rats have lower thresholds to grid shock, whereas heavy rats have higher thresholds (Pare, 1969, p. 217)." If lower thresholds were a result of food deprivation, higher response rates should have been observed, since response rate is positively correlated with shock intensity (Riess, 1970). This discrepancy needs to be resolved by further research.

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BIOGRAPHICAL SKETCH

John David Leander was born on April 8, 1944, at Mount Vernon, Washington. He attended public school in Mount Vernon and graduated from Mount Vernon Union High School in June, 1962. In September, 1962, he enrolled in Pacific Lutheran University in Tacoma, Washington. During the summers between 1962 and 1966, he was employed by the Stokley-VanCamp Company in Mount Vernon. During the school years, he was employed as a bus driver for the Clover Park School District in Tacoma, Washington. In May, 1966, he received the Bachelor of Arts degree from Pacific Lutheran University. In September, 1966, he enrolled in the graduate school of Western Washington State College in Bellingham, Washington, and received the Master of Arts degree from that institution in August, 1967. In September, 1967, he enrolled in the graduate school of the University of Florida. He served as a teaching assistant to Dr. C. M. Levy and as an interim instructor in Experimental Psychology. During the last two years of graduate study, he was the recipient of a fellowship from the Center for Neurobiological Sciences in the College of Medicine at the University of Florida. He is married to the former Kathleen Axelson and they have one son, Sven.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

E. F. Malagodi, Chairman
Assistant Professor of Psychology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Robert L. King
Associate Professor of Physiology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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This dissertation was submitted to the Department of Psychology in the College of Arts and Sciences and to the Graduate Council, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

Dean, Graduate School