Force differentiation in human subjects'

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Abstract

Force of response was differentiated in four human Ss using a quantitative visual feedback procedure. Variations in the force required produced systematic changes in rate of response and in the precision with which the response was made.

Introduction

In a series of experiments with Wistar rats reported elsewhere (Notterman & Mintz, 1965), the proposition is advanced that the ordinary bar press relies to a greater extent than is ordinarily recognized upon proprioceptive and cutaneous feedback for its successful emission. In this sense, the precision with which an organism comes to meet a specific force requirement depends just as much upon cue discrimination as does the occurrence of a response to exteroceptive-stimulus cues (Notterman & Mintz, 1962). If discriminative processes do indeed underly the phenomenon of response differentiation, then the conventional analytic techniques of psychophysics should facilitate their description.

The study reported here extends the earlier work to consideration of a simple, differentiated response emitted by adult human Ss (two males and two females), and attempts to describe their behavior in terms of the well-known Weber ratio.

Method

The apparatus consisted of an operant force measuring system essentially identical to that described in greater detail by Notterman & Mintz (1965). The manipulandum was a strain gauge lever with a 1/2 in diameter horizontal contact surface which each S was instructed to press with his right forefinger. Displacement of the lever was negligible under the range of forces used in the experiment; there were no audible correlates of response emission. A Hewlett-Packard 405 AR Digital Voltmeter was placed at eye level approximately 36 in distant from the S. The voltmeter provided an arabic numeral readout of response peak force in gm to unit values. A panel containing five white christmas tree lamps in horizontal array was placed on top of the voltmeter. Immediately above each lamp was a printed label reading "25," "50," "100," "150," and "200," from left to right. The test chamber was sound-insulated.

A force of 10 gm was required to activate the system and to count as a response. The digital voltmeter registered the peak force of response approximately 200 msec. after response termination. This value remained until the next response was recorded.

Each S was given 10 training sessions on successive weekdays. Prior to each session the following instructions were read by the Ss:

"Your task is to learn to press the lever with a precise force. In front of you is a visual display of five lights directly above the illuminated numbers on the digital voltmeter. The numbers on the voltmeter will tell you the exact force of your response immediately after you have terminated the response. The numbers above the five lights give you the target force. For instance, when the light below "100" is lit, you are to try to press the lever with a force of 100 gm. Immediately after the response the voltmeter will indicate the peak force you exerted. The forces required are as indicated: 25, 50, 100, 150, and 200 gm.

"Your responses are to be made with the right index finger. The hand support and arm rest may be positioned in whatever way you find comfortable. You may press the lever as frequently as you wish, using only the right index finger.

"The force requirement will change periodically. The change will be preceded by a loud audible click and the new requirement will be indicated by the appropriate light. Each target force will be in effect for one minute before changing. Every fifth minute none of the lights will be lit, giving you a one-minute rest.

"It is emphasized that you should try to come as close to the required force value as you can. The entire session will last 23 minutes; four minutes with each force requirement, and three one-minute rests."

Each session began with the 25 gm force requirement, with subsequent ascending and descending sequences of the five force criteria.

Results and Discussion

The data presented are averages for the last two of the 10 daily sessions. No systematic performance changes across these two sessions were apparent. For all measures except response rate, the first five responses following a change in force criterion were omitted from the computations, since the objective of the experiment was to assess stable discriminative performance.

Table 1 provides the mean and standard deviation of peak force, and mean response rate for each S performing under the five force criteria. A small, though significant underestimation is evident in the mean peak force (sign test, 5% level). Rate of response shows a systematic inverse relation to force required (and emitted) for all Ss.

Figure 1 gives the ratio of the standard deviations to the required values for response peak force ($\Delta F/F$), plotted as a function of peak force criterion (F). These measures are comparable to the familiar Weber ratio, and provide an index of the relation between response

Table 1. Mean and standard deviation of response force, and mean response rate for each subject.

Criterion (grams)	Subjects			
	NK	JK	RF	DM
Mean Peak Force (grams)				
25	24.6	24.9	24.9	24.6
50	49.6	51.6	49.1	50.0
100	98.3	101.2	98.3	100.1
150	147.5	152.6	147.7	149.7
200	198.0	200.9	193.8	198.6
Standard Deviation (grams)				
25	3.6	4.3	2.7	2.1
50	6.1	5.3	5.7	4.4
100	10.4	7.5	9.0	7.9
150	15.6	11.5	11.6	10.4
200	20.3	15.7	13.5	13.2
Response Rate (responses per min.)				
25	35.0	30.5	38.9	49.3
50	32.3	28.5	35.6	47.4
100	30.0	26.5	33.0	45.1
150	28.8	25.4	31.3	42.9
200	27.8	23.9	30.8	42.5

variability and required magnitude of the force emission. The form of the obtained function suggests that $\Delta F/F$ is approaching the range of constancy.

The results of this experiment bear a striking resemblance to psychophysical data although the procedure is fundamentally that of a free-operant response differentiation. Reinforcement may be assumed implicit in the visual feedback (force readout) following the response. In addition, the visual feedback serves as a discriminative stimulus for the subsequent response. Part of this cueing function is presumably shared by the S's cutaneous and proprioceptive sensations during response emission. During the course of a given response, the S "adjusts" the response-feedback stimuli concomitant with force emission until they match the "standard," the sensations accompanying previously

Fig. 1. Ratio of standard deviation of peak force to peak force required as a function of the latter. Points are averages for four Ss.

reinforced responses. Upon response termination, the quantitative nature of the visual feedback provides a cue for change in response force on the next response. An indication of supra-criterion force is the cue for subsequent force decrement, and vice versa.

The foregoing analysis suggests that response differentiation is in essence a discriminative process. Reinforcement establishes the implicit "standard" against which subsequent behavior is matched.

Effort expenditure may also influence the results. This is indicated by both the regular decrement in response rate with a higher force criterion, and the general tendency toward underestimation in force emission.

References

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- NOTTERMAN, J. M., & MINTZ, D. E. Exteroceptive cueing of response force. *Science*, 1962, 135, 1070-1071.

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