PROGRESS REPORT

NASA GRANT NGR34-003-041

"DISCRIMINATION OF GRAVITATIONAL STIMULI"

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1. SUMMARY

During the period of this report the construction and installation of an animal centrifuge and its electronic support system was completed. Experimental procedures for obtaining data on the relationship between the discriminability of g-differences and location along the continuum of effective weight were initiated. Data were obtained under two successive discriminations showing discrimination among g-levels. In addition, there was some indication that the discriminability of differences between g-levels associated with reinforcement was the same at two locations along the g-continuum although there were differences in measures of absolute discrimination at these locations.

2. OBJECTIVES

The principal objective of this research is to study the discriminability of accelerations during centrifugation. Procedures are being developed to obtain data on the degree to which behavior can be brought under the discriminative control of gravitational stimuli, and to determine thresholds for the detection of differences in acceleration. This research seeks to determine the mechanical variables of which g-discrimination is a function. In particular, relations between the discriminability of g-differences and location along the continuum of effective weight are being sought. Information of discrimination above 1g is being developed in such fashion that hypotheses can be made for the region below 1g. Experimental procedures are being evaluated in terms of their suitability for in-flight experiments on the discriminative properties of gravitational stimuli below 1g.

3. STATEMENT OF WORK ACCOMPLISHED DURING THE PERIOD OF THIS REPORT

(a) Design, construction, and procurement of equipment. During the period of this report a major activity was the completion of a small animal centrifuge and electronic system for automatic control of resultant acceleration. A number of delays in the delivery of centrifuge conponents were encountered. Difficulty in recruiting qualified local technical personnel caused some delay in installation of the supporting control system. The centrifuge carries two capsules suitable for restrained squirrel monkeys. It has an eight foot effective radius and is presently capable of producing resultant accelerations up to 2.95g. At present only one capsule is available for use and the centrifuge is capable of control by external programming only. Equipment has been purchased to allow for control by subject's responses. Special small primate restraint chairs have been procured. During experimental sessions, chaired squirrel monkeys are situated inside the centrifuge capsule. The capsule contains a retractable lever, a food pellet receptacle, and two small indicator lamps. Floures-cent lamps provide general illumination. Control circuits provide for remote connection of the capsule to the experimental control program, either during rotation or otherwise. To provide for remote presentations of different g-levels within experimental sessions, a special control panel has been designed and constructed. This control panel allows for the sequential presentation of up to ten pre-set g-values.

Because of the unusual delays encountered in completion of

this system, an extension of time without additional funds was obtained for this project during the period of this report. The project period now terminates on 31 August 1973.

(b) Development of experimental procedures. Upon completion and testing of the centrifuge, experiments on gravity discrimination were initiated. Five squirrel monkeys were habituated to restraint, magazine trained in the centrifuge capsule, and then placed on a schedule of continuous reinforcement for level presses. One indicator lamp reported successful lever presses; another reported the delivery of single 190mg. Noyes food pellets. While still under the schedule of continuous reinforcement subjects were exposed to time periods with the level retracted from the capsule. This condition was continued until subjects responded with a lever press as soon as the lever was inserted into the capsule. Subjects were not rotated under these initial conditions.

Following the schedule of continuous reinforcement, two monkeys were dropped from the procedure. This was due partly to the development of undesirable superstitious behavior and partly to the availability of only one centrifuge capsule. The three remaining monkeys were placed under a variable interval schedule of reinforcement whereby lever presses delivered food on the average of only one time per minute (VI 60-sec). Under this schedule, 5-min periods with the capsule lights on and the lever inserted alternated with 2-min periods of darkness with the lever retracted. A masking noise was present during both conditions. This sequence was repeated eighteen times for each animal for a total sessions duration of 126 min. Figure 1 shows average response rates for each animal during 10-minute blocks of a session. Points in Fig. 1 represent mean response rates for the last three days under these conditions. Figure 1 shows that responding within sessions was relatively constant for all animals.

Following stabilization of performance on the VI 60-sec schedule,

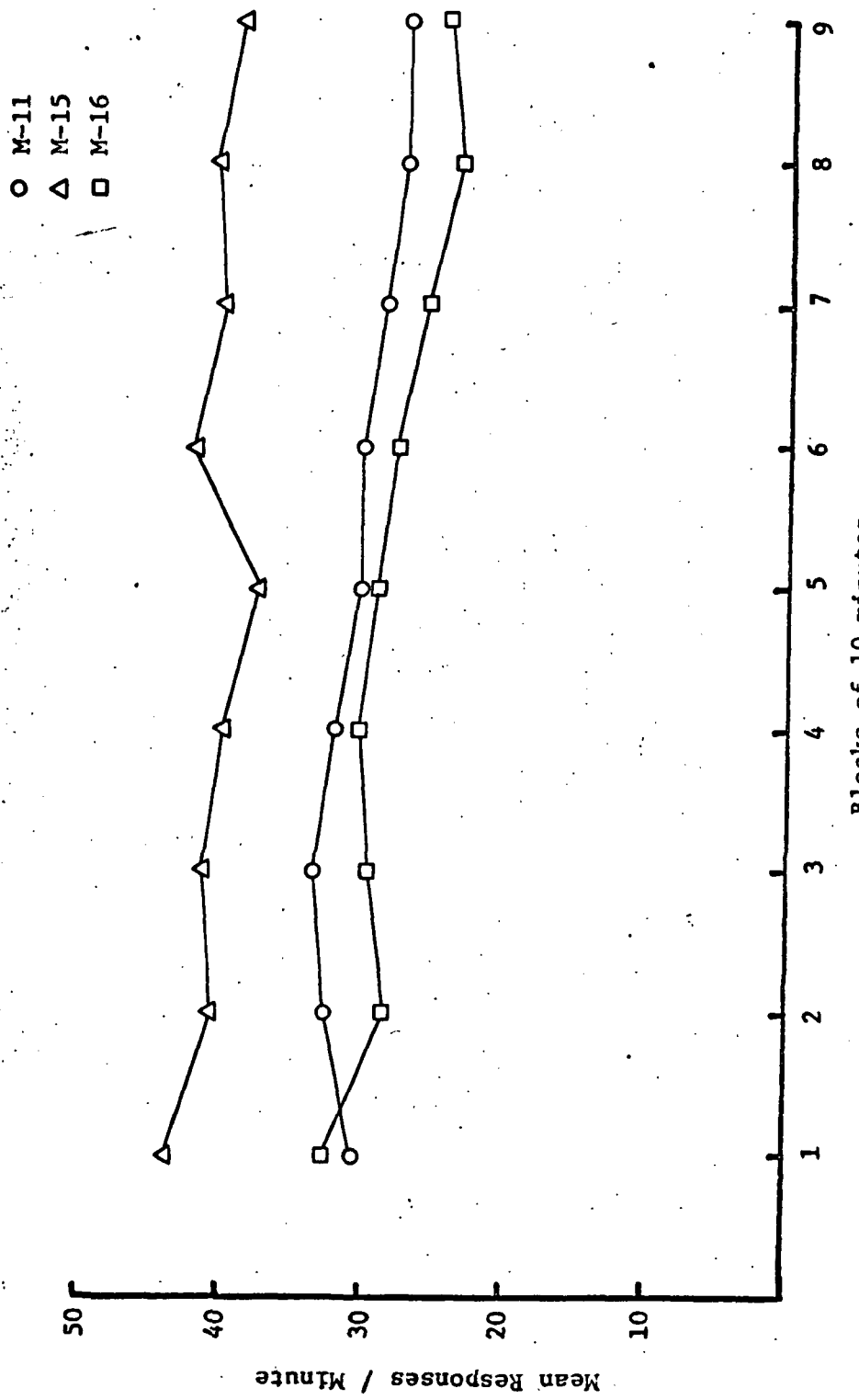

Fig. 1 Mean rate of responding within 10-minute blocks of an experimental session for three subjects. Points represent the mean response rate for the last three days under the variable interval 60-sec schedule of reinforcement at 1g (no rotation).

subjects were rotated for the first time. All other schedule conditions remained unchanged. That is to say, 5-min periods of responding under the variable-interval schedule alternated with 2-min periods of black-out. Artificial gravity under this initial rotation condition was 1.05g. This low g-value was selected to allow for habituation to some of the deleterious physiological reactions to rotation prior to exposure to higher g-values.

After initial exposure to 1.05g, subjects were exposed to nine different g-levels within each session. These g-levels were 1.05g, 1.25g, 1.50g, 1.75g, 2.00g, 2.25g, 2.50g, 2.75g, and 2.95g. Each g-level occurred twice per session, and each g-level occurred once before any other g-level was repeated. Within each session, then, each of the nine g-levels occurred in mixed order during the first half of the session followed by another occurrence of each g-level in a different order during the second half of the session. Exposures at each g-level lasted 5 min. Changes in g-level were made during the 2-min black-out periods. The VI 60-sec schedule was in effect at all g-levels. This treatment was made to obtain data on the relationship between responding and g-level, independent of discrimination training. It is conceivable, for example, that responding should decline at higher g-levels because of fatigue induced by the increased physical output required to perform the task. Figure 2 shows that rate of responding was relatively constant at all of the g-levels used. Points in Fig. 2 represent the mean response rate for each animal over the last three days under the treatment.

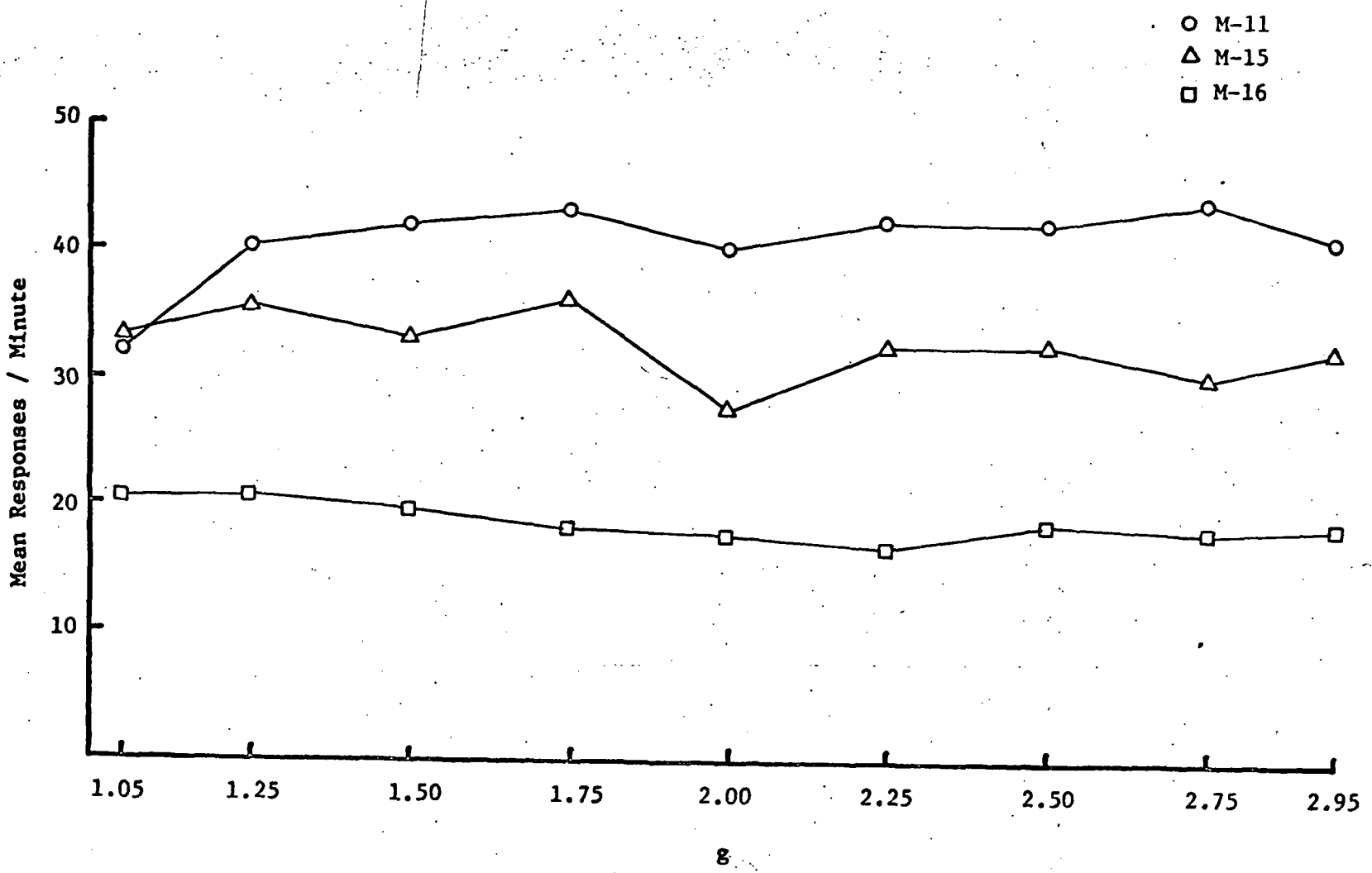

Fig. 2 Mean rate of responding as a function of g-level for three subjects. Points represent the mean response rate for the last three days under the variable interval 60-sec schedule of reinforcement at all g-levels.

After the data shown in Fig. 2 were obtained a discrimination procedure was initiated. This procedure was designed to show relations between discriminability of g-differences and location of effective weight along the continuum between 1.05g and 2.95g. Under this procedure, subjects were exposed to five different g-levels. In the presence of two of these g-levels, lever pressing was reinforced under a variable-interval schedule. In the presence of the remaining three g-levels, lever pressing was not reinforced. A discrimination is said to be established when differences in the pattern or probability of responding in the presence of the different g-levels is attributable to the differences in the conditions of reinforcement correlated with the g-levels. Under the first of the discrimination conditions, subjects were exposed to g-levels at the lower end of the continuum. The g-levels were 1.05g, 1.15g, 1.25g, 1.35g, and 1.45g. The highest two values, 1.35g and 1.45g, were the discriminative stimuli correlated with reinforcement (S^Ds) and the remaining three g-levels were correlated with the non-availability of reinforcement (S^Δs). During S^D reinforcement was available under a VI 60-sec schedule. All g-levels lasted for 5 minutes; changes in g-level were made during 2-min blackout periods. Each g-level occurred four times per session. Restrictions on the order of presentation were that each g-level occur once before being repeated, and that no g-level follow itself in sequence. After 21 sessions under these conditions the procedure was slightly modified. The five g-levels remained the same, but the schedule of reinforcement was changed from VI 60-sec to VI 120-sec. At the same time, g-level

exposure time was changed from 5 min to 4 min and blackout periods were changed from 2 min to 1 min. After 7 sessions under these conditions the procedure was again modified. The schedule of reinforcement remained VI 120-sec, the g-level exposure time remained 4 min, and blackout periods remained 1 min. The change was narrowing the range of g-levels to 1.15g, 1.20g, 1.25g, 1.30g, and 1.35g. Reinforcement was still available at the highest two g-levels. Figures 3, 4, and 5 show the relationship between response rate and g-level under each of these conditions for each animal. Points on these figures represent mean response rate over the last three sessions under each condition. Figures 3, 4, and 5 show that all three animals discriminated among g-levels in that highest response rates were associated with highest g-levels. Effects of changing the variable-interval schedule of reinforcement are most systematic at the three highest g-levels, where in all cases response rate was lowered when the schedule was changed to VI 120-sec. At 1.15g response rate was lowered in two of the three subjects and at 1.05g response rate was virtually unchanged. It is unclear at this point, however, to what degree these effects were controlled by changes in exposure time and blackout durations. Systematic investigation of these variables is intended. Effects of narrowing the range of g-levels are most systematic at the two highest g-levels. The important comparison in this case is between the two VI 120-sec conditions, and it can be seen that decreasing differences between g-levels tended to increase responding during S^D. Changes in S^Δ responding were not systematic between subjects.

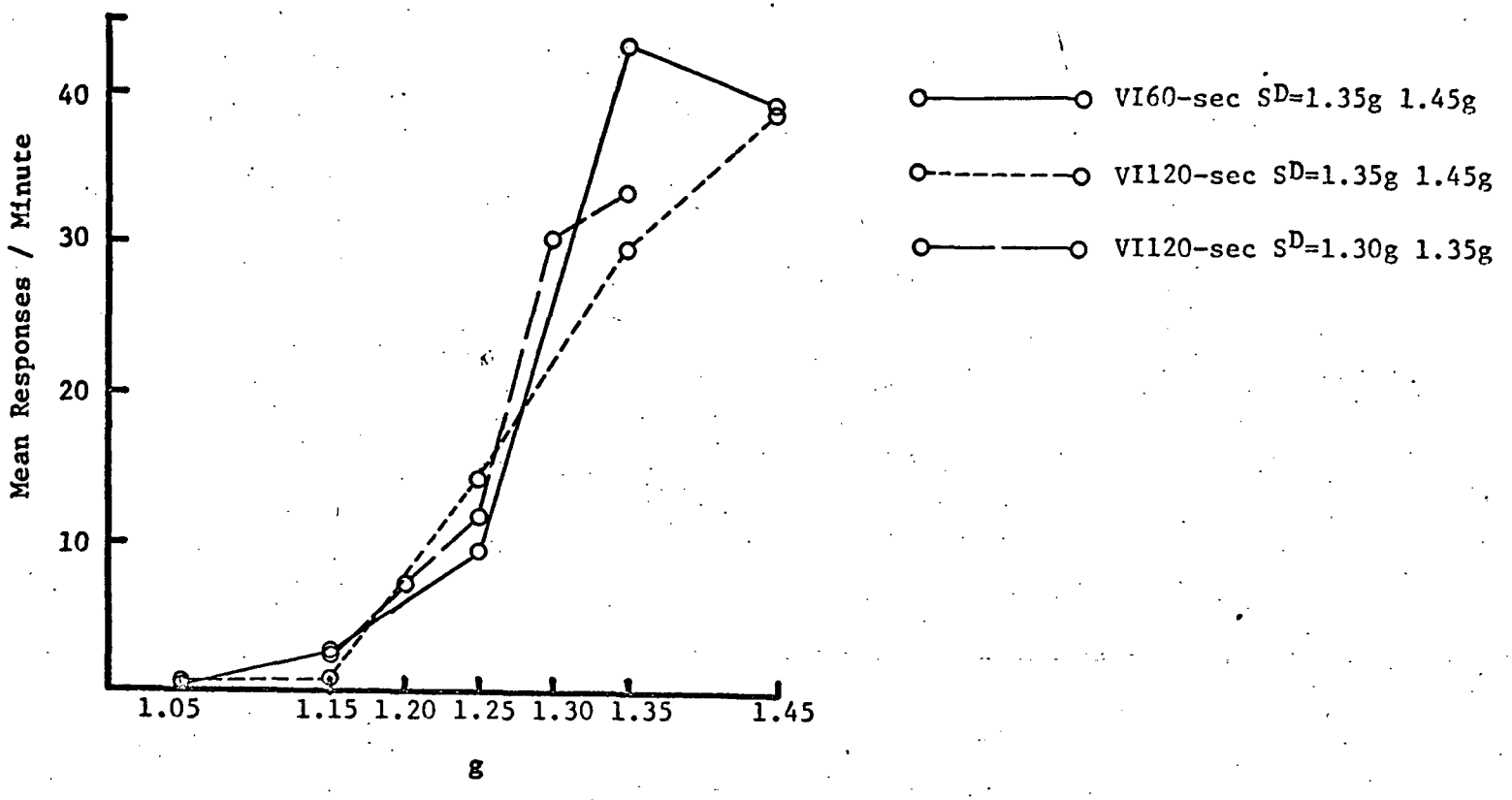

Fig. 3 Mean rate of responding as a function of g-level for M-11 following discrimination training within the range 1.05g-1.45g. Points connected by solid lines represent responding with S^D at 1.35g and 1.45g, and S^Δ at 1.05g, 1.15g, and 1.25g under the variable interval 60-sec schedule of reinforcement. Points connected by short broken lines represent responding with S^D at 1.35g and 1.45g, and S^Δ at 1.05g, 1.15g, and 1.25g under the variable interval 120-sec schedule of reinforcement. Points connected by long broken lines represent responding with S^D at 1.30g and 1.35g, and S^Δ at 1.15g, 1.20g, and 1.25g under the variable interval 120-sec schedule of reinforcement. In all cases points represent the mean response rate for the last three days under the particular schedule and g-levels.

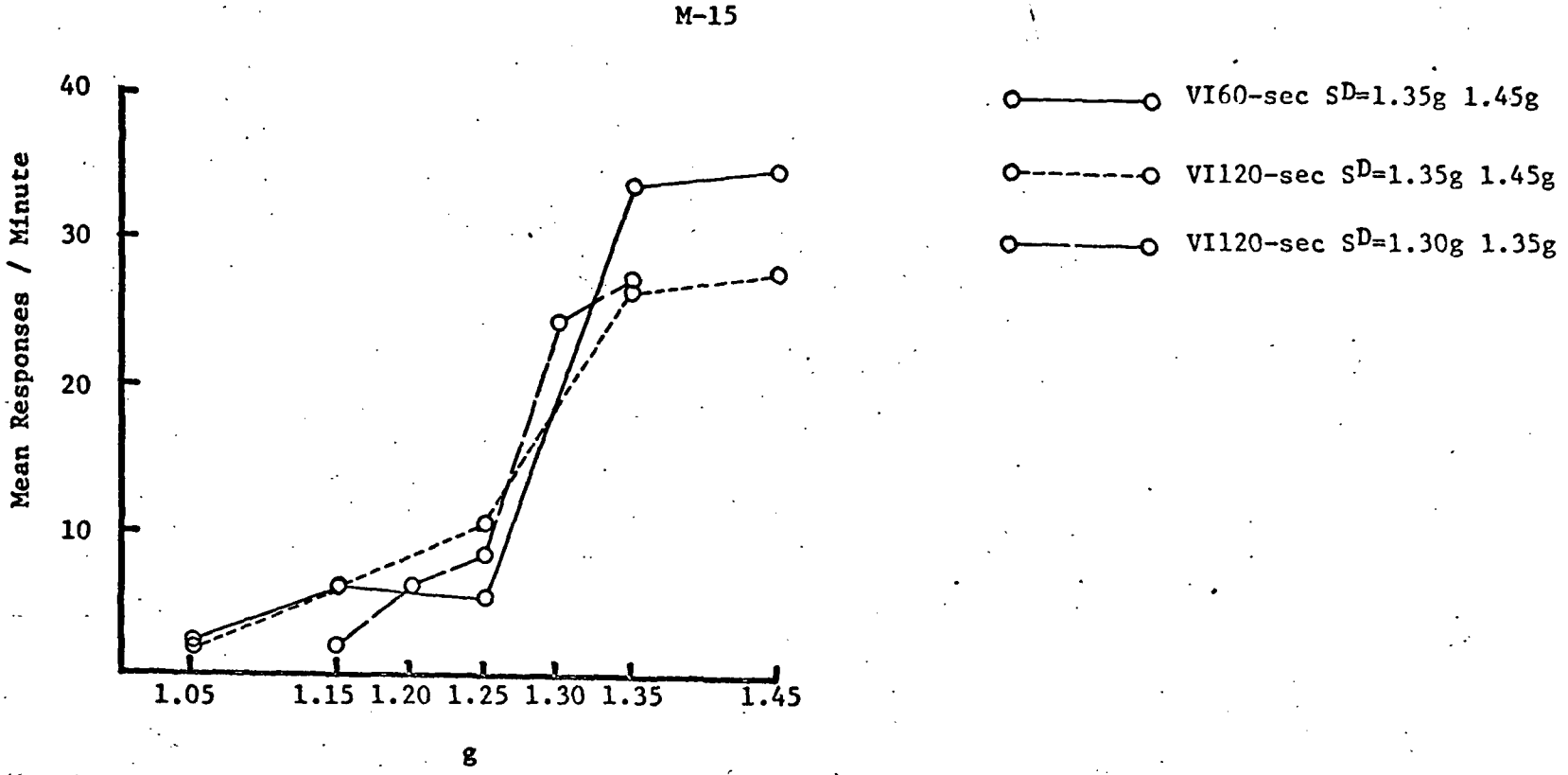

Fig. 4 Mean rate of responding as a function of g-level for M-15 following discrimination training within the range 1.05g-1.45g. Points connected by solid lines represent responding with S^D at 1.35g and 1.45g, and S^Δ at 1.05g, 1.15g, and 1.25g under the variable interval 60-sec schedule of reinforcement. Points connected by short broken lines represent responding with S^D at 1.35g and 1.45g, and S^Δ at 1.05g, 1.15g, and 1.25g under the variable interval 120-sec schedule of reinforcement. Points connected by long broken lines represent responding with S^D at 1.30g and 1.35g, and S^Δ at 1.15g, 1.20g, and 1.25g under the variable interval 120-sec schedule of reinforcement. In all cases points represent the mean response rate for the last three days under the particular schedule and g-levels.

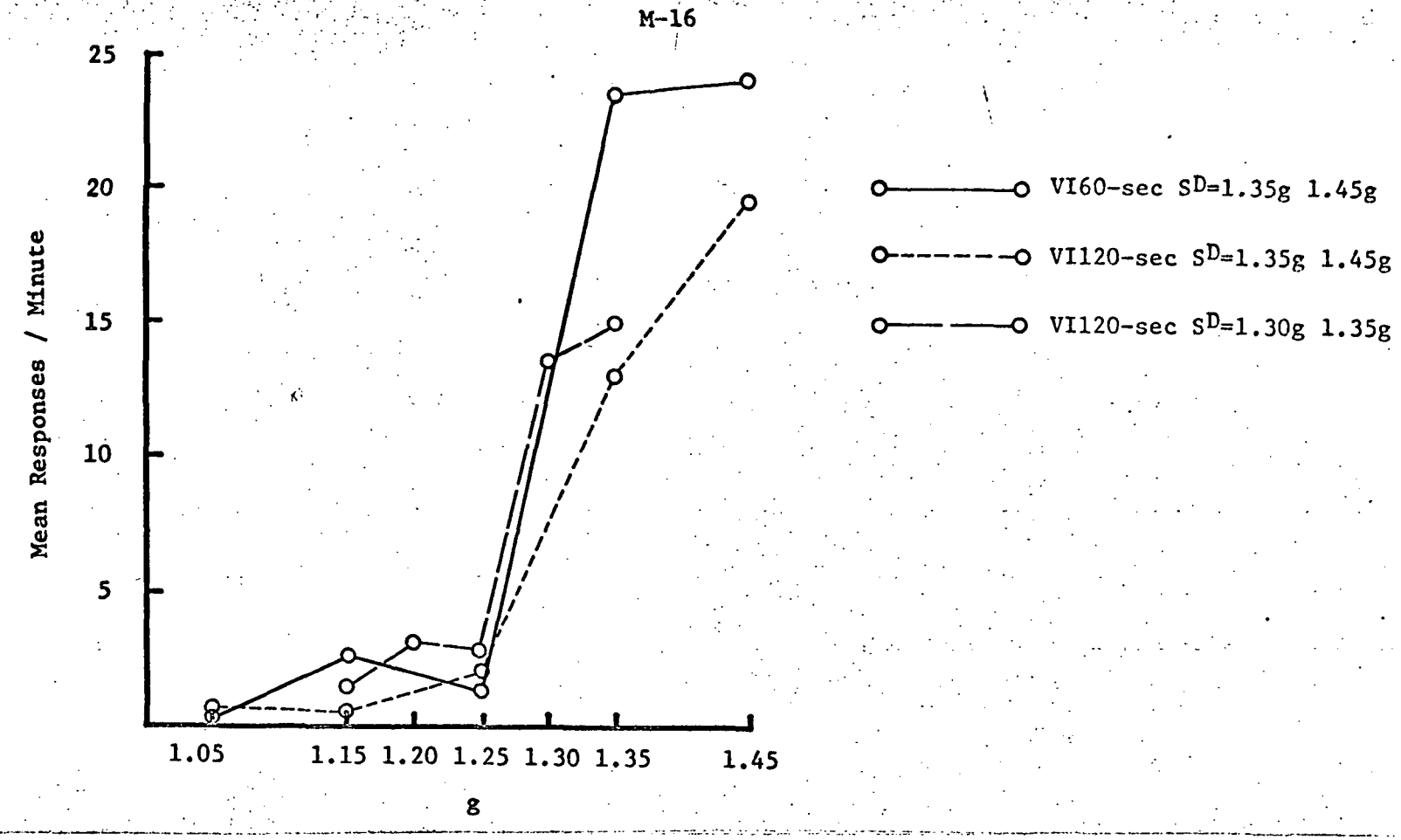

Fig. 5 Mean rate of responding as a function of g-level for M-16 following discrimination training within the range 1.05g-1.45g. Points connected by solid lines represent responding with S^D at 1.35g and 1.45g, and S^Δ at 1.05g, 1.15g, and 1.25g under the variable interval 60-sec schedule of reinforcement. Points connected by short broken lines represent responding with S^D at 1.35g and 1.45g, and S^Δ at 1.05g, 1.15g, and 1.25g under the variable interval 120-sec schedule of reinforcement. Points connected by long broken lines represent responding with S^D at 1.30g and 1.35g, and S^Δ at 1.15g, 1.20g, and 1.25g under the variable interval 120-sec schedule of reinforcement. In all cases points represent the mean response rate for the last three days under the particular schedule and g-levels.

After the data in Figs. 3, 4, and 5 had been obtained a higher set of g-levels was selected and discrimination training was repeated. Within the new range of g-levels S^D was at 1.55g and 1.60g, and S^Δ was at 1.40g, 1.45g, and 1.50g. The schedule of reinforcement associated with S^D remained variable interval 120sec. Under the new conditions, then, the lowest S^Δ g-level was higher than both of the previous S^D g-levels. In order to facilitate the new discrimination a tone was present during the new S^D g-levels for two sessions. Subjects were exposed to this range of g-levels for 10 sessions. Figures 6, 7, and 8 show rate of responding as a function of g-level for all three subjects following discrimination training at the two different locations within the range 1.15g-1.60g. The function appearing on the left in each figure shows responding with S^D at 1.30g and 1.35g, and S^Δ at 1.15g, 1.20g, and 1.25g. The function appearing on the right in each figure shows responding with S^D at 1.55g and 1.60g, and S^Δ at 1.40g, 1.45g, and 1.50g. (The function with S^D at 1.30g and 1.35g is the same as that in the earlier figure for each subject showing response rate as a function of g-level at the lower end of the g-level continuum only.) Figures 6, 7, and 8 show that for each subject the absolute rate of responding during S^D was lower with S^D at 1.55g and 1.60g than at 1.30g and 1.35g. In addition, for M-11 and M-16 the relative decrement in responding was the same at both 1.55g and 1.60g as compared with responding at 1.30g and 1.35g. This suggests that the discriminability of g-differences between 1.30g and 1.35g is the same as that between 1.55g and 1.60g although the absolute rate of responding is higher at the lower g-levels.

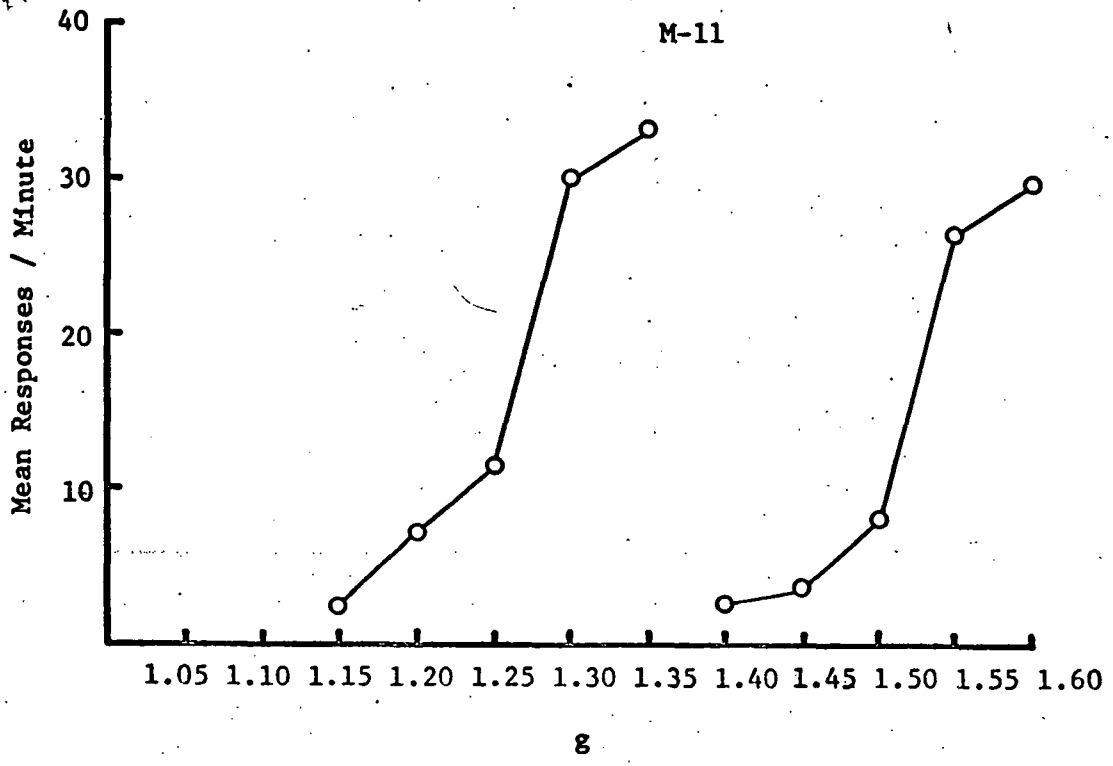

Fig. 6 Mean rate of responding as a function of g-level for M-11 following discrimination training at two different locations within the range 1.15g-1.60g. Under one set of g-levels S^D was at 1.30g and 1.35g, and S^Δ was at 1.15g, 1.20g, and 1.25g. Under the other set of g-levels S^D was at 1.55g and 1.60g, and S^Δ was at 1.40g, 1.45g, and 1.50g. Under both conditions the schedule of reinforcement associated with S^D was variable interval 120-sec. Points represent the mean response rate for the last three days under the particular range of g-levels.

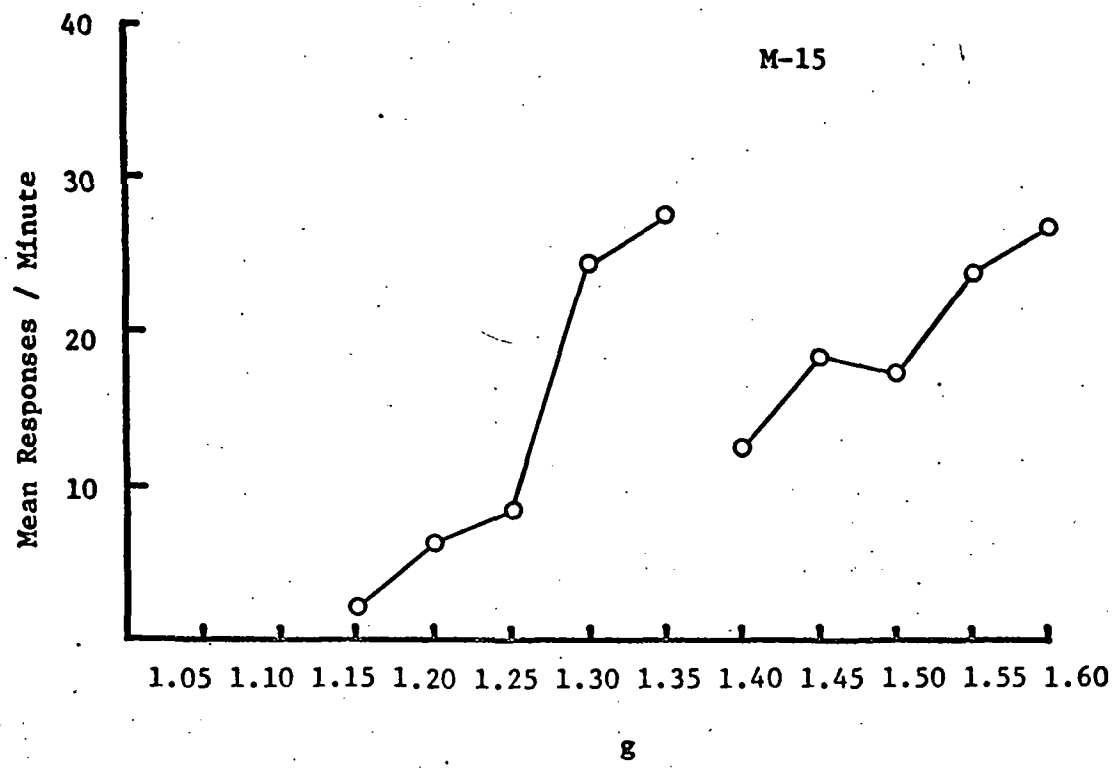

Fig. 7 Mean rate of responding as a function of g-level for M-15 following discrimination training at two different locations within the range 1.15g-1.60g. Under one set of g-levels S^D was at 1.30g and 1.35g, and S^Δ was at 1.15g, 1.20g, and 1.25g. Under the other set of g-levels S^D was at 1.55g and 1.60g, and S^Δ was at 1.40g, 1.45g, and 1.50g. Under both conditions the schedule of reinforcement associated with S^D was variable interval 120-sec. Points represent the mean response rate for the last three days under the particular range of g-levels.

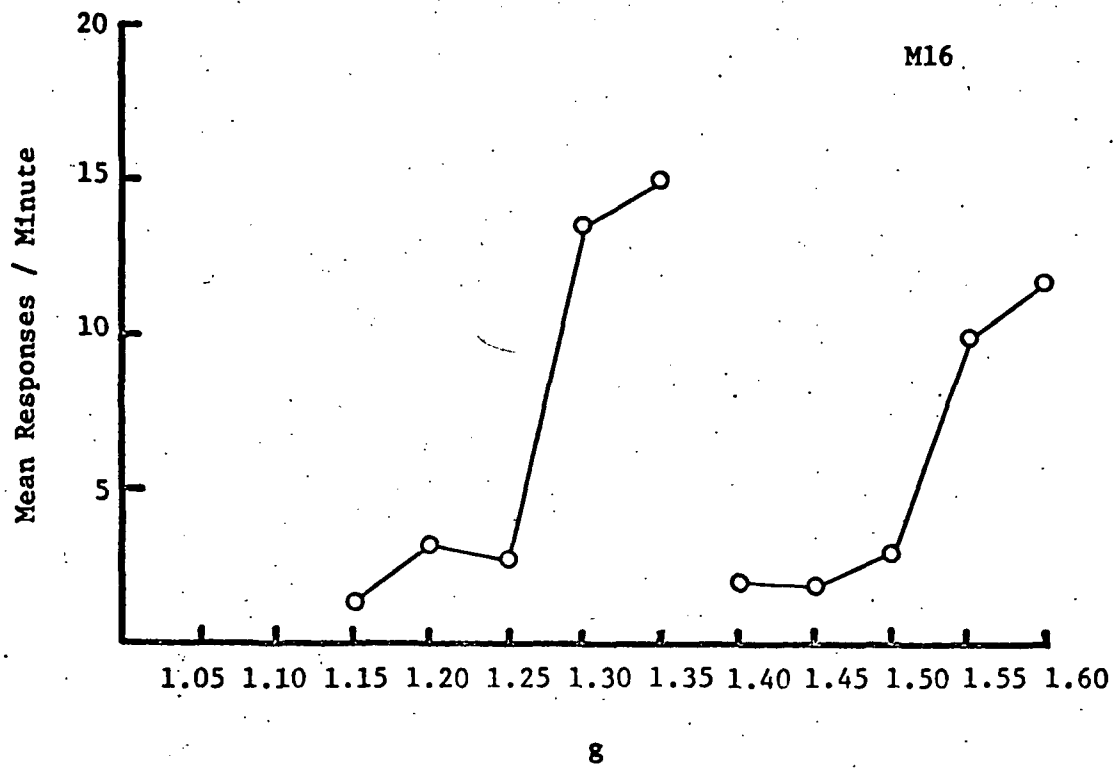

Fig. 8 Mean rate of responding as a function of g-level for M-16 following discrimination training at two different locations within the range 1.15g-1.60g. Under one set of g-levels S^D was at 1.30g and 1.35g, and S^Δ was at 1.15g, 1.20g, and 1.25g. Under the other set of g-levels S^D was at 1.55g and 1.60g, and S^Δ was at 1.40g, 1.45g, and 1.50g. Under both conditions the schedule of reinforcement associated with S^D was variable interval 120-sec. Points represent the mean response rate for the last three days under the particular range of g-levels.

In summary, work accomplished during the present report period has been directed toward obtaining data on response rate as a function of g-level within the range 1.05g-2.95g prior to discrimination training, and within the range 1.05g-1.60g under successive discrimination training. In addition, some preliminary attention was directed toward possible effects of schedule and procedural variables on the relationship between responding and g-level.

4. WORK TO BE ACCOMPLISHED DURING THE NEXT REPORT PERIOD

Investigation of the relations between the discriminability of g-differences and location along the g-continuum will be continued. This will be accomplished by the continuation of successive discriminations at different sets of g-levels in ascending order of magnitude up to a set of g-levels bounded by 2.95g. In each of these discriminations S^D will always be the higher two g-levels. After these data are obtained successive discrimination training will be undertaken with different sets of g-levels in descending order of magnitude. Under this sequence of g-levels, S^D will always be the lower two g-levels.

At the completion of the above manipulations procedures will be developed to determine thresholds of transient accelerations which occur during changes in angular velocity and rotation radius.