

## REACTION TIME AS A FUNCTION OF STIMULUS INTENSITY FOR THE MONKEY<sup>1</sup>

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Monkeys were trained to release a telegraph key in response to a visual or auditory stimulus. The latency of the key release response was measured for different stimulus intensities. In general, the relation between latency and intensity is inverse and exponential with greater variability of latency at the lower intensities. Some preliminary data involving differential reinforcement of short latencies are presented.

The design of the classical experiment for measuring simple reaction time was adapted for use with operant conditioning procedures. In the first of two experiments a buzzer ("ready signal") served as the discriminative stimulus for prolonged depression of a telegraph key. After a variable interval of time (foreperiod) the key press response was followed by a light. Release of the key in the presence of both buzzer and light was followed immediately by food reinforcement. The latency of the key release response was the primary dependent variable. In the second experiment, the "ready signal" was a light and the stimulus for key release was a 1000 cps tone.

An earlier paper (Stebbins and Lanson, 1961) described the training procedures for obtaining stable latencies for the key release response with rats. Later work has shown that response latency varies inversely with both frequency and amount of reinforcement for rats (Stebbins and Lanson, 1962; Stebbins, 1962), and that for monkeys trained in a visual discrimination, latencies to the reinforced stimulus are considerably shorter and less variable than those to the unreinforced stimulus (Stebbins and Reynolds, 1964).

### METHOD

For the first experiment, two monkeys (Nemestrina Macaque), both with previous training in a visual form discrimination ex-

periment (Stebbins and Reynolds, 1964), served as subjects. They were restrained in chairs within a sound-deadened, light-tight room. They earned their entire daily food ration (120, 1 g Ciba whole diet banana pellets) as reinforcement during each experimental session. Initially, reinforcement followed a key press-key release sequence in the presence of the buzzer. After simple conditioning, onset of the buzzer was made contingent upon a period of 30 sec without a response on the key. In addition, Ss were then required to hold the key down during the buzzer until the light appeared. Key release in the presence of buzzer and light was reinforced. The time interval between key press and light onset was continuously variable between .05 sec and 5 sec. If release of the key occurred before light onset, the buzzer was turned off and the 30-sec response-free interval requirement was again in effect.

The light source was a 3-w 115 v dc neon bulb mounted in a black box behind a diffusing glass. The light spot was 1 cm in diameter. The intensity of the light 6 in. from the box (at S's eye) was approximately 20 foot candles. A system of relays and timers outside the sound chamber programmed all of the experimental events automatically. Responses and reinforcements were recorded on counters; response latencies were recorded from a Standard Electric .01 sec timer.

When Ss' behavior had stabilized following training, the intensity of the light was varied (from the training intensity of 20 foot candles) by the use of neutral density filters in steps of one log unit over a range of five log units. For one monkey (H), the range was shortened to 4.5 log units; the lowest intensity was ap-

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parently below threshold for this *S*. For four sessions, 20 trials per session were presented at each of six intensities. The order of presentation of intensity was different for each session. Subjects were dark-adapted for 30 min prior to each session.

Following the first experiment, monkey *F* was trained to depress the key to a light and to release the key to a 1000 cps tone. White noise was used in the sound chamber to mask apparatus noise. Again, when *S*'s behavior became stable, the intensity of the tone was varied with a microvolter attenuator in steps of .6 log unit over a range of four log units. For four sessions, 20 trials per session were presented at each of six intensities, and the order of presentation of intensity was varied as before. No accurate measure of absolute intensity was obtained.

## RESULTS AND DISCUSSION

An example of the discriminative stability obtained after training is illustrated in a typical cumulative response curve for one *S* in Fig. 1. One error, a premature release response in the presence of the buzzer, occurred following the eighth reinforcement.

The latency data from the first experiment for 80 trials at each intensity are presented for monkeys *H* and *F* in the segments labelled "visual" in Fig. 2. Medians and quartile deviations have been plotted. For the three lowest intensities the relation between latency and intensity is inverse and exponential. At the three highest intensities, the functions are almost flat, showing little or no change in latency with further increase in intensity. Variability of latency increases sharply at the

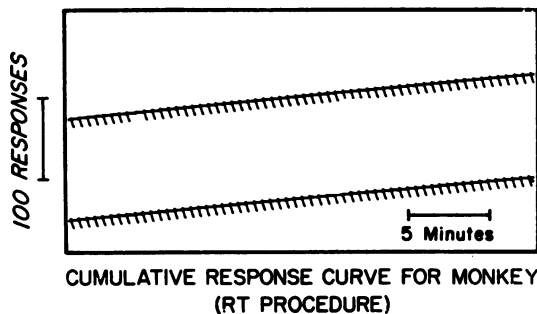


Fig. 1. Cumulative response curve for monkey *F* following training on the RT procedure. Diagonal slash marks indicate reinforcement for the key release response to the light.

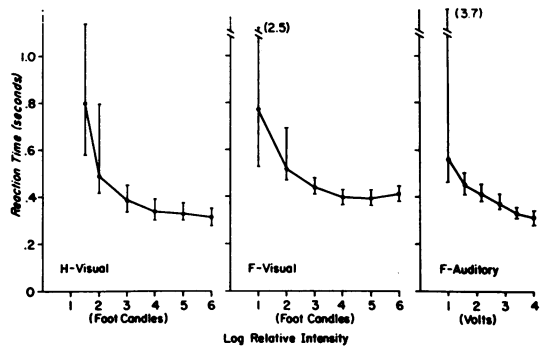


Fig. 2. Reaction time and stimulus intensity. Medians and quartile deviations are shown for each *S*.

lower intensities. The general shape of the functions and the increase in variability at low intensities are similar to Bartlett and Macleod's data for the dark-adapted human eye (Bartlett and Macleod, 1954).

The data from the second experiment for 80 trials are shown in the segment of Fig. 2 labelled "F—Auditory". The exploratory nature of the data and the restricted range of intensities make comparisons with other data tenuous. Close inspection of the auditory function indicates that it resembles an exponential function and is approaching an asymptote at about 300 msec. Romba, Gates and Martin (1963) have reported similar latency data for the monkey with variation in the intensity of a 2000 cps tone. However, shock avoidance was used as a training procedure and the latency of the key press (rather than key release) response was measured. The authors have suggested that a shock avoidance procedure produces shorter latencies than the use of food reinforcement (Martin, Gates and Romba, 1962 p. 16, Romba *et al.*, 1963 p. 5). The results from one *S* in the present experiment have yielded average latencies about 100 msec shorter than those obtained by Romba *et al.*, at the highest tone intensity. They consequently do not support the contention that the use of aversive control necessarily produces a faster response following the onset of an auditory stimulus. The more probable explanation for the shorter latencies obtained in this experiment involves the use of a chaining procedure in which the key press response produces the discriminative stimulus for key release. Thus, the behavior of the *S* immediately before the stimulus for key release, is under precise control which ensures short

latencies and minimal variability of latency for the key release response.

Figure 3 gives an indication of the changes in variability of latency for different stimulus intensities. The figure contains the same data for monkey F previously presented in the form of latency-intensity functions in Fig. 2. The upper half of the figure includes the frequency distributions of latencies for the six tone intensities; the lower half contains the distributions for the different light intensities. The class intervals which include the medians are shaded. The shift in the distributions toward longer latencies at lower stimulus intensities can be clearly seen.

Changing the intensity of the discriminative stimulus for the key release response had no observable effect on the discriminative control established during training at one fixed value of stimulus intensity. Premature release responses never accounted for more than 3% of the total number of responses. Responses in the interval between stimulus presentations rarely occurred (see Fig. 1). In addition, although no formal record was kept, variation in stimulus intensity produced no noticeable change in the latency of the key press response to the buzzer in the first experiment or to the light in the second. Average latencies for this response were on the order of 1 sec.

The method described here for obtaining brief, yet minimally variable latencies for a simple behavioral response to sensory stimulation, has merit as a psychophysical technique for use with non verbal organisms. Latency-

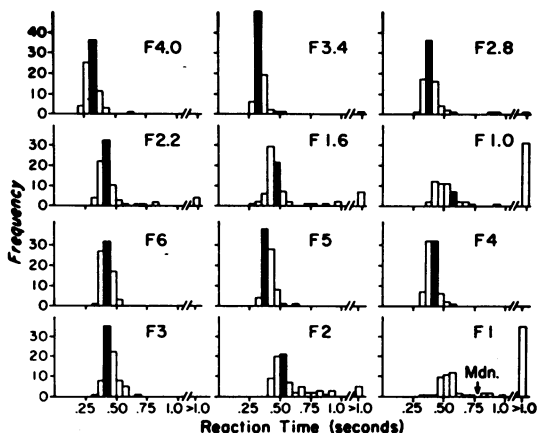


Fig. 3. Frequency distributions of latencies for monkey F for six tone intensities (upper half) and six light intensities (lower half). Class intervals containing medians are shaded.

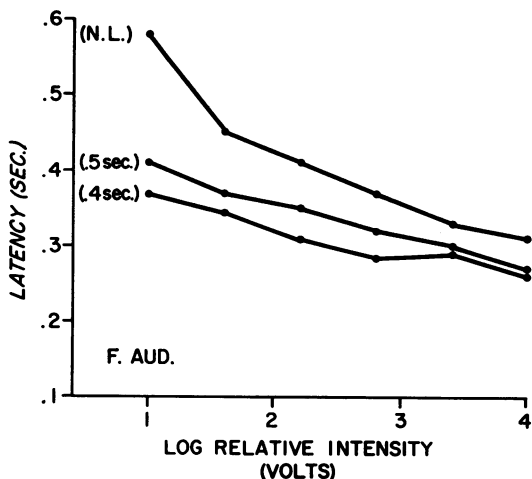


Fig. 4. Auditory latency-intensity functions for monkey F under differential reinforcement procedure. For further explanation see text.

intensity functions are comparable to those obtained with adult humans (Bartlett and Macleod, 1954; Chocholle, 1940; McGill, 1963). Average latencies in the present experiment are 100 to 200 msec longer. However, a recent attempt in our laboratory to selectively reinforce shorter latencies has had some success. Figure 4 shows three auditory latency-intensity functions for monkey F. The uppermost curve (N.L.) was obtained when no limit was placed on the latency of the key-release response to the tone, *i.e.*, all responses were reinforced. The function labelled ".5 sec" was taken from the fifth day of a procedure for which only those release responses occurring within .5 sec of tone onset were reinforced. The tone always remained on until the key was released. The lowest function was obtained on the fifth day following a procedure of reinforcement for responses occurring within .4 sec of tone onset. Coincident with the reduction in average latency with this procedure (see Fig. 4) was a considerable decrease in variability of latency. Some disruption of S's behavior, characterized by increased latencies for key release and increased responding between stimulus presentations, occurred during the continuation of this procedure, and further attempts at differential reinforcement of latency were postponed.

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