SOME PUNISHING EFFECTS OF RESPONSE-FORCE¹

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The present experiment explored the punishing effect of different response-force requirements by means of a two-operand design analogous to a two-component chain schedule. The first component of the chain required a lever pull through 0.25 in. (0.64 cm) at 1 lb (4.45 N) of force. The second component required a lever pull through an additional 0.75 in. (1.90 cm) with the force varied between sessions from 1 lb to 50 lb (4.45 N to 223 N). Completion of the second component of the chain was reinforced after variable intervals averaging 1 min. The average rate of first-component response decreased as the force requirement for second-component responses was increased. This rate reduction did not appear to be due to increased response duration, "fatigue", or differing rates of reinforcement. If the force requirement for the second-component response is viewed as a consequence for the first-component response, then the results of the experiment show that a high force requirement is a punisher.

The attempt to understand and experimentally analyze the behavioral effects of response-force (or effort) can be traced back at least to the nineteenth century (Solomon, 1948). One result of this continuing interest is a large number of studies examining the relationship between responding and effort. Most of these studies have found that a high response-force requirement is associated with reduced responding (*e.g.*, Applezweig, 1951; Capehart, Viney, and Hulicka, 1958; Fitts, 1940; Lawson and Brownstein, 1957; Montgomery, 1951; Mowrer and Jones, 1943; Solomon, 1948; Weiss, 1961), although a few studies reported no effect (Quartermain, 1963; Maatsch, Adelman, and Denny, 1954). These findings have frequently been related to the Hullian conceptualization of effort as an "inhibitory stimulus" (*e.g.*, Hull, 1943). According to this theory, the emission of an effortful response produces an "inhibitory potential" that reduces the organism's response potential. This in turn leads to a reduced tendency to respond.

While the Hullian theory is perhaps the

most influential explanation of the effects of "effort", it contains a number of weaknesses. First, the data base of the theory is weak; even the studies reporting a positive finding demonstrate only a weak and unreliable effect. Second, the theory refers to a variety of explanatory variables that are not directly observable. Even the behavioral measurements vary from study to study, including latency, trials to extinction, and response rate. Also, effort itself is not measured directly; rather, the force required to emit the response is measured. The Hullian theory seems to add little to the simple descriptive statement that high force requirements tend to be associated with a reduction in various indices of responding.

The experimental analysis of behavior would seem to offer a firmer methodological basis and a more descriptive approach to the understanding of the effects of response-force. Several experiments have demonstrated a reliable and strong relationship between response-force and rate of responding (Chung, 1965; Miller, 1968*a*, 1968*b*). These findings have led some to speculate that response-force is a "punishing stimulus" (Blough, 1966; Chung, 1965; Miller, 1968*a*). According to this approach, each response emission is followed by an aversive consequence arising from the effortfulness of the response that reduces the probability of future responding.

Unfortunately, this approach also contains several difficulties. Perhaps the major difficulty

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is that response-force is an integral part of every response. Thus, it cannot be conceptualized as an independent stimulus event occurring after the response. Since this is a basic part of most definitions of a punisher, response-force would not seem to qualify. Furthermore, the precise amount of force required to operate a manipulandum is part of the definition of every operant class. Thus, if the force requirement is changed, a new operant class is defined. This means that studies that compare the rates of responding at different force requirements are also comparing different operant classes. The speculation that punishment accounts for the different rates associated with different force requirements is no more justified than a similar speculation with respect to any two operants such as bar pressing and chain pulling. Thus, the punishment theory of response effort also seems to add little to the simple descriptive statement that high force requirement is associated with a reduction in response rate.

Present understanding of the effects of response-force seems to be limited by the experimental designs thus far used. These designs do not provide direct examination of the general behavioral principles involved in these effects. An ideal design would do at least two things. It would separate the stimulus aspects of response-force from its behavioral aspects. And it would investigate the effects of this stimulus on a single, uniformly defined operant class. Such an experimental design would permit an investigation of the punishing properties of response-force as a consequence.

The present paper reports an experiment based on a two-operant or chain schedule. In this schedule, the completion of the first operant has as its consequence the opportunity to emit the second operant. The emission of the second operant is maintained through intermittent reinforcement. By varying the response-force requirement for the second operant only, its effect as an independent stimulus consequence for the first operant may be examined. This procedure permits both a separation of the stimulus and behavioral aspects of response force, and an investigation of the stimulus effects on a single operant class (the first operant). Thus, the two-operant or chain schedule permits a direct investigation of the punishing effects of response-force.

METHOD

Subjects

Three adult males, 26, 32, and 41 yr old and institutionalized in a mental hospital, and one non-institutionalized 18-yr-old male served. S-1 was used in an earlier study on the effects of different force requirements (Miller, 1968a). All subjects were recruited solely in terms of their willingness to accept money or cigarettes as reinforcers and to attend the experimental sessions regularly.

Apparatus

The experimental chamber was a 6 by 6 by 8 ft (1.83 by 1.83 by 2.44 m) sound-attenuated room. One arm of the subject's chair was hinged to a workbench that extended the length of the wall. When the chair was pulled into position in front of the workbench, the subject could insert a jack connected to the workbench into a plug mounted on the chair, thus turning on the apparatus. This arrangement fixed the subject's position with respect to the manipulandum.

A Lindsley knob (Lindsley, 1956) and two stimulus lights were mounted on a 24 by 12 by 12 in. (61.0 by 30.5 by 30.5 cm) box attached to the bench directly in front of the chair. The first-component response was defined as a pull on the knob through 0.25 in. (0.64 cm) against a 1-lb (4.45 N) spring. The second-component response was defined as a pull through an additional 0.75 in. (1.90 cm). The force requirement for the second response was controlled by attaching a weight to the knob, effective through the last 0.75 in. (1.90 cm) of travel. The weight was varied between 0 lb (0.0 N) and 50 lb (223 N). A white light above the knob went on when the knob was pulled through the entire 1 in. (2.54 cm) and went off after the knob was completely released.

Reinforcers were delivered by means of a Universal feeder located at the right end of the bench. All apparatus was controlled by timers and relay circuitry located in an adjoining room. The experimenter could view the subject through a concealed observation window.

Procedure

Each subject was conducted to the experimental room by the experimenter at the beginning of the first session. After the subject

was seated, the apparatus was turned on; this was indicated by a red session light. The subject was told that he could earn objects (reinforcers) by turning on the white light above the knob and then turning it off. After the first reinforcer was delivered the experimenter left the room. The reinforcers for the institutionalized mental patients consisted of a mixture of equal numbers of pennies, nickels, washers, cigarettes, and candy. The noninstitutionalized subject received nickels. Reinforcers were delivered contingent upon a 1-in. (2.54 cm) pull after varying intervals of time averaging 1 min (VI 1-min). If the subject did not respond within 10 sec after a reinforcer was available, the delivery of that particular reinforcer was cancelled (limited hold 10 sec—LH-10). The session was terminated after 60 min or after the delivery of 50 reinforcers, whichever came first.

Each subject responded for one session at a 1-lb (4.45 N) force requirement for the first and second responses in the chain. The force requirement for the second response was then increased to 10 lb (44.5 N) in the second session and then by an additional 10 lb (44.5 N) in each subsequent session up to a maximum of 50 lb (223 N). Each subject was then returned to the 1-lb (4.45 N) force requirement for the second response for one session.

RESULTS

Figure 1 shows the rate of both responses (*i.e.*, lever pulls of at least 0.25 in. (0.64 cm) and lever pulls through the remaining 0.75 in. (1.90 cm)) at the different force requirements for the second response. The rate of responding for both responses decreased for all subjects as the force requirement on the second response was increased. Completion of over 90% of all first-component responses was followed by completion of the second-component response. This is reflected in the virtual identity of the two functions.

This experiment shows that the overall rate of responding decreased as the force requirement increased. However, since it may take longer to emit a second-component response under high force than during low force condition, the rate reduction may not imply an increase in the interresponse time of the first-component response. To evaluate this possibility, the interval from the end of each sec-

ond-component response to the beginning of the next first-component response was measured. Figure 2 shows these data at each force requirement. As an example of the results, S-1

Fig. 1. Rates of first- and second-component responses at different force requirements for second-component responses. The unconnected dots at 1 lb represent re-determinations of baseline. Note that 1 lb-force = 4.45 N (ewtons).

Fig. 2. Relationship between force requirement and latency between first component responses for each subject. The latency was measured from the end of one second-component response to the beginning of the next first-component response. Note that 1 lb-force = 4.45 N.

paused an average of about 0.1 sec between first-component responses when the force requirement was 1 lb and about 10.5 sec when a 50-lb force was required. There was a similar increase in the interval between responses for all subjects as the force requirement was increased. Thus, these data show that the reduction in response rate was accompanied by an increase in the interval between first-component responses.

These results may reflect the averaging of different response rates within each experimental session. Thus, it is possible that the response rate at each force requirement is similar at the beginning of the session, but that it decreases more rapidly within the session at the higher requirements. To evaluate this possibility, the response rates for each subject were calculated for each 5-min period within sessions for the 1-, 10-, and 50-lb force (4.45, 44.5, and 223 N) requirements. The data are shown in Fig. 3. The data for S-2 at 50 lb (223 N) are not shown because he walked out after a few minutes of failing to meet the criterion. The pattern for S-1 provides an example of the results: the 50-lb (223 N) requirement is associated with a rate that is lower than that associated with the 10-lb (44.5 N) requirement during each period. Likewise, the rate at 10 lb (44.5 N) is lower than the rate at 1 lb (4.45 N) for each period. There is no indication that

the rate differences between the different requirements systematically increased or decreased over time in a session for S-1. The results for the other subjects show no systematic change in rate related to the passage of session time.

The variable-interval schedule of reinforcement permits wide variations in response rate with little effect on rate of reinforcement. In order to assess the degree of effect in the present experiment, the rate of reinforcement was calculated at each force requirement. Figure 4 shows that the rate of reinforcement decreased from an average of 1.00 per min at 1 lb (4.45 N) to an average of 0.70 per min at 50 lb (223 N). Over the entire force range, the density of reinforcement is about 30% lower at 50 lb (223 N) than it is at 1 lb (4.45 N). However, the reduction between 1 lb (4.45 N) and 40 lb (178 N) is less than 10%. Since most of the rate reduction occurs in this same range of force requirements, these results indicate little correlation between response rate and reinforcement rate.

DISCUSSION

The present results would seem to bear directly on the interpretation of response-force requirements as a punisher. According to this conception, response rate is reduced because the emission of a high force response is in some manner punishing. The present procedure removed a major difficulty in the experimental evaluation of this interpretation. In previous

Fig. 3. Average rate of first-component responses during each 5-min period of the experimental session at a high, medium, and low force criterion. Note that 1 lb-force = 4.45 N.

Fig. 4. Average number of reinforcements per minute for all subjects at each force requirement. Vertical lines indicate the range of individual reinforcement rates. Note that 1 lb-force = 4.45 N.

experiments, where the rate of responding was investigated for only a single operant, such as Chung's, it could be argued that different force requirements defined different operant classes of responses. The present experiment avoided this difficulty by examining the rate of the single, constantly defined first-component operant. Thus, the observed rate reduction in first-component responses at high force requirements for second-component responses does not involve comparison of different operant classes. On a purely descriptive level, then, the present experiment permits the conclusion that the response rate of a uniformly defined operant decreases in direct proportion to the response-force required for a second, contingent response.

The present procedure also had the advantage of untangling the response from its consequence. Since response-force requirement can be viewed both as a dimension that enters into the definition of every operant and as a stimulus condition of the environment, it is difficult to conceptualize clearly the functional relationship between response rate and consequence. The present experiment partially untangled this by defining a two-response chain and examining the effect of requiring different force emissions during the second component on the rate of emitting the first component. The requirement for the second response thus becomes an independently defined consequence for the initial response.

The present two-response procedure makes it possible to apply traditional definitions of punishment. The punishment literature has relied on two definitions of punishment. Early definitions were purely procedural: punishment was defined as the contingent application of a negative reinforcer to a response (Keller and Schoenfeld, 1950). This definition requires the assessment of whether the stimulus in question is a negative reinforcer. A previous experiment showed that escape from a situation defined by the opportunity to emit an effortful response was reinforcing (Miller, 1968a). In other words, the opportunity to emit an effortful response was shown to be a negative reinforcer relative to a low force opportunity. In the present procedure, the opportunity to emit an effortful response arises contingent upon completing the initial response. Thus, the results of the present experiment provide direct evidence that response-

force conforms to the procedural definition of a punisher.

A second definition of punishment also requires observation of a behavioral effect: "a reduction of the future probability of a specific response as a result of the immediate delivery of a stimulus for that response" (Azrin and Holz, 1966). In the present case, the opportunity to emit an effortful response arises immediately after the initial response. The finding that this reduces the rate of first-component responses is direct evidence that response-force is a punisher.

The present experiment also makes possible the evaluation of several alternative explanations of the rate reduction. One possible explanation is that the interval between first-component responses does not actually decrease at high force criteria, but rather that the time spent completing second-component responses increases. If this were the case, an apparent rate decrease of first-component responses would be observed. However, a corrected rate computed in terms of the number of responses divided by the time between responses would show no rate decrease. The basis for evaluating this possibility is whether the average interval between responses changes as a function of the force criterion. Figure 2 shows that this average interval increases as the force criterion decreases. Therefore it may be concluded that response rate, corrected for second-component response duration, decreases as the response-force criterion increases.

Another possibility relates to a "fatigue" effect. It is possible that every session began with a high response rate but that a high force criterion led to a rapid rate reduction as the session continued. Figure 3 shows that the rate of responding during each 5-min segment of the experimental session was roughly constant with a 1-lb, 10-lb, and 50-lb (4.45, 44.5 and 233 N) force requirement. Therefore it may be concluded that the rate reduction of first-component responses was a result of the initial contact with the high force criteria imposed on second-component responses and was not a cumulative effect occurring over time.

Finally, the present data also permit an assessment of the relationship between the force criterion and reinforcement density. The force criterion may have produced a rate reduction which in turn produced a decrease in the density of reinforcement. The decrease in density

of reinforcement could lead to a further rate reduction and possibly account for a major portion of the observed rate reduction. But Fig. 4 shows that over 80% of the rate reduction occurs between 1 and 20 lb (4.45 and 89 N) when the average reduction in reinforcement density is about 2%. Thus, the major portion of the rate reduction of first-component responses is associated with a 20-lb (89 N) change in the force criterion for second-component responses but with only a slight change in the reinforcement density. This suggests that the rate of reinforcement was not the major determinant of rate reduction in the present experiment.

The elimination of these alternative explanations of the rate reduction strengthens the conclusion that response-force is a punisher and that the rate reduction can be called the result of punishment.

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