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ABSTRACT

The purpose of this study is to determine categories of learning styles based on research on the chemical and physiological correlates of learning, as well as the development of simple measures that would allow an investigator to place a subject within one or more of these categories. The data from eight experiments with rats suggests that there are reliable differences: (1) between the rates at which male and female rats acquire a barpress response; and (2) between the rates at which hooded and albino rats acquire the same response. The present data is explainable in terms of general activity level: (1) animals with a high activity level appear to learn rapidly and do not benefit from interpolated rest periods; and (2) animals with low activity levels appear to learn more slowly but benefit from interpolated rest periods. It is possible that activity level constitutes one of the broad descriptive categories of individuals learning styles. (Author/EK)

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CORRELATES OF INDIVIDUAL LEARNING STYLES

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February, 1969

U. S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE

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November 1, 1969

The research reported herein was performed pursuant to a grant with the Office of Education, U.S. Department of Health, Education, and Welfare. Contractors undertaking such projects under Government sponsorship are encouraged to express freely their professional judgment in the conduct of the project. Points of view or opinions stated do not, therefore, necessarily represent official Office of Education position or policy.

U. S. DEPARTMENT OF
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SUMMARY

The goal of the research program supported by this grant is the determination of one or more relatively broad descriptive categories of learning styles based on research on the chemical and physiological correlates of learning, as well as the development of relatively simple tests or measures that would allow an investigator to place a subject within one or more of these categories. Eight experiments with two species of rats are described in detail. The data from these experiments suggest that there are reliable differences (1) between the rates at which male and female rats acquire a bar-press response, and (2) between the rates at which hooded and albino rats acquire the same response. Significant differences also obtain between the effects on male and female animals of "incubation" or rest periods interposed during training; the male animals seem to benefit more from such "incubation" periods than do the females. Additionally it appears that albino rats may benefit from such "incubation" periods more than do hooded animals. Both slow and fast learners show improvement during "incubation" periods, but male slow-learners appear to benefit more than do female slow-learners. The present data seem tentatively explainable in terms of "general activity level:" Animals with a high activity level appear to learn rapidly, extinguish rapidly, and do not benefit too much from interpolated rest periods. Animals with low activity levels appear to learn more slowly, but benefit from interpolated rest periods to the extent that their slower learning rates can be compensated for with proper scheduling of training trials; once they have mastered the response, however, they appear to retain it better than do high-activity-level animals. It seems possible that "activity level" constitutes one of the "broad descriptive categories" of individual learning styles whose determination is the goal of the present research.

INTRODUCTION

Learning is the sine qua non of the educational process. A complete understanding of the educational process can never be achieved unless one understands the physiological and biochemical processes by which memories are formed, stored and retrieved, and unless one appreciates how these processes vary from one individual to another. It is not enough to seek "generalized laws of learning," for it should be clear by now that individuals vary immensely in their styles of learning. Unless we know something about the neurological and biochemical underpinnings of the learning process, we cannot hope to understand (much less compensate for) these personal learning styles. The practical consequences of being able to classify individuals into certain broad categories of learning styles should be considerable, for this could eventually allow the specification on a priori grounds of which type of training paradigm might be optimum for a given individual. The research described in this Final Report constitutes a first approach to the determination of one or more relatively broad descriptive categories of learning styles based on research on the chemical and physiological correlates of memory formation and storage. Before the research projects themselves can be meaningfully described, however, the presentation of some background material seems called for.

The dominant theories of memory formation and storage in the past have typically postulated some kind of change in the flow or patterning of neural activity due to past experience. The best-known of these theories are probably those of Hebb (1949) and Eccles (1966) in which learning is thought to result from some kind of change at the level of the synapse. In the face of considerable evidence that long-term memory is not coded merely in terms of electrical activity, however, a number of scientists have concluded that long-term retention of experiential information must be mediated at least in part by permanent chemical changes in the central nervous system (Barondes, 1965; Booth, 1967; Katz & Halstead, 1950; Pribram, 1969). Nevertheless, the bulk of empirical research dealing with this problem suggests that the chemical code for memory, if it exists, is highly elusive. In fact, almost all the available experimental evidence for such a code is largely indirect. Studies using electro-convulsive shock or other disrupting agents to study memory have provided the best evidence against the proposition that long-term information is held in perseverating electrical activity. Yet, such studies have done little to provide direct evidence for a molecular storage mechanism in long-term retention and retrieval of experiential information. Similarly, studies of changes in ribonucleic acid (RNA) base ratios during learning (Hydén, 1967; Shashoua, 1968), although providing indirect evidence for a molecular storage mechanism for information, require sophisticated procedures that have prevented independent replication of the work in other laboratories. Even if these very elegant techniques were generally available, the task of separating RNA base-ratio changes that are correlated with learning from those changes that occur as the result of some non-specific factors, such as activity or stress, must still be undertaken. Furthermore, these base ratio changes are apparently not permanent, so investigators using this approach have the additional problem of making inferences from transient changes in RNA base ratios to a complexity of unknown steps that must occur following these apparently ephemeral changes.

About 1960, quite a different approach to elucidating the chemical correlates of memory was initiated in this laboratory. First it was discovered that when trained planarian flatworms were transversely sectioned and allowed to regenerate, both of the newly formed worms showed savings of the task in which the original worm had been trained (McConnell, Jacobson & Kimble, 1959). This finding was of particular interest since only the head-regenerates contained the brains of the original animal. Subsequent research (Corning & John, 1961; Cherkashin & Sheiman, 1967) has indicated that the factor responsible for retention following regeneration probably is RNA. Later experiments indicated that cannibal worms fed on trained worms and then themselves trained acquired a conditioned response significantly faster than did cannibals ingesting untrained material (McConnell, Jacobson & Humphries, 1961). In addition, this laboratory showed that this type of "memory transfer" could be achieved by extracting a crude RNA mixture (that also contained proteins and other substances) from the trained worms and injecting it into untrained animals (Zelman et al., 1963). Other laboratories soon confirmed this finding in planarians and showed that ribonuclease, which hydrolyzes RNA, erased the "transfer" effect (McConnell, 1968).

In 1965, a number of investigators independently applied the "memory transfer" paradigm to mammals and reported a striking degree of success in transferring experiential information to naive recipient mice or rats via injection of material taken from the brains of trained animals (Albert, 1966; Babich et al., 1965; Fjerdingstad et al., 1965; Reinis, 1966; Ungar & Oceguera-Navarro, 1965). Although several laboratories subsequently reported a distinct lack of success in replicating these early experiments (Byrne et al., 1966), much of this failure appears due to a lack of understanding of what the critical factors are that influence the "transfer" effect (McConnell, 1967). At an International Symposium on the Chemistry of Memory held in Hungary in September, 1969, and at an I/D/E/A conference on the same topic held in Memphis in October, 1969, it was determined that more than 30 different laboratories have now reported successful "transfer" experiments with fish, mice, rats and hamsters. The search for those specific factors that mediate the "transfer" effect goes on, however.

In the spring of 1968, this laboratory undertook a series of attempted replications of a "memory transfer" paradigm first reported by Gay and Raphelson (1967) but which has been modified extensively by Ungar (Ungar et al., 1968). In this type of experiment, donor animals are trained to escape from a black into a white chamber in order to avoid painful electric shock. When extracts from the donor brains are injected into untrained recipients, and the recipients placed for the first time into the apparatus, the rats that are injected with chemicals from trained donor brains typically show a statistically reliable tendency to avoid the black chamber and to approach the white chamber, while control animals injected with material from untrained donors show the "natural" reaction of avoiding the white box and remaining in the black chamber. The first attempted replication of this paradigm in this laboratory was highly successful; however, following this initial success, no differences between experimental and control groups of recipients were found in the next five experiments. After failing to find an adequate interpretation for these failures, efforts were undertaken to repeat a paradigm originally developed by Dyal and his colleagues at Texas Christian University (Dyal et al., 1967; Dyal & Golub, 1968).

In the Dyal-Golub paradigm, one group of donor animals is given 10 days of continuously reinforced bar-press training with food as a reward. A second group of rats serves as controls for handling, activity, and sensitization. A third group of animals receives the same number of training sessions as do the experimental animals; however, three days of extinction training, in which bar-presses are not reinforced with food, are interposed between days eight and nine of acquisition training. Following these training sessions, the donors are sacrificed, brain homogenates prepared from their brains, and these homogenates subsequently injected intraperitoneally into naïve recipient rats. "Memory transfer" effects are consistently obtained for animals receiving material from donors that have had experience both with acquisition and extinction. No transfer effects seem to occur, however, when recipient animals are injected with material from either the control group donors or from donors given training with no interposed extinction training. The puzzling fact that one must interpose extinction trials in order to obtain the "transfer effect" was not explained by the TCU group, but four published replications of their studies, as well as a replication in this laboratory (Golub & McConnell, 1968), suggest that the phenomenon is statistically reliable.

Following failure of the Ungar paradigm to yield consistently reproducible effects, work in this laboratory turned to the Dyal-Golub paradigm in order to repeat once more the basic study and then to extend the work in future experiments. In this replication, the subjects were 37 male Sprague-Dawley rats 60-90 days old. Twenty-four of the animals served as donors and were assigned at random either to an experimental (N = 12) or a control (N = 12) group. The remaining 12 animals were randomly assigned to two recipient groups of 6 rats each. The experimental donors were given 8 days of bar-press training in an operant chamber (food was the reward), then three days of extinction training in which pressing the bar did not yield the animal a pellet of food. Following extinction, training was discontinued for 7 days due to difficulties in obtaining recipient animals from the supplier; during this time, the donor animals remained on a food deprivation schedule. Training was subsequently completed by giving these experimental donors three days of reacquisition training of the bar-press response with food again as a reward. The control donors were given no training but were handled and were kept on the same food-deprivation schedule as were the experimental donors. At the end of training, all donors were sacrificed and a homogenate made of their brains. Recipient animals were lightly etherized and injected intraperitoneally with 3.22 cc. of homogenate from either experimental or control donors. The recipients were then given daily bar-press training in the operant chamber. Both injections and testing were carried out using "blind" procedures.

The results of this experiment are shown in Fig. 1. As can be seen, by the third or fourth day of testing, the control and experimental recipients departed significantly from each other in terms of the mean number of bar-press responses they made daily. But, for the first time in several attempted replications, the control recipients were significantly superior to the experimental animals that received homogenate from trained brains. An investigation of this "reversal" effect has led the present writer to the discovery of the importance of "incubation periods" in "memory transfer" experiments.

There was one significant difference between the present study and all others using the Dyal-Golub paradigm. In the present experiment, the donor

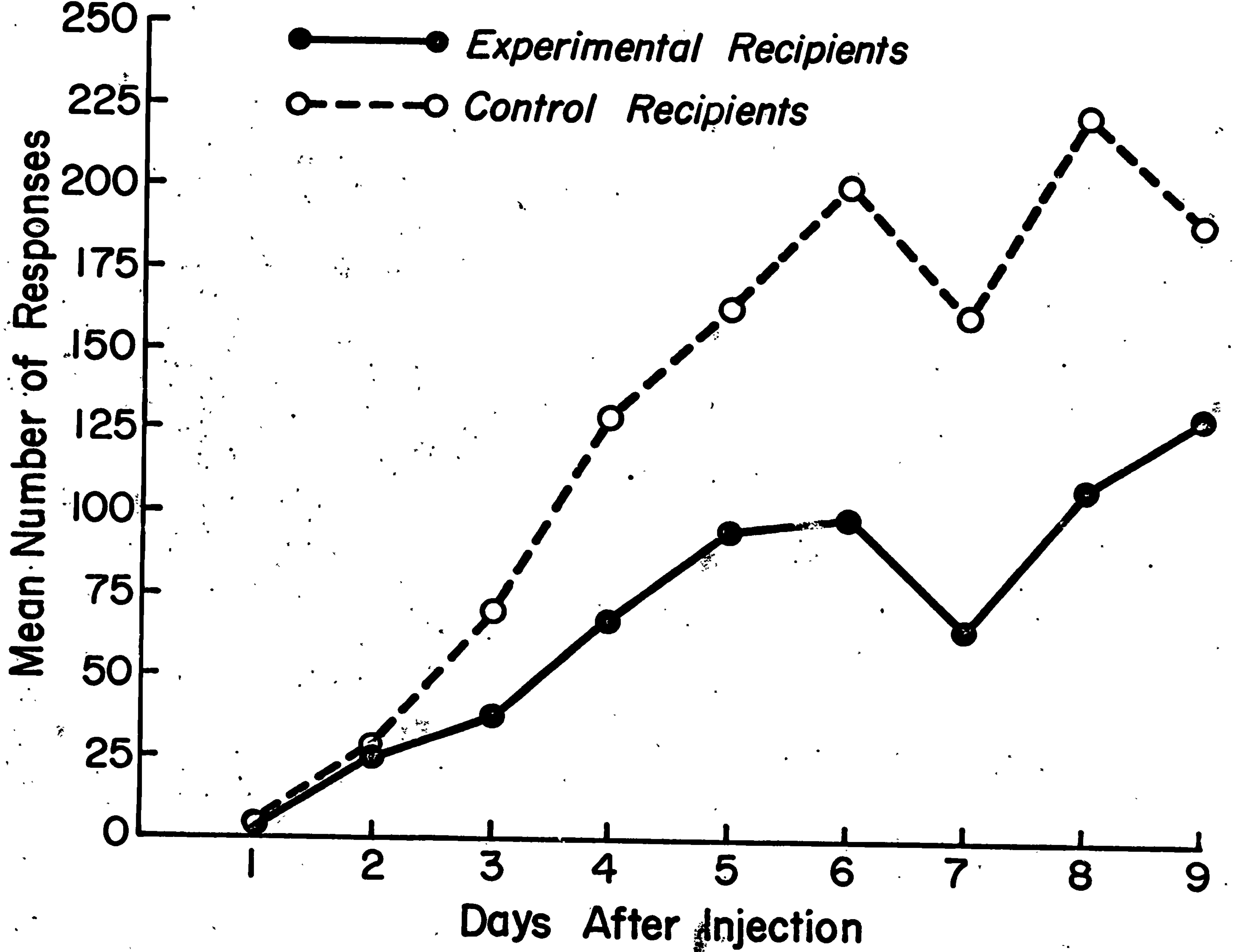

FIG. 1. Mean number of bar presses on each of nine daily sessions for recipient animals injected either with brain homogenate from the experimental or from the control donor groups.

animals were given a 7-day rest period immediately following extinction training. Two possible interpretations of this "reversal" effect suggested themselves. First, it seemed possible that the 7-day rest period served the function of permitting "consolidation" of the training experience just preceding it which, in the present experiment, would be extinction training. Therefore, it was possible that, in the present study, the investigators transferred some portion of the extinction training and that the present experiment provided an instance of the successful "transfer" of extinction. On the other hand, it was possible that the rest period did not serve to "incubate" the extinction training but rather that it merely suppressed the positive effect reported in previous replications of this paradigm that did not include the rest period. It was decided to test these two interpretations by performing a second experiment.

If the rest period functions by suppressing the transfer effect, it should not be critical when it is interposed during training. If, on the other hand, it serves an "incubation" function, it should be possible, by interposing the "incubation" period during different phases of training, to manipulate the kind of transfer effect one obtains. Thus, in the next experiment, three groups of donor animals were used. One group served as untrained control animals, the second and third differed only in terms of when during training the "incubation period" was interposed. In one group of experimental donors, a 7-day rest period followed the initial 8 days of acquisition training in the operant chamber; thus these donors were given 8 days of initial bar-press training, followed by a 7-day rest period, followed by three days of extinction training, then three days of reacquisition training. For the other group of experimental donors, the 7-day rest period followed the extinction training; thus these animals were given 8 days of initial bar-press training, three days of extinction training, then 7 days of rest, followed by three days of reacquisition training. There were 6 animals in each of the three groups of untrained recipients. In all other respects, including the use of "blind" testing procedures, the methodology for this experiment was the same as in the previous study.

The results of this second "incubation" study are shown in Fig. 2. As can be seen, there are highly significant differences among the three groups of recipient animals. Those rats injected with homogenate from donors given the rest period immediately after training were significantly superior to all other animals throughout the test period. Those rats injected with homogenate from donors given the rest period immediately after extinction training were significantly inferior to all other animals for the first few days of testing. It would seem then that the rest period does indeed "incubate" whatever experience immediately precedes it. Several additional successful replications of this basic effect followed in this laboratory and led us to examine anew many of the other experiments performed in this and other laboratories. It was found that, almost without exception, those experimenters who were able to achieve highly reliable "memory transfer" effects trained their donors on a 5-day week rather than giving the animals training every day in the week. On the other hand, almost without exception those experimenters who reported they were unable to obtain "memory transfer" effects in their laboratories trained their animals on a 7-day week. A few investigators, such as Reiniš in Ghana and the present writer at Michigan, typically achieved success when employing a 5- or 6-day training schedule but not when training their animals every day in the week. For the most part, unfortunately, none of the experimenters had bothered to report what their actual training schedule was like.

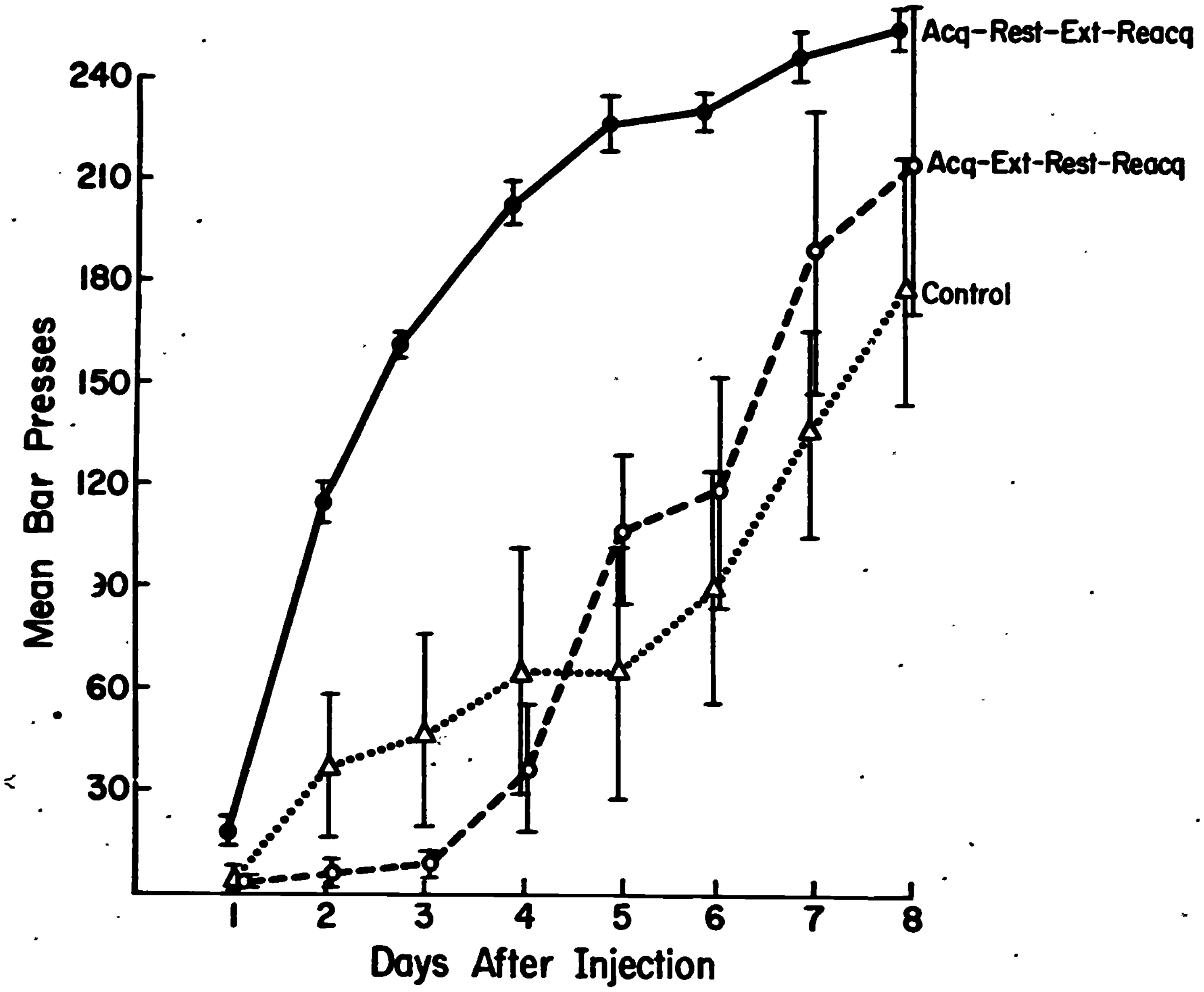

FIG. 2. Mean number of responses emitted by the recipient groups on each of eight days following injection of brain RNA. The RNA was extracted from donor animals trained on either Acq-Rest-Ext-Reacq, Acq-Ext-Rest-Reacq, or from quiet control animals. The vertical bars represent one standard error of the mean.

Obviously, donor animals that are trained but 5 days a week are given at least one week end in which "incubation" effects possibly occurred. Following this line of thinking, this laboratory subsequently undertook yet another replication of the Ungar dark-avoidance paradigm in which the donor animals were given an "incubation" period in the middle of training and, for the first time in several attempts, statistically significant "memory transfer" effects were obtained.

The exact mechanism by which "incubation" periods facilitate the appearance of the "transfer" effect is not yet known, but one might logically expect that a well-learned habit would "transfer" more effectively than a habit that was weakly learned. Prior studies in this laboratory (McConnell et al., 1968) and in Ungar's (Ungar, 1967) suggest that, within limits, the more training given the donor animals, the stronger the transfer effect is likely to be. Thus it is likely that the interposing of rest periods in the middle of training serves to increase or "consolidate" the strength of the learning in the donor animals much as does overtraining (Deutsch, 1968). The "incubation" studies further suggest, however, that one may often substitute rest periods quite effectively for additional training, a suggestion that has perhaps enormous significance as far as education is concerned.

It is axiomatic in most behavioral laboratories that animals are given training on a 7-day-per-week work schedule. What evidence is there that such a schedule promotes the best learning? It is axiomatic in most educational institutions that students are given training on a 5-day-per-week work schedule (with the possibility of outside homework on the "off" days). What evidence is there that such a schedule promotes the fastest learning and the longest retention? "Incubation" periods, during which the organism is either resting or is performing some other task, seem to facilitate learning and remembering. But would one expect that all organisms, human and otherwise, would benefit equally from the same "incubation" periods? Would one expect genetic differences to obtain? What about sex differences or age differences? It would seem that the best methodof proceeding would involve the identification of broad categories of learning styles that would allow educators and others to make useful generalizations about the individual organisms that possess these styles. The research described in this Final Report constitutes part of Stage One of a program designed to identify one or more relatively broad descriptive categories of learning styles, the development of relatively simple tests or measures that would allow an investigator to place a subject within one or more of these categories, and finally the determination of optimum teaching strategies for each category. In this first stage, animals of different species, sex and maturity have been used as subjects in different types of learning tasks. Correlations have been sought between physiological and biochemical variability and variability in learning. During Stage Two of this research, to be undertaken in the future, an attempt will be made to overcome this variability by correctly programming learning trials and tests. Stage One research has involved animal subjects since most of the experiments involve various biochemical and physiological interventions that, at the present time, are difficult or impossible to undertake with human subjects.

METHODS

The following eight experiments, conducted with financial support from the present Office of Education grant, constitute part of Stage One of our research program. The experiments were designed to determine one or more relatively broad descriptive categories of learning styles based on research on the chemical and physiological correlates of learning.

EXPERIMENT ONE:

Procedure

Subjects. Twenty-eight male, albino rats, 60-90 days old, were tamed and maintained on a 22.5 hr. food deprivation schedule. Six days later they were assigned at random to one of 4 groups. Each of these groups received acquisition training in the operant situation. At the end of day 4 of acquisition training on a CRF schedule all Ss were systematically assigned to one of four groups to equate them on the basis of their bar-press rates. Animals in Group 1 received five days of rest, followed by two additional days of acquisition training (Acq 4-R5-Acq 2); animals in Group 2 received an additional 7 days of training (Acq 11); animals in Group 3 received an additional 2 days of training, followed by a five-day rest period during which they were not trained (Acq 6-R5); animals in the fourth group received two additional days of training, but received no rest period (Acq 6). On the day following the last training session, or rest day, depending upon which group the animal had been assigned to, all Ss received four 30-min. sessions of experimental extinction, one session a day, during which bar-presses were not reinforced with food.

Results

No statistically reliable differences were found between any of the groups on the final day of acquisition. The data collected during extinction sessions provide evidence, however, that the groups were not equivalent at the end of acquisition training. The mean number of bar-presses made on the first day of extinction was 140, 134, 110, and 106 for animals trained on Acq 4-R5-Acq 2, Acq 11, Acq 6-R5, and Acq 6, respectively. The difference between group Acq 4-R5-Acq 2 and group Acq 6 was statistically reliable ($t = 2.2$, $p = .05$). No differences were found between any of the other groups on the first day of extinction. On Day 2 of extinction the difference between the mean number of bar-presses between group Acq 4-R5-Acq 2 and group Acq 6 was statistically reliable ($t = 3.03$, $p < .05$). Again no differences were found between any of the other groups. On Day 3 of extinction, there were no reliable differences between groups Acq 4-R5-Acq 2, Acq 11, and Acq 6-R5; however, both the Acq 11 and the Acq 4-R5-Acq 2 groups were reliably different from the Acq 6 group ($t = 2.52$, $p < .05$, and $t = 2.58$, $p < .05$, respectively). These results are presented in Fig. 3.

Discussion

These results provide evidence that incubation periods play an important role in donor training. Furthermore, these data, taken together with the results of the operant chamber studies, described earlier in this Report, suggest that it is possible to coordinate factors important in donor training with

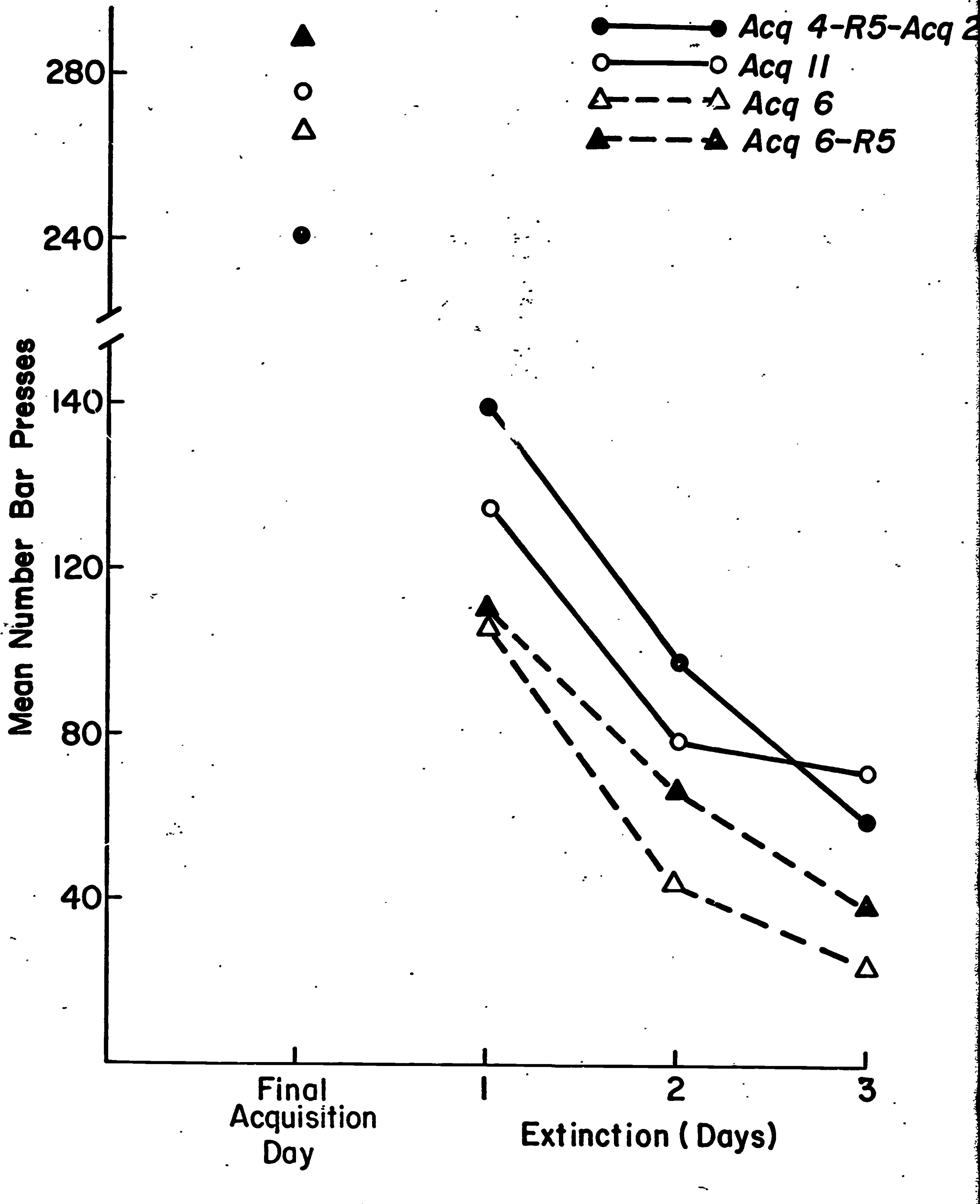

FIG. 3. Mean number of bar-presses emitted by the various groups during the final acquisition session and on each of the extinction sessions.

the type and extent of memory transfer effect one obtains. Furthermore, if incubation periods do play an important role in memory transfer, it should be possible to obtain transfer effects using paradigms that have been unsuccessful in the past, providing one includes an incubation period at some relevant point in donor training.

EXPERIMENT TWO:

Procedure

Subjects. Thirty-two hooded rats, 16 males and 16 females, 30-60 days old, were tamed and maintained on a 22.5-hr. food-deprivation schedule for six days prior to training.

Apparatus. Two Grason-Stadler rat chambers (Model E3125A) were modified such that the single bar was moved to the side of the chamber opposite the food cup and centered 1 in. from the plexiglass door. A photocell beam was passed across the entrance to the food magazine so that each time S stuck its nose at least 1 cm. into the food magazine, the event was cumulated on counters. Bar-presses were also cumulated on counters.

Method. All Ss were given an initial 30-min. session of food magazine training in which a 45-mg. Noyes pellet was delivered via the food dispenser into the food magazine once each min. for 30 min. On each of the four following days, all Ss received one 30-min. bar-pressing session per day, in which each bar press was followed by presentation into the food magazine of one 45-mg. Noyes pellet.

Results

The results are presented in Fig. 4. As can be observed from Fig. 4, on each day after the first, the female hooded rats bar-pressed at a rate higher than that of the male animals. Eight of the female and 12 of the male animals did not acquire the bar-press response by day 4 of training. Hence although the females are bar-pressing at a rate obviously higher than that of the males, the difference in mean bar-presses on day 4 is not statistically reliable. There is simply too much variability in individual performance.

EXPERIMENT THREE:

Procedure

Not all animals learn at the same speed; some are slow learners, some are rapid learners. In Experiments Three and Four, the slow and fast learners were separated and given additional training.

All Ss not acquiring the bar-press response by day 4 of training were randomly assigned either to an incubation or a non-incubation group. Animals in the non-incubation condition (4 female and 5 male) received an additional day

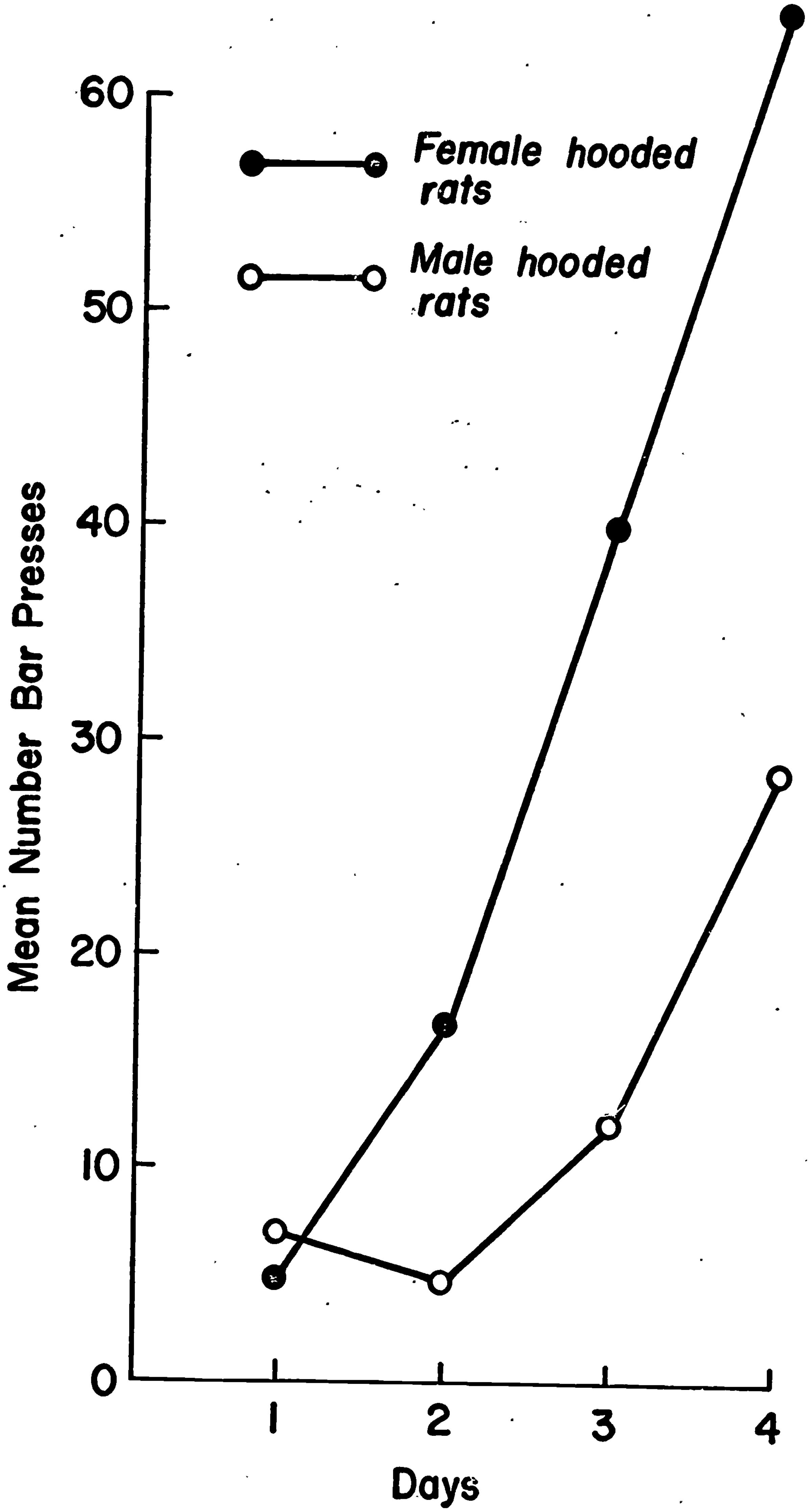

FIG. 4. Acquisition of bar-press response.

of bar-press training (30-min. session, CRF), whereas animals in the incubation condition (4 female and 7 male) were given one day in which to incubate the training experience. Following this single incubation day, they received a fifth day of bar-press training.

Results

As can be observed from Fig. 5, groups of both male and female animals receiving incubation appear to have acquired the bar-press response, while non-incubated females have not improved by day 5 of training. Of the four female and seven male animals assigned to the incubation condition, only one female acquired the bar-press response on day 5 whereas four of the seven males did so. This is not reflected in the data point for day 5 (Fig. 5) because the lone female presses at a very high rate. The differences between the various groups are not statistically reliable (again because of the large variability); yet, they probably reflect a valid phenomenon.

EXPERIMENT FOUR:

Procedure

At the end of day 4 of bar-press training, all Ss that had acquired the bar-press response were assigned either to an incubation or a non-incubation condition. Animals in the incubation condition were given a five-day period during which they were not trained. This five-day incubation period was followed by two additional days of training, followed by four extinction sessions, each of which were 30-min. in duration and were administered once a day. Animals in the non-incubation condition received 7 additional days of training (days 5-11), followed by four extinction sessions.

Results

As can be observed from Fig. 6, there are no reliable differences between the incubation and non-incubation groups on the final acquisition day. Although incubation appears to have an effect, as measured in terms of resistance to extinction, the differences between the two groups on each of the extinction days are not statistically reliable. This finding contrasts sharply with the data presented in Fig. 3 in which incubation was shown to have a reliable effect in albino rats and suggests species differences in consolidation. Hence albino rats appear superior to hooded animals in consolidating material during periods of interpolated rest.

EXPERIMENT FIVE:

Procedure

Given the above data, it was of interest to determine whether albino rats acquire the bar-press response more rapidly than hooded animals.

Subjects. Twenty-five male albino rats, approximately 90-110 days old and 24 male hooded rats, approximately 50-70 days old, were housed in individual cages and maintained on a 22.5-hr. food-deprivation schedule.

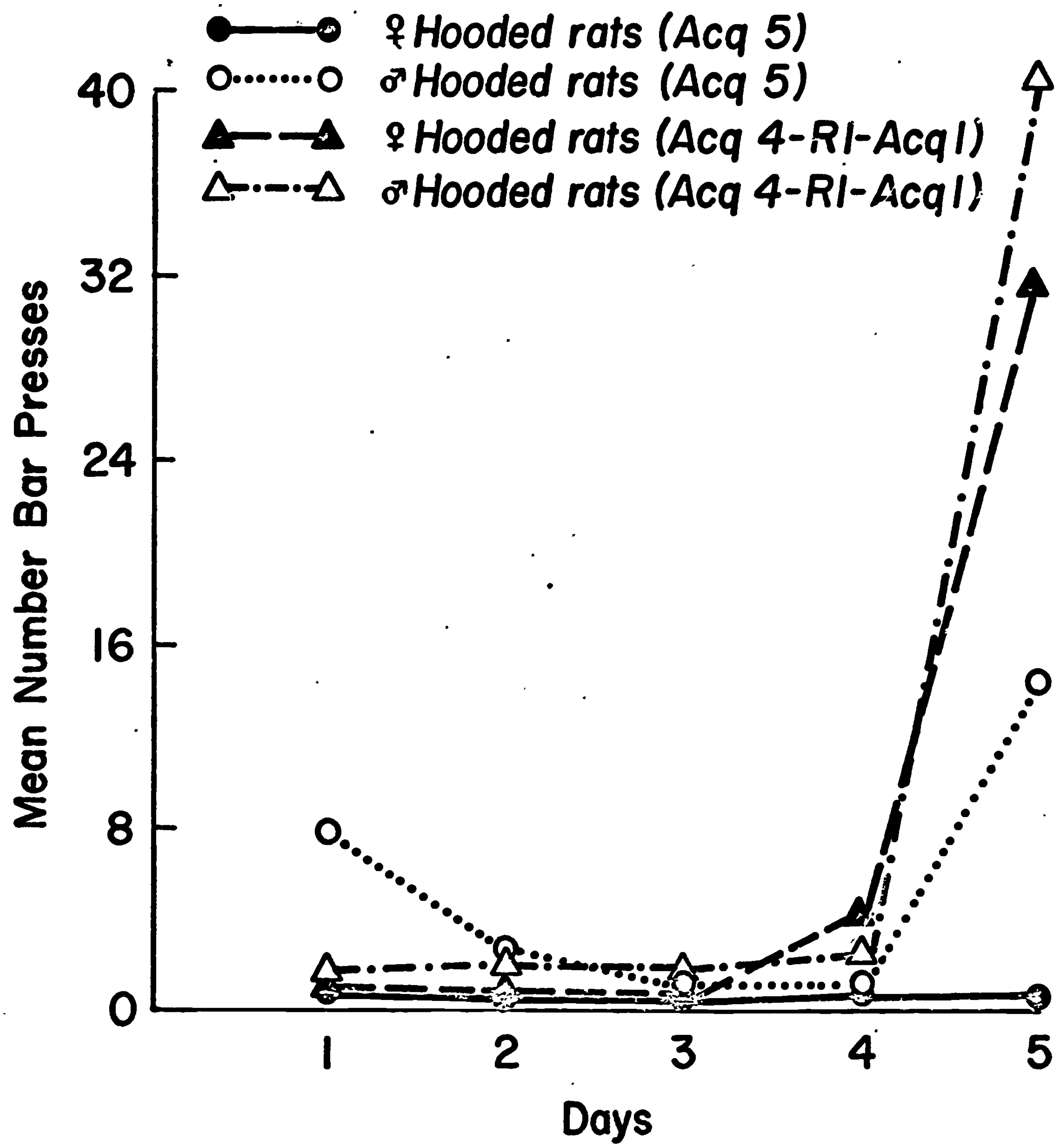

FIG. 5. The effect of incubation on bar-pressing in animals that have not acquired the bar-press response by day 4 of training.

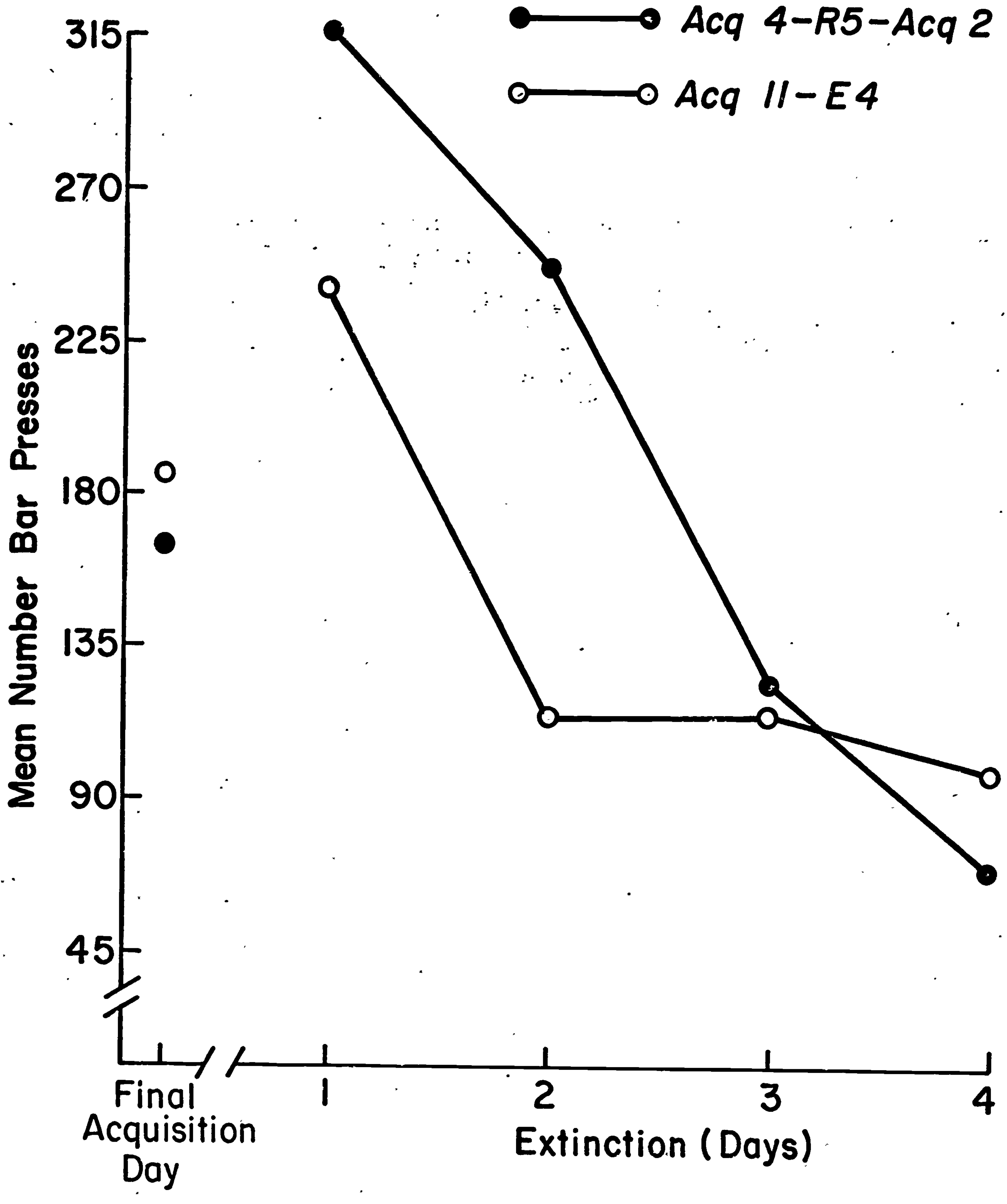

FIG. 6. The effect of interpolated rest (five days) on resistance to extinction in hooded rats (groups included both male and female).

Method. All animals received an initial 30-min. magazine-training session during which a pellet of food was delivered into the food cup once a minute. Following this initial magazine-training session, all Ss received four bar-pressing sessions during which each bar-press produced a 45-mg Noyes pellet. Each session was 30 min. in duration.

Results

Of the 25 albino animals, 18 had acquired the bar-press response by day 4 of training. Of the 24 hooded animals, 18 had acquired the bar-press response by day 4 of training. These data are presented in Fig. 7. As can be observed from Fig. 7, the albinos are pressing at a higher rate on each of the four days of training. Unfortunately, because of the large variability within groups, the difference between each of the points is not statistically reliable.

Fig. 8 presents the data only for the 18 albino and 18 hooded rats that had acquired the bar-press response by day 4 of training. As can be observed for Fig. 8, the albino animals are responding at a higher rate than the hooded on each of the four days of training. These differences, however, are not statistically reliable.

EXPERIMENT SIX:

Procedure

Subjects. Fourteen male and 14 female, 60-90 day old Sprague-Dawley albino rats were housed in individual cages and tamed. Six days before the start of training these animals were placed on a 22.5-hr. food deprivation schedule.

Method. Half of the males and half of the females were assigned at random to an incubation group. The other half of the animals were assigned to a non-incubation group. All animals received an initial session of magazine-training during which a pellet of food was dispensed into the food cup once each min. for 10 min. Animals in the incubation group were then given two days of rest during which time they were not trained. Animals in the non-incubation group were given a 30-min. bar-pressing session for food on a CRF schedule on each of the two following days. Animals in the incubation condition received identical training on each of the two days following the incubation period.

Results

One male rat in the non-incubation group died and thus no data are presented for that animal. The results are presented in Fig. 9. As can be observed from Fig. 9, there is no effect of incubation on acquisition of the bar-press response in female albino rats. However, male albino rats appear to benefit from the incubation experience as can be observed from their superior performance on day 2 of acquisition training. The difference between the mean number of bar presses on day 2 in the male incubation group versus the female non-incubation group is not statistically reliable. This is not too surprising,

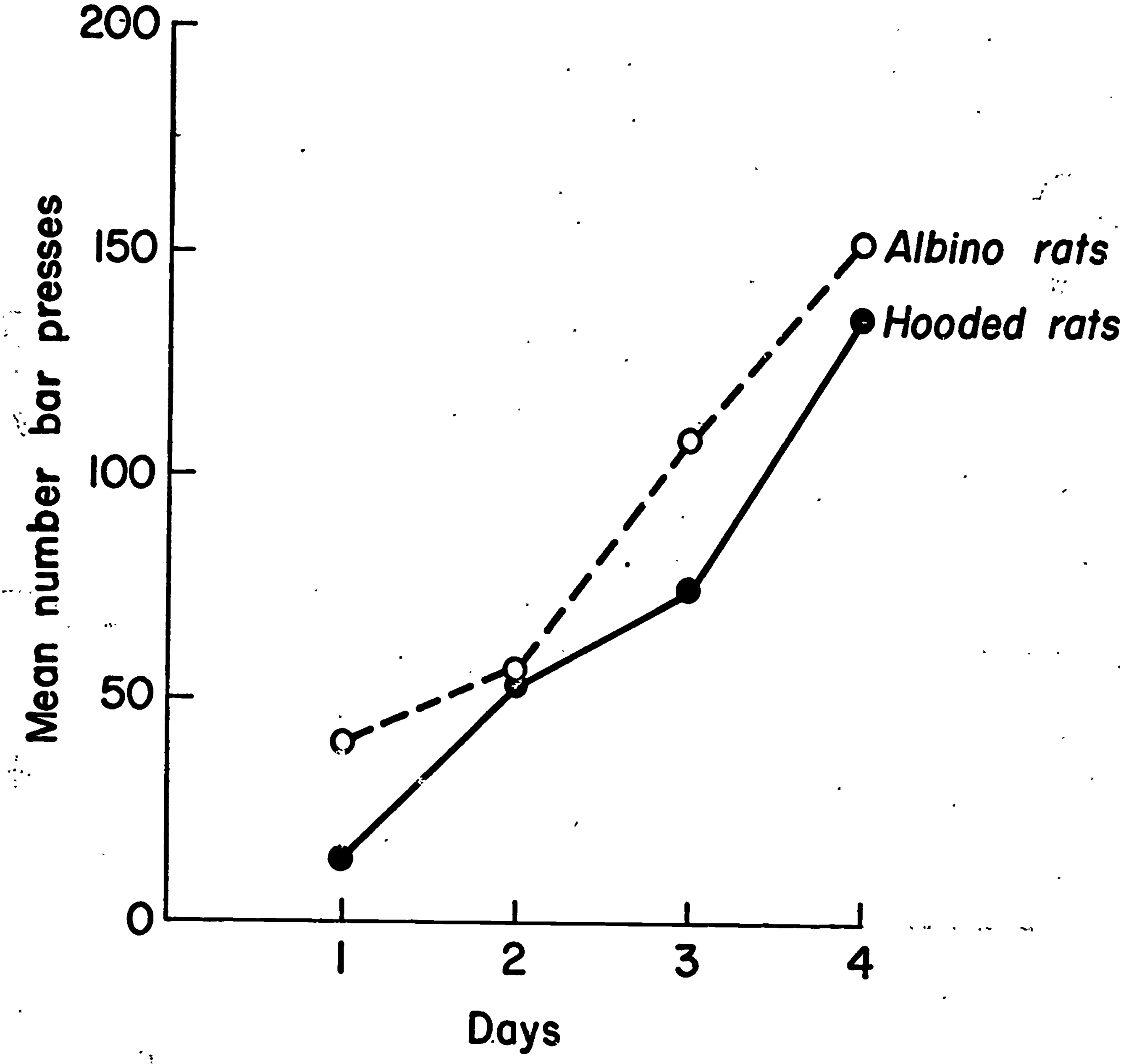

FIG. 7. Acquisition of the bar-press response (hooded vs. albino rats). Each data point includes responses of seven albinos and six hooded rats that did not acquire the bar-press response.

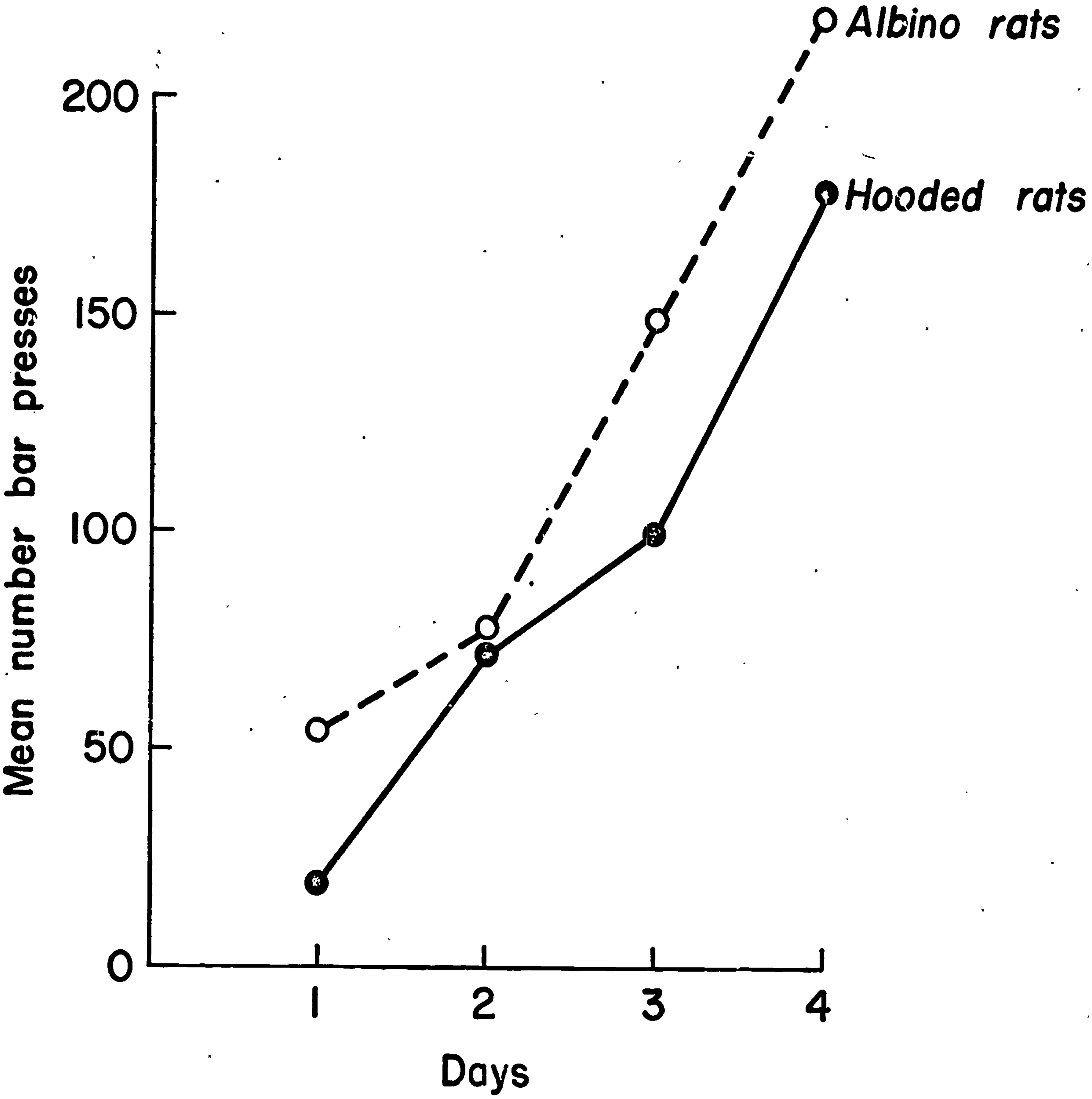

FIG. 8. Acquisition of the bar-press response (hooded vs. albino rats) for animals that acquired this response by day 4 of training.

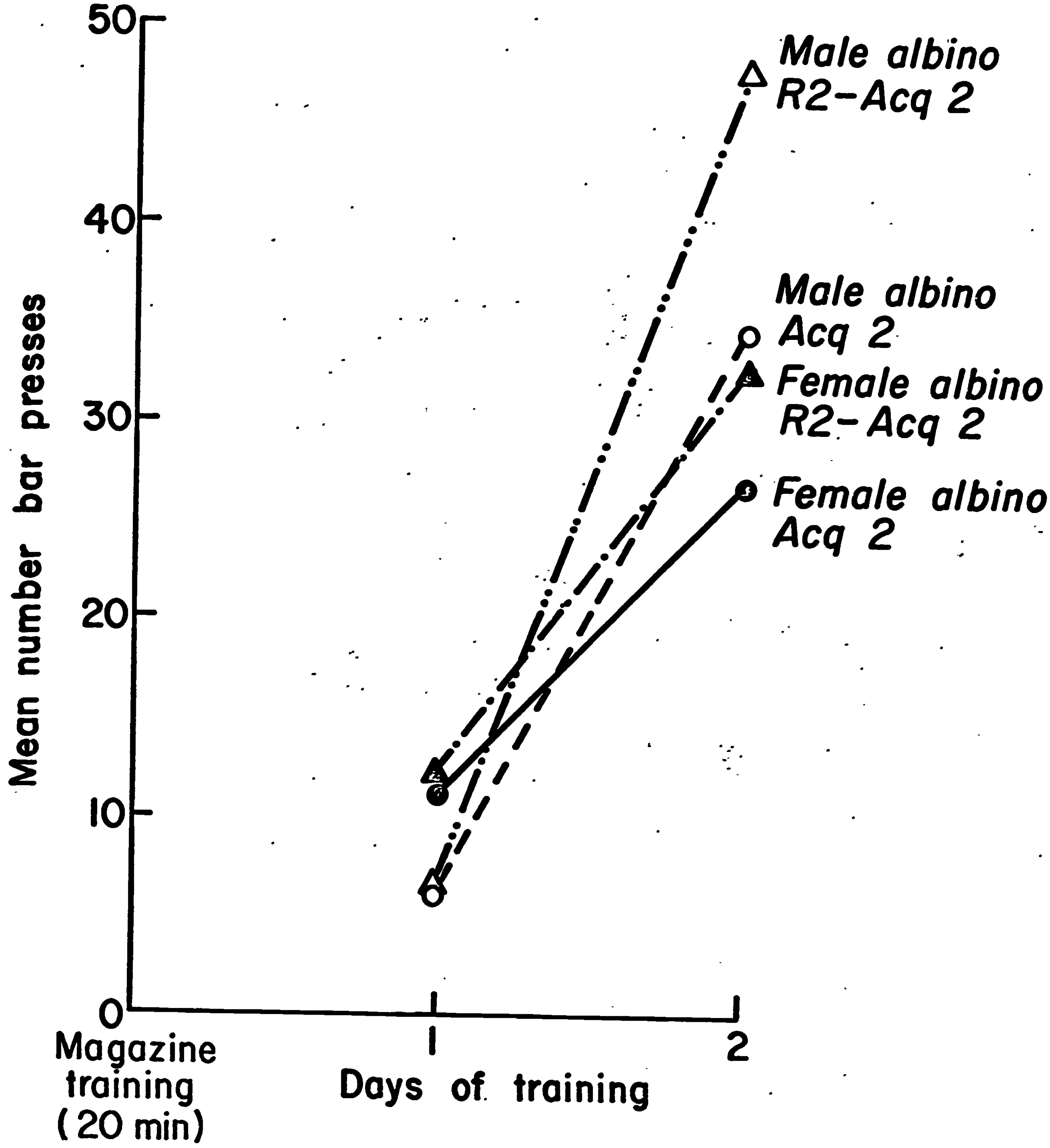

FIG. 9. Incubation of magazine training in male and female albino rats.

since these animals may have not learned enough from the 10 click-food presentations to profit from the incubation time. It was thus decided to carry out an additional experiment in which the previous procedure was repeated, but in which the magazine training period was extended to 20 min.

EXPERIMENT SEVEN:

Procedure

Ss, apparatus, and procedure was the same as in Experiment Six, except that the magazine training period was extended to 20 min.

Results

The results are presented in Fig. 10. As can be seen from Fig. 10, by day 2 both male and female rats that received incubation of the magazine-training experience,are superior on the bar-press measure to animals receiving the same training regime, but without incubation time interpolated between magazine training and bar-press training. These results approach statistical reliability, but because of the sample size are not reliable at the .05 level of confidence.

EXPERIMENT EIGHT:

Procedure

It was therefore decided to repeat Experiment Seven, this time using a larger sample size.

Subjects. Fifty-six male, Sprague-Dawley albino rats, 60-90 days old were housed in individual cages and tamed. Following this, they were placed on a 22.5-hr. food deprivation schedule.

Method. The animals were assigned at random to two major groups: incubation (N = 28) and non-incubation (N = 28). Fourteen of the animals in each group were randomly assigned to a 10 min. magazine-training condition; the other fourteen were assigned to a 20 min. magazine-training condition. During the magazine training session, a 45 mg Noyes pellet was delivered into the food cup once each min. Following this single magazine-training session, all animals were returned to their home cages. Animals in the non-incubation group received a single bar-press session on the following day during which each bar-press was reinforced with a Noyes pellet. The bar-press session was 30-min. in duration. Animals in the incubation group were not trained on the two days following their magazine-training experience. Following these two incubation days, they received a single bar-press session using the procedures reported above for the non-incubation group. All bar-presses were automatically cumulated on counters.

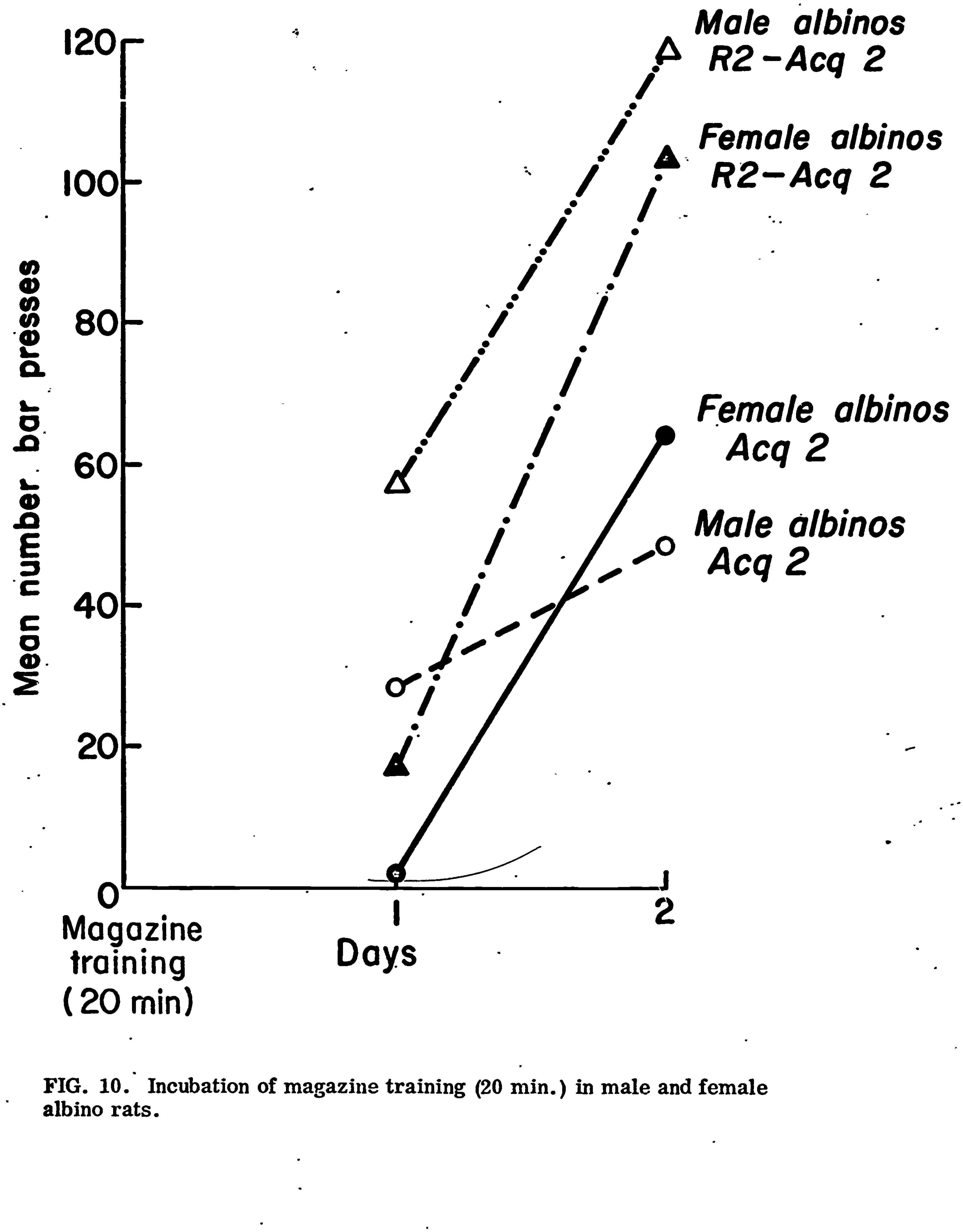

FIG. 10. Incubation of magazine training (20 min.) in male and female albino rats.

Results

The results are presented in Fig. 11. As can be seen from Fig. 11, there are no differences between the groups on the bar-press measure when a 10 min. magazine-training session is used; however, when the length of the magazine-training session is increased to 20 min., the group receiving the 2 day incubation period prior to the bar-press session is clearly superior to the non-incubation group ($t = 2.1$, $p < .05$).

DISCUSSION AND CONCLUSIONS

The data from the eight experiments described in detail above suggest that a number of conclusions are tentatively warranted. To begin with, it would seem that there are reliable differences (1) between the rates at which male and female rats acquire a bar-press response, and (2) between the rates at which hooded and albino rats acquire a bar-press response. There are also differences between the effects of incubation periods on male and on female rats--the male animals seem to benefit more from interpolated rest periods than to the females. The data in Experiment Four suggest additionally that albino rats may benefit from interpolated rest periods more than do hooded animals. Both slow and fast learners appear to benefit from incubation periods, but male slow-learners appear to benefit more than do female slow-learners. Although the data that led to these conclusions were not always statistically significant, they are strong enough to yield the tentative conclusions stated above; additional studies, with better controls and with larger sample sizes, will be run to confirm these first impressions.

The goal of Stage One of the present research program is the determination of one or more relatively broad descriptive categories of learning styles based on research on the chemical and physiological correlates of learning and the development of relatively simple tests or measures that would allow an investigator to place a subject within one or more of these categories. The results of the present eight experiments suggest that it may be particularly appropriate to investigate possible correlations between activity levels and speed of learning and strength of retention. It is common knowledge that female rats are typically more active (on some measures) than are males, particularly during certain parts of the œstrus cycle. It could likewise be the case that, on some measures of activity, albinos would (in general) have a higher activity rate than do hooded animals. If this were the case, and if correlations could be obtained across sexes and across species between speed of learning and activity level, it could be that "activity level" might constitute one of the "broad descriptive categories" whose determination is the goal of Stage One research. It would appear, for instance, that animals with a high activity level learn such responses as a bar-press for food rather rapidly, do not benefit from interpolated rest periods, and forget the response rapidly. Animals with lower-than-average activity levels appear to learn more slowly, but benefit from interpolated rest periods to the extent that their slower learning rates can be compensated for with proper scheduling of training trials; once they have mastered the response, however, they retain it better than do high-activity animals.

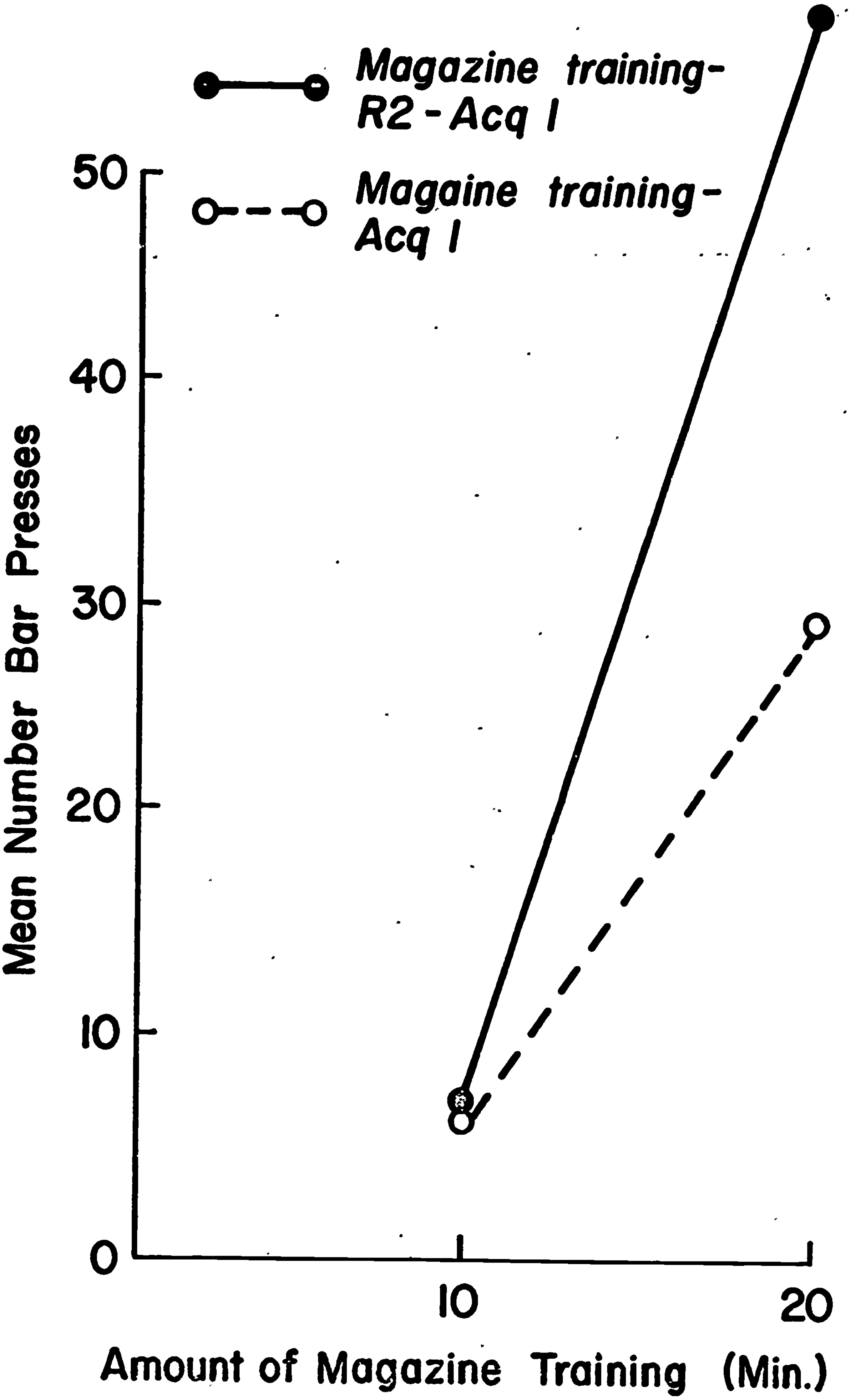

FIG. 11. The effect of two intervals of magazine training on bar-pressing following a two-day incubation in male rats.

If the activity-level and speed-of-learning correlations hold up, it should be a simple matter to study the chemical and physiological processes that underlie these correlations. One might expect, for instance, that RNA might be produced more slowly in the brains of animals with lower-than-average activity levels. Experiments involving pulse-labeling techniques to measure the amount of brain RNA produced during training, similar to studies reported recently by Zemp et al.(1966) and Shashoua (1968), might well yield very interesting results. One might also hypothesize that, whatever the "memory transfer" material turns out to be, it could well be produced in greater quantity in low-activity-level animals that are given incubation periods than in high-activity-level animals whether the latter are given incubation periods or not. Experiments such as these, which hopefully will be undertaken during Stage Two of the present research program, might well shed considerable light on the chemical correlates of learning and remembering.

Obviously there is much that still is not known about the "incubation" effect itself. Experiments must be run to determine how many interpolated rest periods (and of what duration) should be given to maximize the "incubation" effect. The data from Experiment Eight suggest that there is also an optimum amount of pre-incubation training that must be given to the animals to maximize the "incubation" effect, but additional studies are necessary to determine whether this hypothesis has merit.

All in all, it would seem that the three-stage research program outlined in the original research proposal is a viable and productive program that already has yielded significant findings during the first four-month period of its existence. Although no work with human subjects is anticipated until the third stage of the program, it does appear that results of the eight experiments described herein (which constitute but one part of Stage One of the program) offer a fair chance of eventual payoff in knowledge that will be applicable in classrooms.

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