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DIFFERENTIATION OF A PRECISE TIMING RESPONSE[1]

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Humans, monkeys, and rats were trained by a process of successive differentiations to press a bar for at least 1.00 sec but for no longer than 1.27 sec. Initially, animals were reinforced for all responses, then a minimum duration of response was gradually differentiated, below which no responses were reinforced. Finally, a maximum duration of response was differentiated above which no responses were reinforced. The duration of response in all three species approximated the minimum duration of response necessary for reinforcement. As the duration of response necessary for reinforcement increased, so did the mean duration of response in the three species. As the maximum allowable duration decreased, further compression of the mean occurred. The fact that the acquisition of the differentiation was approximately the same in all three species is a further indication of the control reinforcement exerts on operant responding.

This experiment was an attempt to study the acquisition of the differentiation of a precise timing response of the type reported by Stelter, Barnes, and Homme (1959). Under such a schedule, all responses are reinforced during the initial training. As training progresses, the subjects are required to press the bar for increasing durations of time, until a predetermined duration (minimum hold) of the bar-press has been established, above which responses must fall to be reinforced. Once a minimum hold has been established, upper limits of time (maximum hold) are set below which a response must fall in order to be reinforced. The maximum hold is gradually decreased, until a precisely defined response with both upper and lower limits has been differentiated.

The present study traced the successive differentiation of a precise timing response in three different species and compared their asymptotic performances.

METHOD

Subjects

Three naive, 120-day-old, male rats of the Sprague-Dawley strain; three naive, adolescent, male rhesus monkeys; five undergraduate college students (two female and three male); and one high school student (male) were used.

Apparatus

The recording and programming equipment has been described in detail elsewhere (McMillan, Cochran, and Patton, 1963). Since a 1.5-sec period was needed to reset the timing relays after a bar press was completed, it was necessary to employ a discriminative stimulus. A small discriminative stimulus light was turned on (S^D) signaling the beginning of a trial. Closure of the bar contacts extinguished the S^D light and activated the timing circuitry for the duration of the bar press. Release of the bar initiated the 1.5-sec reset period (S^Δ) during which the S^D light remained out. Any responses made during the S^Δ period were tabulated but not timed. At the end of the S^Δ period, the S^D light signaled the beginning of another trial. Bar presses in the presence of the S^D light were reinforced, if the presses were of the proper duration. Bar presses in the presence of S^Δ were never reinforced, regardless of their duration.

All of the rats and two of the monkeys were tested in modified Skinner boxes. Water reinforcements were delivered through the

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floor of the rat test chamber in a .2 cc cup. In the monkey test chamber, 45 mg Noyes food pellets were delivered into a food cup from a Foringer #1284 pellet feeder mounted outside the test chamber. A third monkey (M193) was tested in a Foringer primate chair. This monkey remained in the primate chair for the entire study. When tested, M193 was wheeled to the test room. In the test room a second primate chair (operandum chair), partially dismantled, was weighted to the floor. On this operandum chair were mounted the lever, food cup, S^D light, and pellet feeder. The chair containing the monkey was clamped to the operandum chair. The humans were seated in office chairs in front of the same operandum chair used for monkey testing. They pressed the same bar as did the monkey and they were informed that their responses were of the reinforced duration by the sound of the empty Foringer pellet feeder, which normally held the monkey food pellets.

The Skinner boxes for both species and the operandum chair were all located in the same room. Programming was accomplished from a separate room by means of permanent ducts between the rooms. When rats or monkeys were being tested in Skinner boxes, the room lights were off (both Skinner boxes had their own sources of illumination). When the monkey in the primate chair, or the humans, were being tested, room lights were on. White noise was present in the room at all times.

The bars were equally weighted for all three species. The bar contacts could be closed by a 20 g force.

Procedure

The humans who were to be used for repeated test sessions were told that they would receive $30 for a maximum of 30 test sessions of 45 min each. They were further informed that if they worked hard and did well they could finish the task in less than 30 sessions and still receive the same amount of money. The other three humans were volunteers for a single 45-min session. The monkeys and rats were 23 hr food (monkeys) or water deprived (rats) and were reinforced with food pellets (monkeys) or water (rats).

The rats, the monkeys, and the humans to be used for more than one test session were reinforced for S^D responses of at least .01 sec in duration during the initial test session. This schedule was for all practical purposes a continuous reinforcement schedule for S^D responses, since the undifferentiated duration of the bar press was longer than this in all three species.

The minimum hold sequence was increased as follows: .01, .02, .05, .10, .20, .30, .40, .50, .60, .70, .80, .90, and 1.00 sec. The criterion for shifting the minimum hold upward was that 50% of the S^D responses made in a single test session fall within the reinforced interval (longer than the minimum hold and shorter than the maximum hold). Once the final minimum hold of 1.0 sec had been established, the maximum hold was decreased from infinity as follows: 4.07, 3.07, 2.07, 1.57, 1.37, and 1.27 sec. At the final interval the subject was reinforced for responses between 1.00 sec and 1.27 sec.

Care was taken in the instructions given to the humans not to give any hint that the timing of the bar press was the response dimension relevant for reinforcement, since this verbal information would give them an unfair advantage over the other two species. Humans received the following instructions:

> "We are attempting to measure certain aspects of human performance and will need the help of several people. There is no discomfort, pain, or stress involved at any stage of these measurements. When these tests have been completed we will discuss the results with you. However, until the entire series is completed, no information as to your progress can be given. The task will be the manipulation of this lever. When the lever has been manipulated in the correct manner you will be informed by the sound of this mechanism. Wait here and I will sound the mechanism" (at this point the experimenter left the room and sounded a Foringer pellet feeder from the equipment room). (After returning) "Here is a chair if you prefer to sit while manipulating the lever. If you are wearing a watch, would you please leave it with me during the test period, as we prefer to inform you of the end of each session, rather than having you use your watch for this purpose. I will be across the hall recording the number of times the lever has been manipulated correctly and I will return at the end of 45 min. I am leaving now.

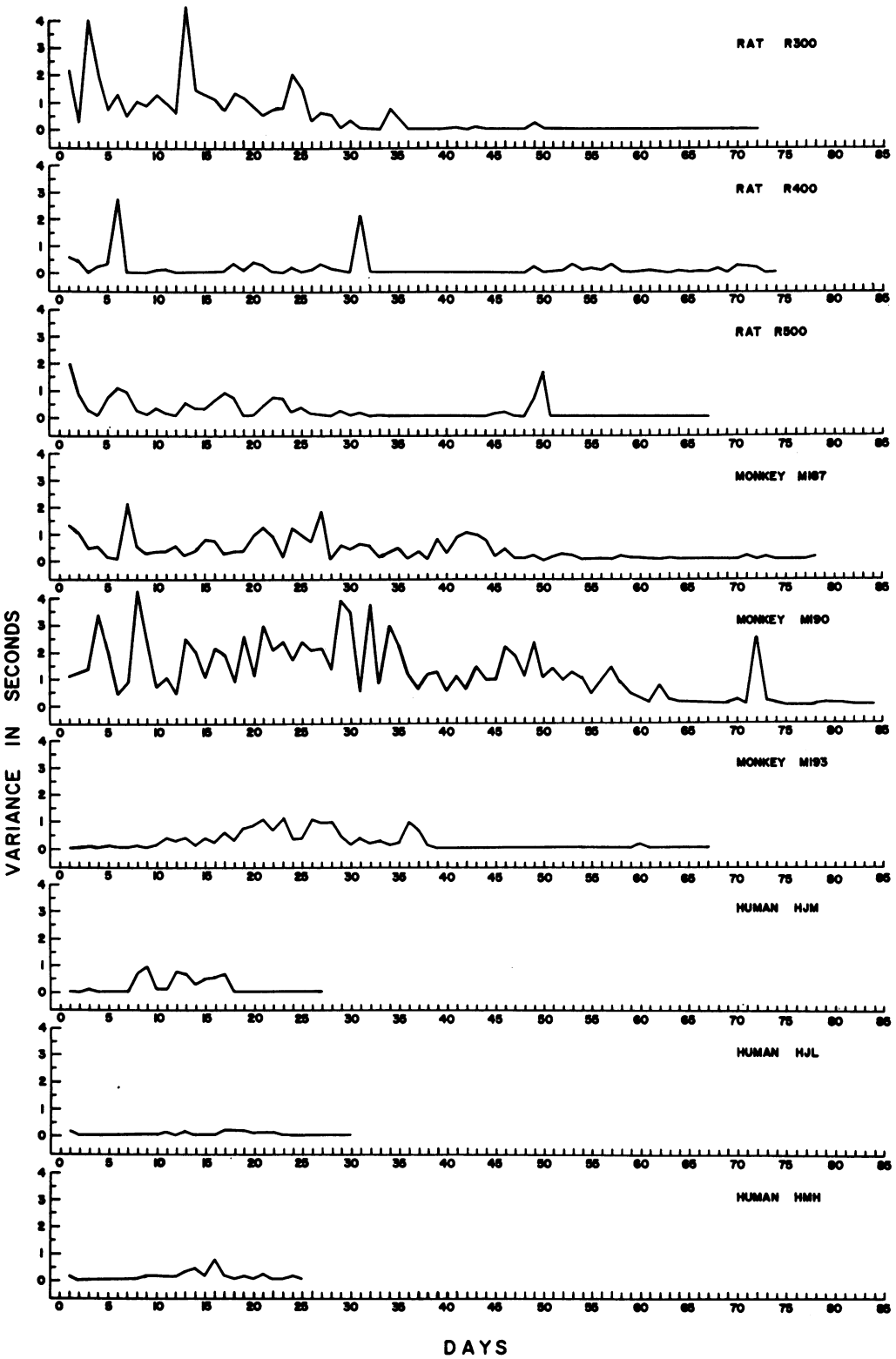

Fig. 1. Variance of responses duration for rat, monkey, and man.

Please do not smoke during the test session. You may begin immediately."

Aside from these verbal instructions, the procedure followed with the humans was exactly the same as that which was followed with the animals.

It was of interest to compare the performance of the humans who had undergone differentiation training with humans who had been given verbal instructions to hold the bar down for 1.00 to 1.27 sec. For this comparison, the three volunteers reported for a single session and were instructed to hold the bar down for 1.00 to 1.27 sec. The data from the volunteers were compared with the data of the differentiation subjects on their first day of testing at the final interval. The first day of testing at the final interval was chosen so that both groups of humans would have equal amounts of practice on the interval where comparisons were to be made.

RESULTS

In Fig. 1 the variance of response duration for the three species has been plotted. Each point on this graph represents the variance in seconds for each animal on each day of testing. The three upper curves are for rats, the three middle curves are for monkeys, and the three bottom curves are for humans.

It can be seen that there is considerable overlap among the variances for the three species. For example, the variance curves for rats R-400 and R-500, humans HMH and HJM, and monkey M-193 are all very similar, as are the variances of rat R-300 and monkey M-187. Moreover, when repeated measurements are taken at the final interval the variance becomes very low in all three species.

Figure 2 presents the daily means of the response durations for the rats. The shaded area of the graph represents the reinforcement interval. The arrows in Fig. 2 represent the point at which each subject reached a level of at least 50% reinforcement of S^D responses made in one day at the final reinforcement interval. For two of the three rats, response duration increases as the minimum hold increases, staying for the most part at a value just above the minimum hold necessary for reinforcement. The same trend is suggested in the third rat, although the day-to-day variability is of such magnitude in this animal so as to partially obscure the trend.

It can also be seen from Fig. 2 that on the first two to four days when the minimum hold requirement was very limited, there was a tendency for the mean response duration to decrease. During this time the animal was, for all practical purposes, on continuous reinforcement, since the "natural" duration of the response was considerably above the minimum hold. This finding agrees with the report of Notterman (1959) who found a decrease in response duration with continued testing on a CRF schedule, and with similar findings for a spatial response dimension by Antonitis (1954).

Figure 3 presents the daily response duration means for the monkeys. Their records are also marked by a mean duration of response which follows the minimum limited hold interval during shaping, staying for the most part a few tenths of a second above it. Again one animal is extremely variable from one day to the next, however, the upward trend of the mean is not obscured by this variability.

The human data are shown in Fig. 4. Again the mean duration of the bar press tends to fall just above the minimum hold duration during the shaping phase of the study.

All three species were quite capable of earning reinforcement on more than 50% of their S^D response at the final interval. The day on which they obtained this level of proficiency is represented in the Figures by the arrow. Since the human reached this point so much more quickly than the other two species, it was desirable to continue testing all three species to see if they reached similar asymptotic performance levels. All the monkeys and one human continued to decrease response variance with further testing, although the mean changed further in only one monkey. All three species increased the percentage of reinforced S^D responses with continued practice at the final interval with rats, monkeys, and humans averaging 66%, 70%, and 80% reinforcement respectively, on the final day of testing.

In comparing Fig. 2, 3, and 4 there is only one notable difference. The rats tend to hover closer to the minimum hold (and often fall below it) than do the monkeys and the humans.

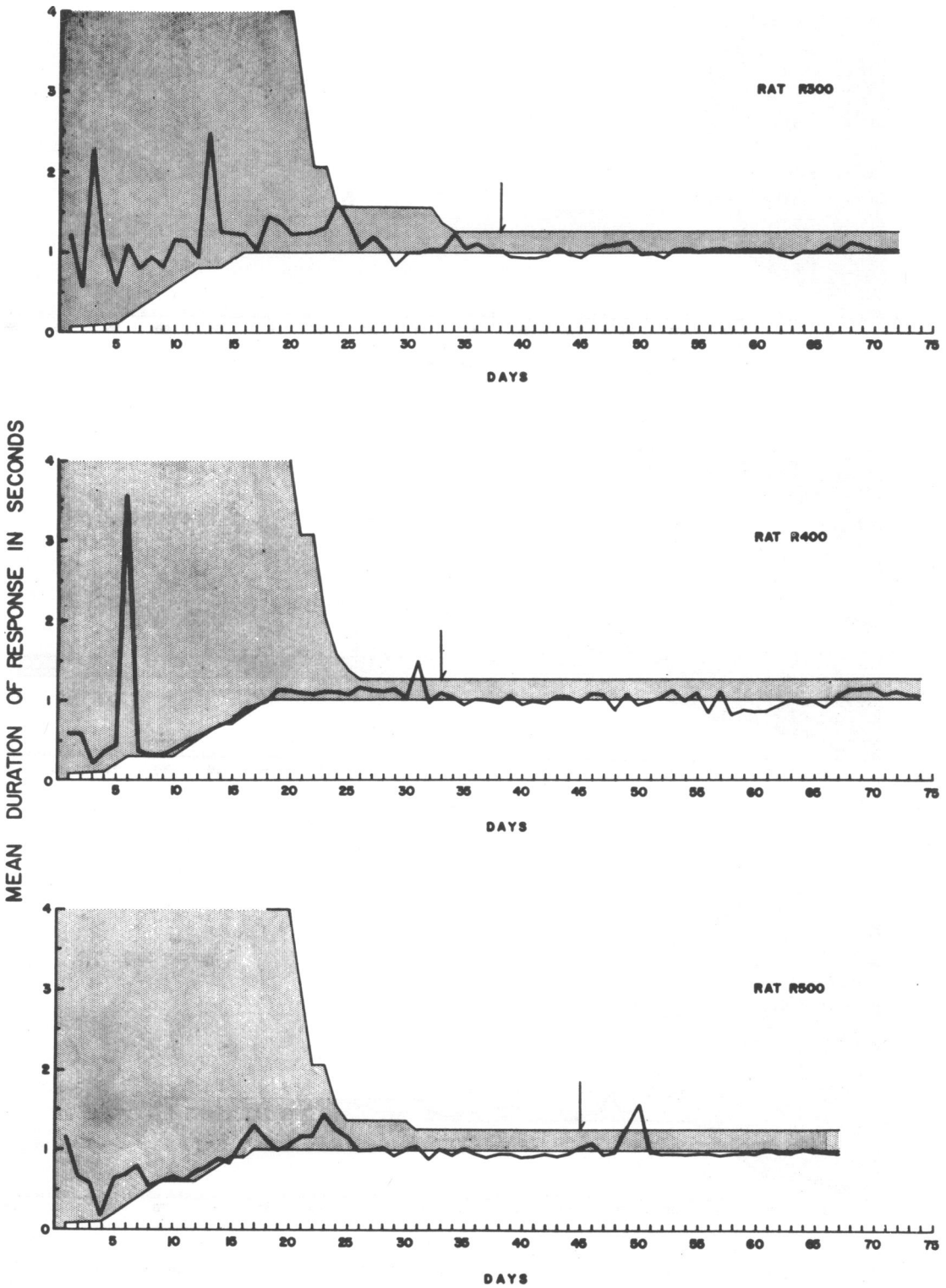

Fig. 2. Mean duration of response in the rat. The shaded area represents the reinforcement interval. The arrow represents the point at which the subject first obtained 50% reinforcement of S^D responses at the final interval.

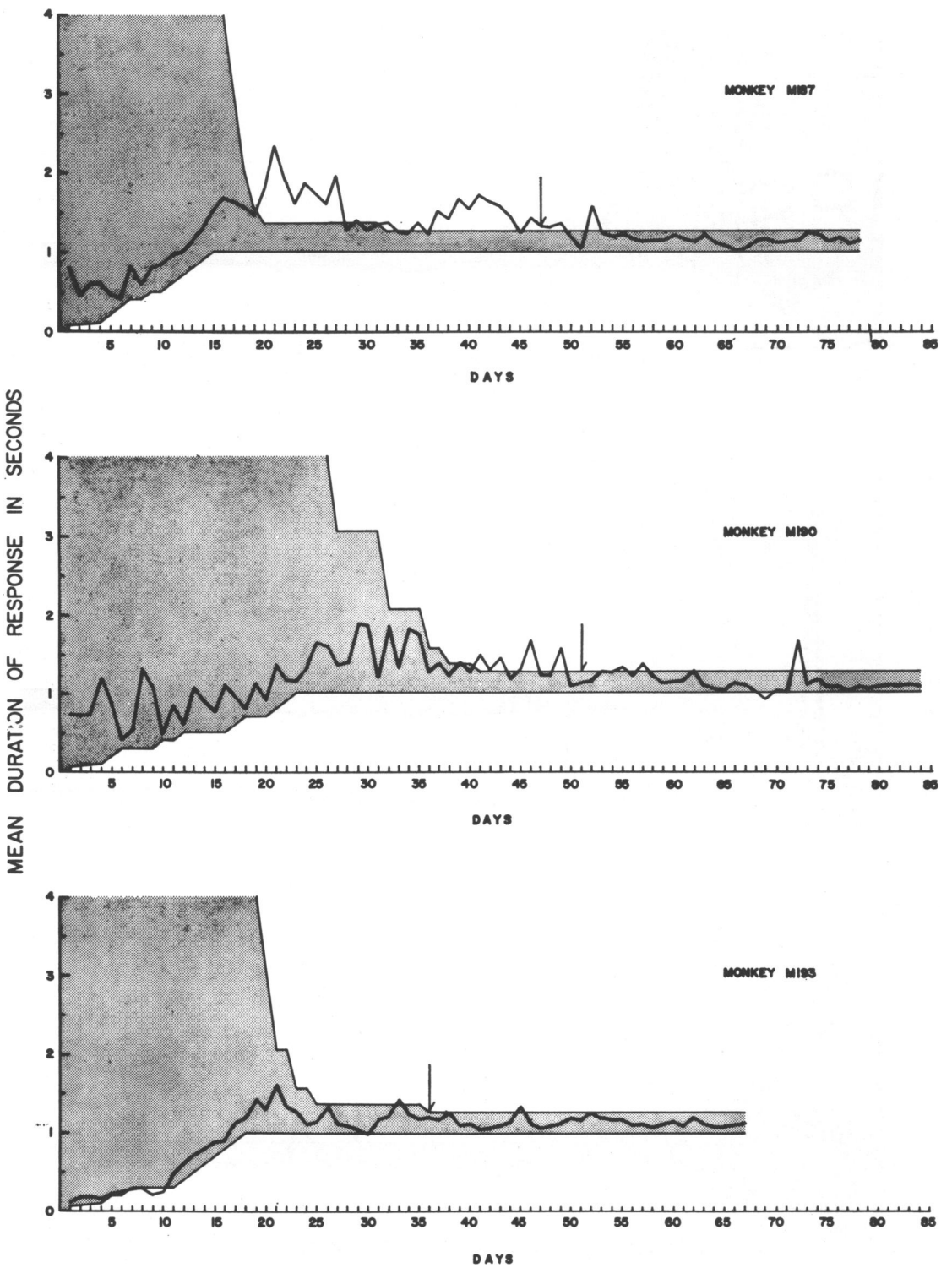

Fig. 3. Mean duration of response in the monkey. The shaded area represents the reinforcement interval. The arrow represents the point at which the subject first obtained 50% reinforcement of S^D responses at the final interval. On day 72 there was an equipment failure during the run of monkey M-190. No reinforcements were delivered that session.

It was of interest to compare the performance of the humans who had undergone differentiation training with the humans who had received verbal instructions to attempt to hold the bar down for 1.00 to 1.27 sec. Their data were compared with the data of the other humans on the first day of testing on the final interval. A summary of the results is presented in Table 1. The subjects that had received differentiation training attained a higher percentage of reinforcement than the subjects who had not had this training. However, the mean and variance of response duration were about the same in both groups.

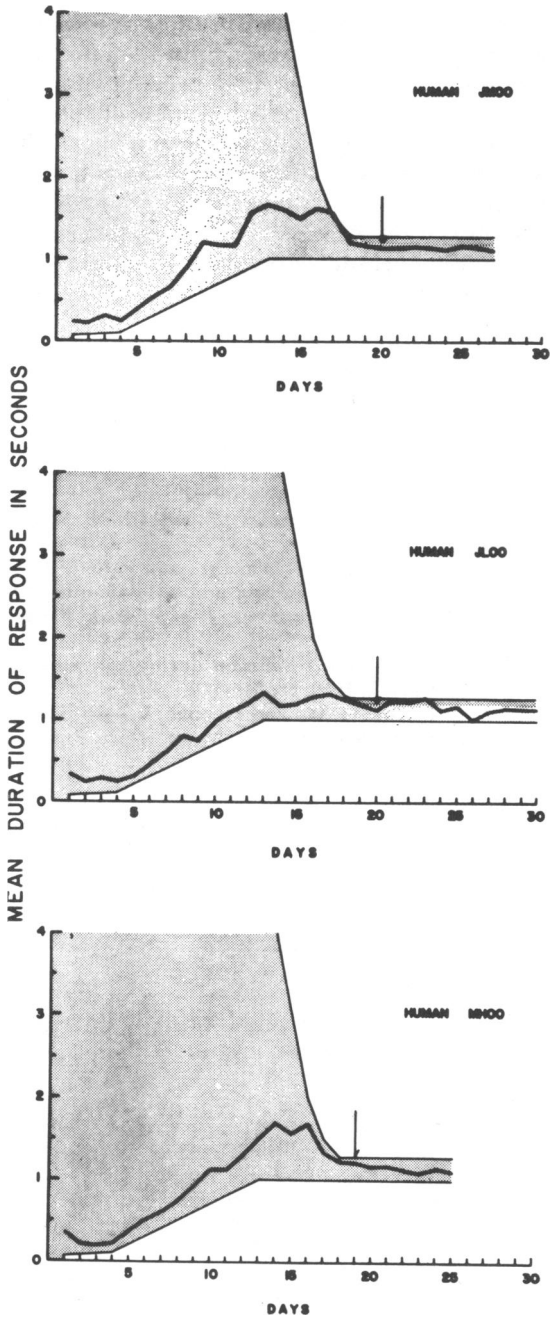

Fig. 4. Mean duration of response in the human. The shaded area represents the reinforcement interval. The arrow represents the point at which the subject first obtained 50% reinforcement of S^D responses at the final interval. The subject designations JMOO, JLOO, and MHOO are equivalent to the designations HJM, HJL, and HMH in Fig. 1.

Table 1

	Reinforcement Range	*Mean Response Duration Range*	*Response Variance Range*
Differentiated humans	52-70	1.18-1.22	.045-.217
Volunteer humans	31-54	1.14-1.37	.077-.121

DISCUSSION

Herrick (1964) demonstrated a "least effort" tendency in a force differentiation. In Herrick's study the rats pressed the bar with only slightly more force than was necessary for reinforcement. In the present study a similar effect was discovered. All three species pressed the bar for a duration only slightly longer than the minimum duration required for reinforcement. With continued testing at the final interval, the effect was much more striking in rats than it was in the other two species. The reason for the prominence of the "short responding" in the rats may be related to Herrick's suggestion that the least effort effect in force differentiation is a function of the absolute amount of effort the task requires. In the present experiment, the effort required to maintain 20 g of force on the bar for more than 1 sec may have been a great deal more for the rat than it was for the other two species. Thus the conditions of the experiment may have favored the larger species, making the effect of the upper limits of response duration less important in the rats.

It is possible that similar data might have been generated if no hold durations had been imposed on the bar press. All animals might have exhibited mean response durations of

about 1 sec without successive differentiation training. Some pilot data are available from a monkey which indicate that this possibility is not likely. This animal was tested for 18 days. During this time this monkey was reinforced for all S^D responses, regardless of their duration. The mean duration of response in this animal dropped slightly (from .180 sec to .159 sec) over the 18 days of testing. These data can be contrasted with the data of monkey M193 which began testing with a response duration magnitude approximating that of the pilot animal. After 18 days of testing, monkey M-193 exhibited a mean response duration of more than 1 sec, a figure much higher than the mean of the pilot animal. These data suggest that the reinforcement conditions of the experiment brought about the changes in response duration.

An interesting discovery was the fact that response duration variance did not always correlate well with the percentage of reinforcement. It would be expected that the less variable the response durations were, the higher would be the percentage of reinforcement. However, although there was considerable overlap in variance between humans and rats, the humans attained a higher percentage of reinforcement. It was also found that although the humans who had received differentiation training had response duration variances roughly equal to those who had not had the training, the trained humans had a higher percentage of reinforcement.

The most important indication from the experiment was that the duration of response in three different species approximates the minimum duration of hold necessary for reinforcement during the acquisition of the differentiation of a precise timing response. The fact that the acquisition curve follows a similar function in all three species is a further demonstration of the control reinforcement exerts on operant responding in a wide variety of species.

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