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# *STIMULUS CONTROL AND GENERALIZATION OF POINT-LOSS PUNISHMENT WITH HUMANS*

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Two experiments demonstrated stimulus control and generalization of conditioned punishment with humans. In both studies, responses first were reinforced with points exchangeable for money on a variable-interval schedule in the presence of one line length ($S^D$). Next, a second line length was introduced, and point loss followed every response in the presence of that line ($S^D_p$). In the final training condition, points were deducted at session end. Response rate was lower in the presence of the $S^D_p$ despite equal rates of points for money in the presence of both stimuli. In generalization testing for Experiment 1, the two lines were included in a 10-line continuum; $S^D_p$ fell in the middle and the trained $S^D$ was at one end. Lines were presented randomly, and point delivery and loss contingencies were as in training but with points available in the presence of all lines. For all subjects, response rates were lowest around $S^D_p$ and increased towards the $S^D$ end of the continuum. Because testing included only one or two lines beyond $S^D$, this pattern did not rule out $S^D$ generalization. Thus, in Experiment 2, stimuli beyond $S^D$ were added to generalization tests. Response rates did not decrease as a function of distance from $S^D$, clarifying the demonstration of punishment generalization.

*Key words:* punishment, stimulus control, discrimination training, stimulus generalization, lever press, plunger pull, humans

When responding is reinforced in the presence of one stimulus it often also occurs in the presence of physically similar novel stimuli, and response rate typically varies as a function of physical similarity between the novel stimuli and the original stimulus (i.e., stimulus generalization). Stimulus generalization of reinforcement has been demonstrated with both nonhuman animal subjects (see Honig & Urcuioli, 1981, for a review) and human subjects. Stimulus generalization based on reinforcement with humans has been obtained with stimulus dimensions such as auditory frequency (Baron, 1973), visual wavelength (Doll & Thomas, 1967), weight (Hebert & Capehart, 1969), line angle and visual intensity (Thomas, Lusky, & Morrison, 1992), and shades of gray (Hebert, 1970).

Relatively little is known about stimulus control and generalization with punishment. Moreover, until recently this form of stimulus generalization has been studied almost exclusively with nonhuman animal subjects and unconditioned punishers such as electric shock (e.g., Hoffman & Fleshler, 1965; Honig, 1966; Honig & Slivka, 1964). Previous studies of stimulus control and generalization with punishment used procedures different from those used for studying stimulus control and generalization with reinforcement. In typical reinforcement-based procedures, discrimination training is conducted with reinforcement available only in the presence of one stimulus and extinction in effect for the other stimulus, and generalization testing is conducted with extinction in the presence of all stimuli. Testing for stimulus generalization of punishment effects in extinction, however, would confound response suppression due to punishment and response decrements due to extinction. This potential problem has been avoided by maintaining reinforcement and punishment contingencies throughout test-

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ing (i.e., a steady-state test; see Honig & Slivka, 1964).

We found only two published studies of punishment generalization with human subjects (Birnbrauer, 1968; Lovaas & Simmons, 1969), and these both involved an unconditioned punisher. Studies of conditioned punishment effects on human behavior are essential for a complete understanding of stimulus control of punishment. Although conditioned and unconditioned punishers both suppress responding and share other behavioral effects such as contrast and induction (e.g., Crosbie, Williams, Lattal, Anderson, & Brown, 1997; McMillan, 1967), there is evidence that they may not be functionally equivalent (e.g., Branch, Nicholson, & Dworkin, 1977). Studying stimulus control and generalization with a conditioned punisher (point loss) would provide another way of assessing the functional similarity of conditioned and unconditioned punishers.

Filling this gap in the literature would also have practical benefits. For ethical and safety reasons, conditioned punishers are common in application. When punishment is a component of a behavior modification program, stimulus control issues are critical. For example, it is important to consider the likelihood that punishment effects will generalize to new settings. Often, generalization of punishment effects is desirable (Johnston, 1972) but it can be difficult to obtain (Birnbrauer, 1968; Lovaas & Simmons, 1969; Newsom, Favell, & Rincover, 1983; Risley, 1968; Wolf, Risley, Johnston, Harris, & Allen, 1967). On the other hand, some punishment effects may need to be context specific, as when behavior is inappropriate in only one situation (e.g., interacting with one particular person).

In previous attempts to study the stimulus control and generalization of conditioned punishment with humans, procedures analogous to those used by Honig and Slivka (1964) with nonhuman animals did not establish control by the stimulus correlated with punishment contingencies. In those studies (O'Donnell & Crosbie, 1998), subjects earned points exchangeable for money by pressing and releasing a lever in the presence of 10 horizontal lines that differed only in length. The presentation of each line constituted one component of a 10-component multiple schedule, in which each component was correlated with a variable-interval (VI) 60-s schedule of point delivery. After response rate stabilized in the presence of each line length, subjects lost points in the presence of the sixth-longest line ($S^D_p$)[1] either after each response (Experiment 2) or on an intermittent schedule (Experiment 4), with the VI 60-s point delivery maintained in the presence of all stimuli. Responding was suppressed in the $S^D_p$ component when point loss followed each response and when it was delivered intermittently. In neither procedure, however, was response suppression under control of $S^D_p$. Rather, suppression occurred only after delivery of the first punisher in the component, prior to which response rate was near $S^D$ levels (see also O'Donnell, 1997, Experiment 4). If the stimulus correlated with point loss had been discriminative, responding would also have been suppressed before the first punisher was delivered (see Jenkins, 1965, for a discussion of similar effects with reinforcement). Instead, the punisher itself exerted stimulus control by signaling potential additional delivery of punishers (Azrin & Holz, 1966).

Those outcomes suggested that delivering punishers at any time in the presence of $S^D_p$ promoted control by the punisher and blocked control by other stimuli. To promote control by $S^D_p$ rather than by the punisher, in another study point loss was contingent on each response during the $S^D_p$ component but the total number of points lost was not displayed until the component had ended (O'Donnell & Crosbie, 1998, Experiment 3). Under this procedure, however, response rate decreased in the presence of all stimuli. The suppression across all stimuli illuminated potential problems with the procedures. First, all stimuli, including the stimulus in the presence of which punishers would be arranged in a subsequent condition, were correlated with the same reinforcement conditions for many sessions prior to the introduction of punishment. Thus, stimuli were functionally equivalent from the outset of training. Sec-

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[1] For clarity, the notation $S^D_p$ will be used in the present paper to refer to the stimulus correlated with punishment, so as not to confuse it with S− (a stimulus correlated with extinction) or $S^p$ (the punishing stimulus). The traditional notation $S^D$ will refer to the stimulus correlated with reinforcement in discrimination training. We thank Jack Michael for the suggestion of using $S^D_p$.

ond, because points were deducted after the line had been removed from the screen, point loss was never correlated with the stimulus itself. These factors may account for the finding that all stimuli occasioned response suppression.

Given that all of the aforementioned studies involved many sessions of reinforcement in the presence of all stimuli prior to the introduction of punishment, another study eliminated these initial training conditions (O'Donnell, 1997, Experiment 4). In that study, discrimination training included only two stimuli, $S^D$ and $S^D_p$, with intermittent punishment in the presence of $S^D_p$. Again, however, responding was suppressed only after a punisher was delivered.

In summary, point loss delivered during the punishment component resulted in discriminative control of response suppression by the punisher, even though responding was still maintained by the $S^D$. When point loss was presented at the end of the component, however, control by neither $S^D$ nor $S^D_p$ was shown; responding was suppressed in the presence of all stimuli. The present study had two goals. The first was to continue our pursuit of procedures that would establish antecedent stimulus control of punishment. The second was to test for stimulus generalization.

## EXPERIMENT 1

The primary purpose of Experiment 1 was to bring response suppression under control of $S^D_p$ while maintaining control of responding by $S^D$. Based on previous results, we reasoned that two phases of discrimination training might be necessary. In the first phase responding was reinforced in the presence of both $S^D$ and $S^D_p$, and each response in the presence of $S^D_p$ was followed immediately by point loss. We expected these procedures to establish control of responding by $S^D$ and control of response suppression by the delivery of the punisher, as shown in O'Donnell (1997, Experiment 4) and O'Donnell and Crosbie (1998, Experiments 2 and 4). The second phase was a modification of O'Donnell and Crosbie's Experiment 3 and was designed to establish control by $S^D_p$ by eliminating punisher presentation during the component. In this phase, points were deducted for each response in the presence of $S^D_p$, but point loss was not displayed until the end of the entire session. To facilitate transition between phases and prevent loss of control by $S^D_p$, subjects in the present experiment were given minimal instructions about the change in point-loss conditions prior to this phase (no instructions were given in O'Donnell & Crosbie's Experiment 3). The second goal of Experiment 1 was to test for stimulus generalization, which consisted of presenting novel stimuli in conjunction with $S^D$ and $S^D_p$ while maintaining reinforcement in the presence of all stimuli and delayed point loss in the presence of $S^D_p$.

### METHOD

#### *Subjects*

Individuals interested in participating signed up on a recruitment sheet posted in the Department of Psychology at West Virginia University. Two male and two female students (ages 19 to 23 years) who had taken no courses in learning principles nor had participated in psychological research were chosen. At the end of the experiment, each subject was paid 12 cents for every 1,000 points he or she earned (approximately $5 per hour), plus a $50 bonus for attending all scheduled sessions.

#### *Apparatus*

Sessions were conducted in spaces (2 m by 3 m) enclosed by partitions. Programs written in Turbo Pascal® presented stimuli and recorded responses. Each subject sat facing an IBM® PC-compatible computer with a VGA color monitor, keyboard, mouse, and a lever mounted inside a wooden box (19 cm long, 30 cm wide, and 19 cm high) located to the left of the computer. The lever consisted of a steel rod 2 cm in diameter hinged to a metal bracket over a Lafayette® 76613 force transducer. The rod, wrapped in tennis-grip overwrap, was positioned 26° below horizontal and protruded 4.5 cm through a hole in the front of the box (see Crosbie, 1993, for further details). Lever presses with peak force $\geq 30$ N were defined as responses, and were followed by a 10-ms 2000-Hz feedback tone.

#### *Procedure*

Prior to the first session, subjects received written instructions that described the task and the monetary value of points (see the Appendix for complete text). The instructions were posted at the work station throughout the experiment. Questions about the experiment were answered by the experimenter reading the appropriate part of the instructions to the subject. Subjects participated in at least four sessions each day, 5 days per week, and were given a short break between sessions. In each phase described below, sessions consisted of 40 30-s components, each separated by a 5-s blank screen. Before each component began, a gray horizontal line drawn with underline characters (ASCII 196; each character was 3 mm long and approximately 0.5 mm high) was displayed in the center of the screen. To begin the component, subjects positioned the mouse cursor over the left end of the line and pressed the left mouse button, causing the line to flash briefly. Subjects then did the same on the right end of the line. Immediately after the right mouse click, the mouse cursor was removed, the line turned red, and the component began. This observing response was designed to enhance discriminative control by line length.

To increase both schedule sensitivity and control exerted by programmed contingencies, a consummatory response was required (Matthews, Shimoff, Catania, & Sagvolden, 1977). Whenever points were made available, a yellow square (2 cm by 2 cm) was presented in the upper right corner of the computer screen and the mouse cursor was presented at the bottom of the screen. If the subject moved the mouse cursor into this box and pressed the left mouse button within 5 s, a 1000-Hz tone sounded for 10 ms, and 1,000 points were added to the subject's score. No sound or other exteroceptive stimuli accompanied presentation of the box, so subjects had to watch the screen continuously to obtain points. After points were collected or the 5-s limit elapsed, the yellow box and mouse cursor disappeared from the screen, and the session continued.

Throughout each session, a box (2.5 cm by 2.0 cm) at the top center of the screen displayed two numbers: On the left was the total points accumulated and on the right was the change in the total after points were either collected (printed in green and indicated by a plus sign) or lost (printed in red and indicated by a minus sign). At the end of each session a message on the screen showed how many points the subject had accumulated thus far in the study.

To ensure moderate to high response rates, which were required to assess punishment effects, points initially were delivered on a variable-ratio (VR) schedule (i.e., after a variable number of responses). The VR parameter began at 20 and was increased by 5 each session until subjects were obtaining 1,000 points (one reinforcer) approximately every 30 s. The point-delivery schedule was then changed to VI 30 s (i.e., points were delivered following the first response after various durations averaging 30 s), and the VI parameter was increased 5 s per session until it reached a terminal value of 60 s. In all subsequent conditions, point delivery was arranged on a VI 60-s schedule. Interval values ranged from 3.12 s to 198.18 s and were determined with the Fleshler and Hoffman (1962) progression.

*Baseline.* During all components, only $S^D$ was presented and points were delivered on a VI 60-s schedule. The length of $S^D$ was 102 mm for Subject H101 and 138 mm for Subjects H100, H103, and H113. At the end of each session, the following message was displayed: "You may stop now [subject name]. Your score is —." Baseline sessions continued until response rate was stable for eight consecutive sessions (i.e., when there was minimal variability and no increasing or decreasing trend in response rate according to visual inspection).

*Discrimination training.* In this condition, we attempted to establish a discrimination based on punishment. In traditional discrimination training, reinforcement is in effect in the presence of one stimulus (i.e., $S^D$) and extinction is in effect in the presence of another stimulus (i.e., $S^\Delta$). In the present study, however, reinforcement was in effect for both $S^D$ and $S^D_p$, and point-loss punishment conditions were also in effect during $S^D_p$ presentations (i.e., $S^D_p$ was correlated with both point delivery and point loss). Thus, line length and punishment in the presence of $S^D_p$ were the only programmed differences between $S^D$ and $S^D_p$ presentations.

Half of the components consisted of $S^D$ presentations, and the other half consisted of $S^D_p$ presentations. The length of $S^D_p$ was 120 mm for all subjects; therefore, $S^D_p$ was either 18 mm longer or shorter than $S^D$. The order of the components was random, with the constraint that neither stimulus appeared more than three times consecutively. Independent VI 60-s point-delivery schedules were arranged for $S^D$ and $S^D_p$ components, and point loss was also delivered during $S^D_p$ components. Training was completed in two phases. In the first phase (immediate point-loss condition), each response in the presence of $S^D_p$ was followed by a 500-Hz tone (and not the 2000-Hz response-feedback tone) for 10 ms and immediate deduction of points from the total score (which was shown continuously at the top of the screen). Point-loss magnitude initially was 1 point and was increased by 1 point each session until response rate was less than 50% of the average rate in baseline (Azrin, 1960; Azrin & Holz, 1966). This point-loss magnitude was maintained until response rate in the presence of both stimuli was stable for eight consecutive sessions.

Prior to the second phase of training, subjects read the following instructions:

> From now on, you will lose points in the same way, but you will not know how many you have lost until after the session is over. After each session, when the computer tells you to stop, there also will be a message on the screen telling you how many points you lost for the session, and how many total points you have.

In the second phase of training (delayed point-loss condition), several features were altered to promote the discriminative stimulus as the only source of control over responding. Each response in the presence of $S^D_p$ produced point loss of the same magnitude as in the first phase of training, but points were not deducted from the total score until the end of the session. During the session, the total score changed only when points were delivered. Furthermore, responses produced the 10-ms 2000-Hz feedback tone only, and not the point-loss tone. Thus, $S^D$ and $S^D_p$ presentations were identical except for the length of the line displayed. At the end of each session, the following message was displayed: ‘‘You may stop now [subject name]. You lost — points this session. Your score is —.’’ The second phase of training continued until response rate in the presence of both stimuli was stable for eight consecutive sessions.

*Generalization testing.* Subjects received four consecutive test sessions. Each test consisted of four blocks of 10 30-s components. Each component in a block presented one of 10 line lengths (including $S^D$ and $S^D_p$) ranging from 90 mm to 144 mm in 6-mm units. The 6-mm length difference was chosen to increase the probability that punishment effects would generalize, because previous research showed that lines differing by as much as 7.5 mm are not discriminable (O'Donnell & Crosbie, 1998, Experiment 1). The sequence in which stimuli were presented varied across blocks and sessions.

Testing procedures were identical to those in the second phase of training except for the number of different line lengths presented. The VI 60-s point-delivery schedule was in effect in all components. Each response in the presence of $S^D_p$ still produced a loss of the same number of points as in training, and only the 2000-Hz tone sounded after each response (i.e., as in the second phase of training, the tone correlated with point loss was not presented). At the end of the session points were subtracted from the total score and the point-loss message was presented.

## RESULTS

The top portion of Table 1 lists for each subject the number of sessions in each condition, mean response rate in the presence of $S^D$ and $S^D_p$ for the final eight sessions in each condition, and point-loss magnitude in the immediate and delayed point-loss conditions. For all subjects, a loss of no more than 5 points per response was sufficient to suppress responding.

Figure 1 shows number of responses per minute in the presence of $S^D$ and $S^D_p$ during the final eight sessions of baseline and the immediate and delayed point-loss conditions. For all 4 subjects, there was a substantial decrease in response rate during $S^D_p$ components in both point-loss conditions. Subjects H100 and H103 had lower rates in the delayed point-loss condition than in the immediate point-loss condition.

Figure 2 shows number of responses per minute in the presence of each stimulus line on all four generalization tests for each subject. On Test 1, all subjects showed asymmetrical response patterns, with the highest response rates at or near $S^D$ and the lowest response rates on the $S^D_p$ end of the stimulus

Table 1

Number of sessions and mean responses per minute in the presence of $S^D$ and $S^D_p$ in each condition, and point-loss magnitude (number of points lost per response) in the first phase of training with immediate point loss and the second phase of training with delayed point loss. Data are from the final eight sessions of each condition.

| Subject | Condition | Number of sessions | Mean responses per minute $S^D$ | Mean responses per minute $S^D_p$ | Point-loss magnitude |
|---|---|---|---|---|---|
| Experiment 1 | | | | | |
| H100 | Baseline | 15 | 49.83 | | |
| | Immediate | 12 | 37.92 | 10.36 | 1 |
| | Delayed | 15 | 29.23 | 5.46 | 1 |
| H101 | Baseline | 16 | 112.24 | | |
| | Immediate | 11 | 129.12 | 15.03 | 1 |
| | Delayed | 10 | 88.14 | 25.46 | 1 |
| H103 | Baseline | 13 | 165.85 | | |
| | Immediate | 23 | 140.74 | 27.95 | 5 |
| | Delayed | 10 | 140.90 | 5.79 | 5 |
| H113 | Baseline | 31 | 81.86 | | |
| | Immediate | 22 | 114.27 | 2.25 | 1 |
| | Delayed | 10 | 107.79 | 2.01 | 1 |
| Experiment 2 | | | | | |
| H106 | Baseline | 13 | 94.81 | | |
| | Immediate | 13 | 124.51 | 0.05 | 1 |
| | Delayed | 9 | 112.33 | 0.0 | 1 |
| H107 | Baseline | 19 | 120.70 | | |
| | Immediate | 11 | 97.99 | 49.52 | 4 |
| | Delayed | 11 | 84.63 | 49.92 | 4 |
| H108 | Baseline | 16 | 135.24 | | |
| | Immediate | 20 | 138.23 | 17.16 | 2 |
| | Delayed | 12 | 133.38 | 1.67 | 2 |
| H109 | Baseline | 12 | 118.89 | | |
| | Immediate | 19 | 125.55 | 2.01 | 1 |
| | Delayed | 9 | 111.80 | 2.04 | 1 |

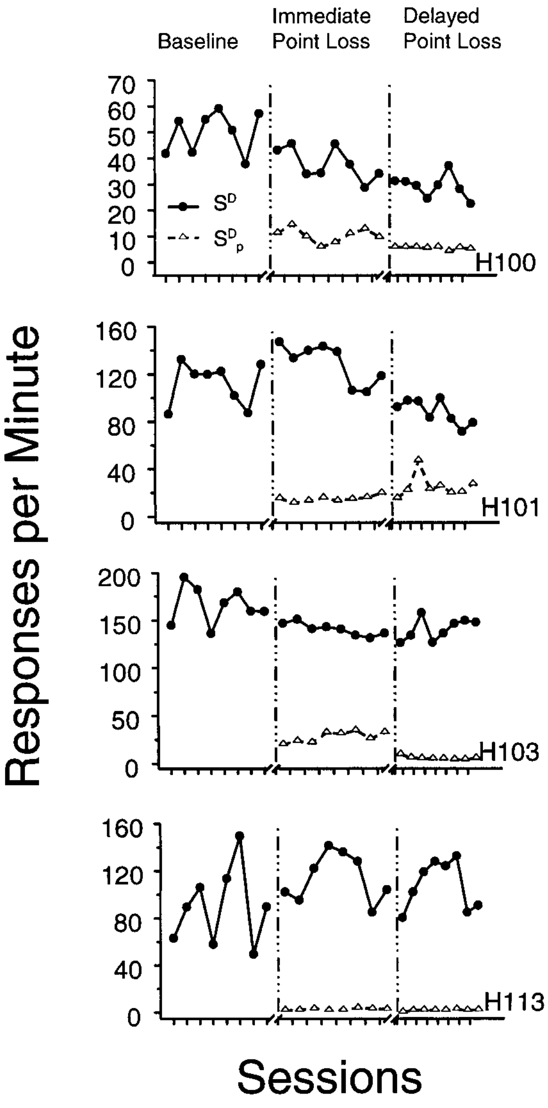

Fig. 1. Responses per minute in the presence of $S^D$ (circles) and $S^D_p$ (triangles) during baseline, the first part of discrimination training (labeled "Immediate Point Loss"), and the second part of discrimination training with point deduction at the end of the session (labeled "Delayed Point Loss") for all subjects in Experiment 1. Note different scaling along the ordinate for each subject.

continuum. This pattern remained the same across all tests for H100 and H113. For H103, a U-shaped function emerged on Tests 3 and 4: Responding was nearly absent in the presence of $S^D_p$ and closest stimuli and increased in the presence of stimuli on both sides of $S^D_p$. For H101, by the fourth test, response rates were the same across all line lengths.

## DISCUSSION

The first aim of the present study was met: Stimulus control based on punishment was established. After discrimination training, response rate was suppressed in the presence of $S^D_p$ when point loss occurred but was not delivered during the component. Thus, 120 mm was a discriminative stimulus for punishment. In previous attempts (O'Donnell, 1997; O'Donnell & Crosbie, 1998), point loss itself was the discriminative stimulus, and it apparently blocked the development of control by the antecedent stimulus. A previous attempt to establish stimulus control (O'Donnell & Crosbie, Experiment 3) used a delayed-punishment procedure similar to the present procedure, but without the prior immediate-punishment condition. Discriminative control

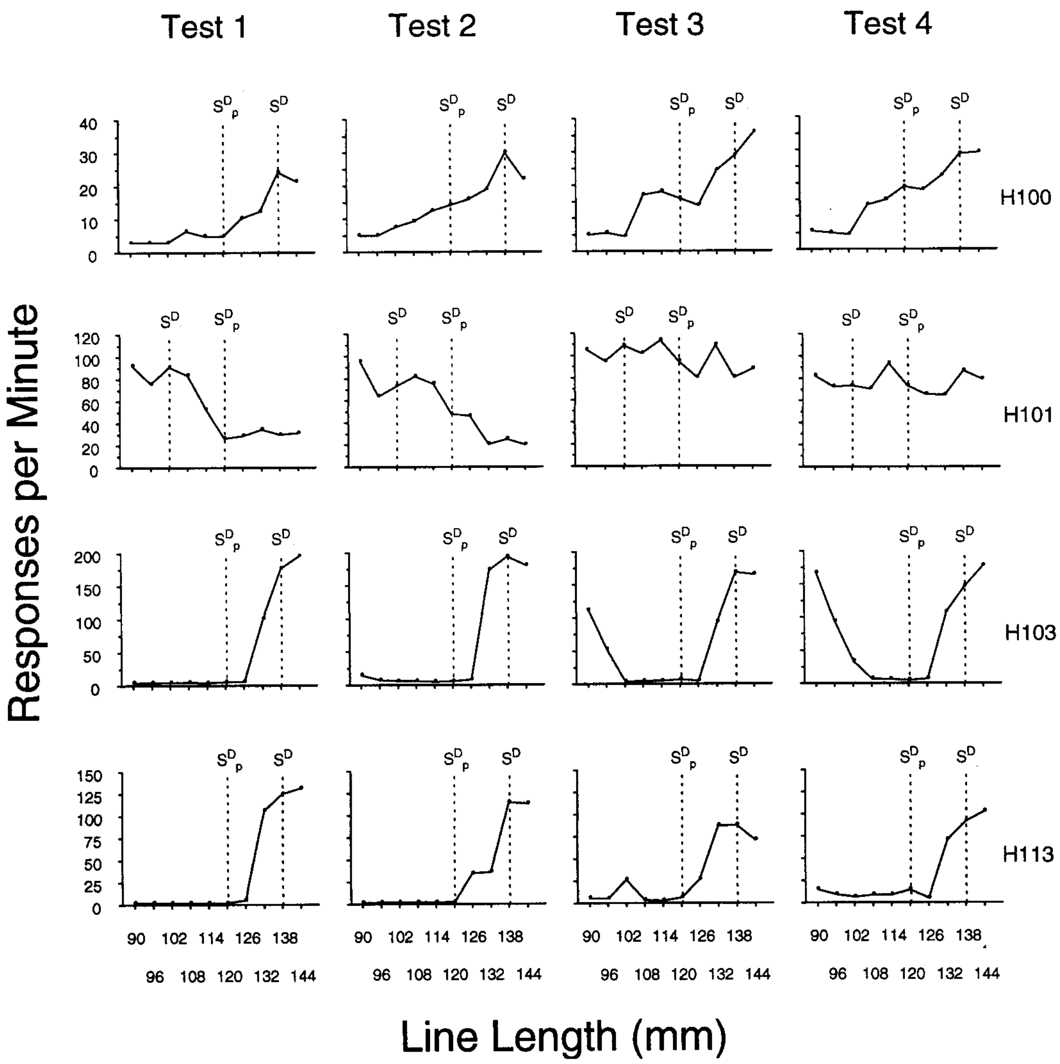

Fig. 2. Responses per minute in the presence of all 10 line lengths on Generalization Tests 1 through 4 for all subjects in Experiment 1. Note different scaling along the ordinate for each subject.

was not established in that study, suggesting that both phases of training are necessary.

The second aim of the present study was to test for stimulus generalization. In general, response rate was lowest at $S^D_p$ and most similar line lengths, and increased as lines became physically dissimilar to $S^D_p$. The U-shaped function around $S^D_p$ shown by H103 provides unequivocal evidence of generalization of punishment (cf. Honig & Slivka, 1964). The asymmetrical gradients shown by H100 and H113 also may be interpreted as generalization of punishment, with complete suppression of responding in the presence of stimuli on the $S^D_p$ end of the line-length continuum.

An alternative interpretation of the asymmetrical functions, however, is that they partially represent generalization of $S^D$ control (i.e., decreases in responding as test stimuli become physically different from the trained $S^D$ as opposed to physically similar to the trained $S^D_p$). This interpretation is made less plausible by the fact that equal reinforcement rates were programmed in the presence of all stimuli, *including* $S^D_p$. That is, although a single stimulus served as the $S^D$ in training, every stimulus had an $S^D$ function during testing. Thus, any suppression in the presence of $S^D_p$ and physically similar stimuli must be due to the punishment condition in effect during $S^D_p$. That most of the present subjects showed graded functions supports the conclusion that generalization test results were due to the punishment-correlated $S^D_p$.

These logical arguments notwithstanding, the best way to rule out alternative interpretations would be to conduct generalization testing with more stimuli located outside of $S^D$ on the continuum. By doing so, the $S^D$ would be an intermediate line length and no longer one of the shortest or longest lines. This would allow unconfounded measurement of potential decrements as a function of distance from $S^D_p$.

## EXPERIMENT 2

In this experiment, we increased the range of line lengths presented in generalization testing (but maintained the 6-mm line-length difference) to determine whether gradients obtained in Experiment 1 were primarily decremental around $S^D$ or incremental around $S^D_p$. Although the line-length continuum was expanded on both ends, the important addition was on the $S^D$ side of the continuum. In particular, there were six stimuli located outside $S^D$ on the continuum for 2 subjects and nine stimuli outside $S^D$ for the other 2 subjects. (In Experiment 1 there were no more than two stimuli outside $S^D$ for any subject.) Decrements as a function of distance from the $S^D$ would be indicated by equivalent decrements in response rates on both sides of the $S^D$. Generalization of punishment effects would be demonstrated if response rate on the $S^D$ end of the continuum remained near $S^D$ levels and decreased around $S^D_p$.

### METHOD

#### *Subjects*

Four female students (aged 18 to 22 years) served as subjects. Selection criteria and payment contingencies were the same as in Experiment 1. Subjects earned approximately \$5 per hour plus a \$50 bonus for attending all scheduled sessions.

#### *Apparatus*

The apparatus was the same as in Experiment 1, except that the response device was a plunger (Lindsley, 1956) contained in a wooden enclosure located to the left of the computer. Responses, defined as plunger pulls with peak force ≥ 30 N, were followed by a 10-ms 2000-Hz tone.

#### *Procedure*

Except for the following, details were identical to those in Experiment 1. Sessions consisted of 38 30-s components. The length of $S^D$ was 102 mm for Subjects H106 and H107 and 138 mm for Subjects H108 and H109. As in Experiment 1, the length of $S^D_p$ was 120 mm. Generalization test sessions consisted of two random presentations of 19 lines, including $S^D$ and $S^D_p$, ranging from 66 mm to 174 mm in length.

### RESULTS AND DISCUSSION

The bottom portion of Table 1 lists for each subject the number of sessions in each condition, mean response rates in the presence of $S^D$ and $S^D_p$ over the final eight sessions in each condition, and point-loss magnitude in the immediate and delayed point-loss conditions. As in Experiment 1, a loss of no more than 5 points per response was sufficient to suppress responding throughout training for all subjects.

Figure 3 shows number of responses per minute in the presence of $S^D$ and $S^D_p$ during the stable portions of baseline and during the immediate and delayed point-loss conditions. Results from training resembled those in Experiment 1: Immediate point loss greatly reduced response rate, and rate remained low during the delayed point-loss condition. The present results corroborate the evidence from Experiment 1 that 120 mm functioned as a discriminative stimulus for punishment.

Figure 4 shows number of responses per minute in the presence of each stimulus line during all four generalization tests. As in Experiment 1, there was a relation between response rate and line length for all subjects. For 3 subjects (H106, H108, and H109), the lowest response rate occurred around $S^D_p$ on all four tests. By the end of testing for H106 and H109, response rate increased as a function of physical distance from $S^D_p$ (i.e., U-shaped gradients emerged). For H108, however, response rate remained low in the presence of all stimuli shorter than $S^D_p$, but rate increased between $S^D$ and $S^D_p$ and re-

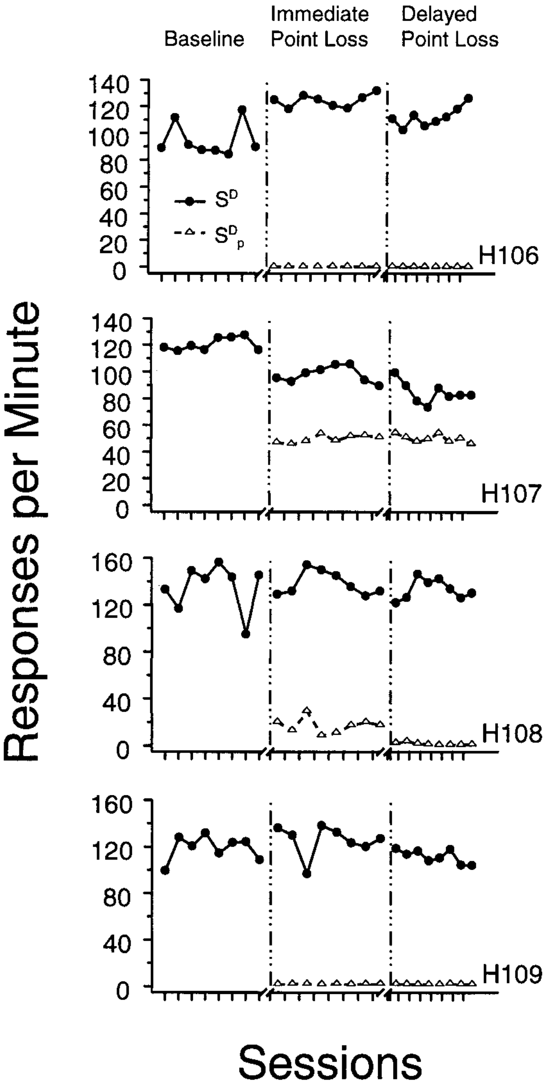

Fig. 3. Responses per minute in the presence of $S^D$ (circles) and $S^D_p$ (triangles) during baseline, the first part of discrimination training (labeled "Immediate Point Loss"), and the second part of discrimination training with point deduction at the end of the session (labeled "Delayed Point Loss") for all subjects in Experiment 2. Note different scaling along the ordinate for each subject.

mained high in the presence of all stimuli longer than $S^D$. Subject H107's results were similar to those of H101 in Experiment 1: Response rate was initially related to line length around $S^D$ but by the end of testing was the same in the presence of all line lengths.

Adding stimuli to the line-length continuum on both sides of $S^D$ and $S^D_p$ provided evidence that the present gradients were due to punishment. Although interdimensional training, in which the training stimuli represent distinct dimensions, would be necessary to determine unequivocally the nature of the gradients, the present procedures may represent a way of addressing this issue intradimensionally. If the present gradients reflected generalization around the $S^D$ only, an equivalent decrease in rate would be expected for stimuli on both sides of $S^D$. For all subjects, however, response rate on the $S^D$ side of the continuum remained high across six line lengths. In contrast, rate decreased within one or two line lengths between $S^D$ and $S^D_p$. Furthermore, in some cases rate increased as stimuli became increasingly dissimilar to $S^D_p$. Additional evidence of punishment generalization is provided by H109: What looked like a potential gradient around $S^D$ on the first few tests (rate decreased on both sides of $S^D$) developed into a U-shaped gradient with high, relatively stable response rates at both ends of the continuum.

Additional support for a punishment generalization interpretation is provided by comparing the present results to those from studies of reinforcement generalization with humans. Typically, reinforcement gradients show a central tendency effect, which occurs when the peak of the gradient is located at the central stimulus value of the continuum even though that value is not the $S^D$ (e.g., Helson & Avant, 1967; Thomas & Bistey, 1964; Thomas & Jones, 1962; Thomas, Strub, & Dickson, 1974). The degree of the central tendency effect is modified by the presence and location of an extinction-correlated $S^\Delta$ on the continuum (e.g., Newlin, Rodgers, & Thomas, 1979; Thomas, Mood, Morrison, & Wiertelak, 1991; Thomas, Svinicki, & Vogt, 1973). If present gradients were based on the reinforcement-related effects of $S^D$, the peak would have been closer to the central stimulus value. Instead, peaks were located at or near the $S^D$.

## GENERAL DISCUSSION

The present studies demonstrated stimulus control and stimulus generalization of conditioned negative punishment. Despite the widespread use of conditioned punishment procedures (e.g., in child rearing), the stim-

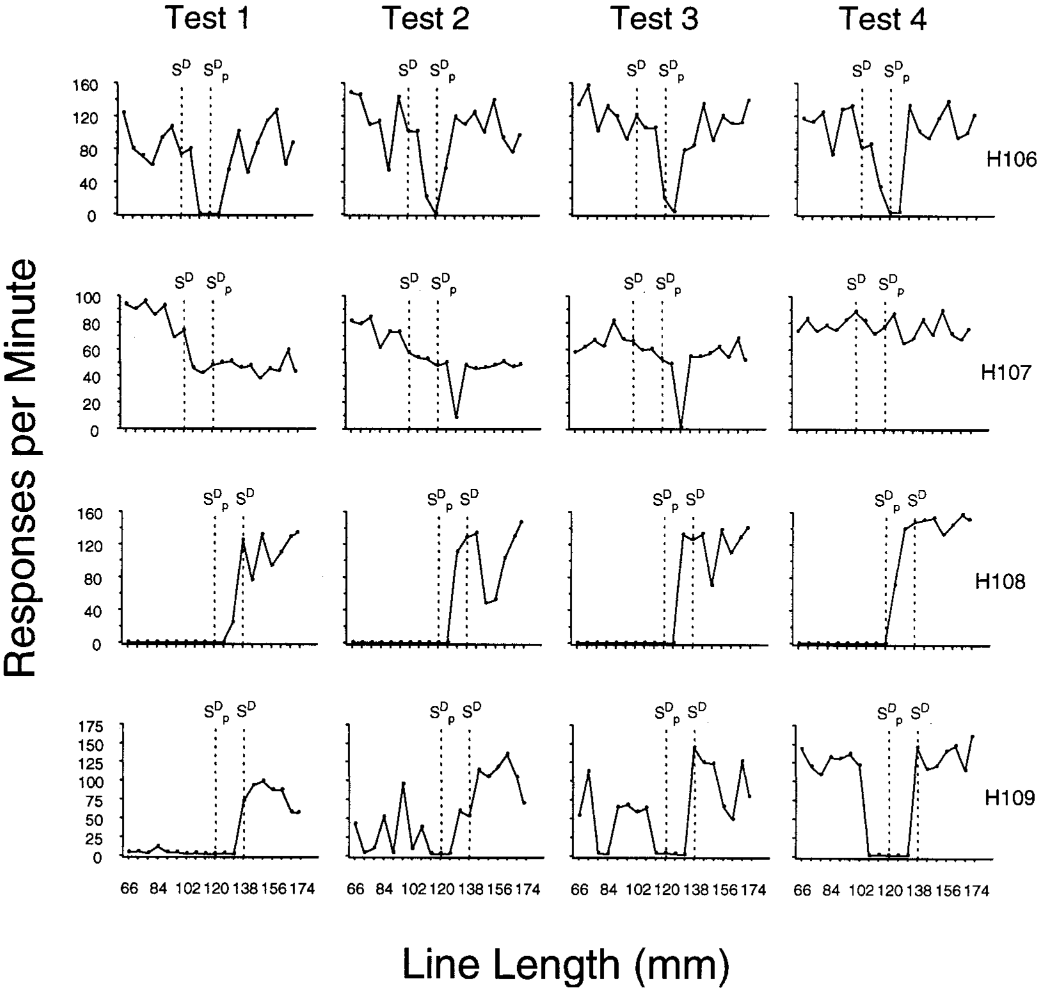

Fig. 4. Responses per minute in the presence of all 19 line lengths on Generalization Tests 1 through 4 for all subjects in Experiment 2. Note different scaling along the ordinate for each subject.

ulus control involved in such procedures has received little empirical attention. Thus, the first step in this research program has been to study procedures for establishing stimulus control of punishment with humans. The initial studies (O'Donnell, 1997; O'Donnell & Crosbie, 1998) found that when punishers were delivered contiguously with responses, antecedent stimuli did not suppress responding. Instead, suppression occurred only after the punisher was delivered. The presentation of the punishing stimulus itself had become a discriminative stimulus (see Azrin & Holz, 1966; Dinsmoor, 1952).

In the present study, stimulus control was established using a two-step procedure. First, each response produced immediate point loss in the presence of the antecedent stimulus. Next, each response in the presence of the stimulus continued to produce point loss, but points were not deducted until the end of the session. This delayed-punishment procedure was a modification of one used in Experiment 3 of O'Donnell and Crosbie (1998). In that study, responding of both subjects was suppressed in the presence of all stimuli. Given that neither of the training steps used in the present study established stimulus control when presented alone, the finding that the combination of immediate and delayed punishment resulted in control by the stimulus correlated with punishment suggests that both conditions were necessary. Immediate punishment suppressed responding and established the punisher as discriminative for punishment, and delayed punishment maintained response suppression while preventing the punisher and its correlated events from becoming discriminative for punishment.

The failure to establish stimulus control with immediate punishment is at odds with other results. For example, Hoffman and Fleshler (1965) established stimulus control using immediately contingent shock with pigeons, and Lovaas and Simmons (1969) demonstrated stimulus control when shock was made immediately contingent on children's self-destructive behavior. Currently there are insufficient data to determine the conditions under which immediate punishment results in stimulus control. A number of procedural differences among the studies could account for these discrepancies: the type of subject, the nature of the punishing stimulus (conditioned vs. unconditioned), and the magnitude of the punishing stimulus. O'Donnell and Crosbie (1998) suggested that, at least with typically developed, verbal adult humans, discriminative control by contiguous punishers blocks the development of control by antecedent stimuli. Subjects in successful demonstrations of stimulus control of punishment have been either nonhuman animals (Hoffman & Fleshler, 1965) or children with severe or profound mental retardation (Lovaas & Simmons, 1969).

Across-study differences also may be due to the type of punisher used. The Hoffman and Fleshler (1965) and Lovaas and Simmons (1969) studies used electric shock—a positive, unconditioned punisher. We used point loss—a negative, conditioned punisher. In a similar vein, the relative magnitude of the punishers may have been critical. In the present study, the quantity of points lost was adjusted to a value that did not produce total response suppression. Points lost were a small fraction of the number of points delivered on the point-delivery schedule (e.g., less than 10% for the subject with the highest $S^D_p$ response rate [H107]). In contrast, the magnitude of shock used by Lovaas and Simmons was sufficiently high to eliminate responding with only a few presentations. Perhaps contiguous point loss would also produce discriminative stimulus control if it was large enough to suppress responding immediately and completely.

The second major finding of the present experiments concerns stimulus generalization. Response suppression occurred not only in the presence of the antecedent stimulus correlated with the punishment contingency but also in the presence of physically similar stimuli. To our knowledge, this is the first such demonstration involving conditioned punishers.

The shape of the present generalization gradients varied across subjects. On initial generalization tests, 7 of the 8 subjects showed relatively broad generalization with response suppression in the presence of all stimuli on the $S^D_p$ end of the line-length continuum. By the fourth generalization test, 2 subjects showed no suppression at any line length. The other 6 subjects showed one of two patterns of generalization: Three subjects showed U-shaped gradients with suppression limited to stimuli closest to $S^D_p$, and the other 3 continued to show generalized suppression at all line lengths on the $S^D_p$ end of the continuum.

It is unknown why 2 subjects (H101 and H107) showed progressively diminished stimulus control across the four test sessions, with response rate in the presence of all stimuli either near or above prepunishment levels on the last test. This loss of stimulus control could have been due to the relatively small number of $S^D_p$ components in test sessions. In training, half of the components were $S^D_p$ components, but in testing only 2 of 38 (for H107) or 4 of 40 (for H101) components were $S^D_p$ components. Thus, fewer total punishers were delivered during testing than in training. This loss of stimulus control might be less likely with a greater proportion of $S^D_p$ components in test sessions. Presenting $S^D_p$ more frequently than other stimuli in testing, however, may affect generalization. For example, Thomas, Windell, Williams, and White (1985) found that after discrimination training with reinforcement, presenting the extinction-correlated $S^\Delta$ more frequently than other stimuli greatly increased responding in the presence of stimuli located between $S^D$ and $S^\Delta$ and shifted the gradient peak toward $S^\Delta$. Other studies have found similar gradient shifts toward the stimulus presented most frequently in testing (e.g., Hebert, Bullock, Levitt, Woodward, & McGuirk, 1974; Thomas et al., 1992).

The variables that produced the asymmetrical generalization gradients obtained in the present study are not known. The potential influence of collateral verbal behavior on subjects' responding during generalization testing, however, must be considered. It is possible that subjects labeled the training stimuli "short" and "long" and that responding in the presence of each test stimulus was determined in part by whether the subject labeled it as short or long. The instruction given prior to the second training phase that subjects were to "lose points in the same way" may have increased the probability of such labeling effects. The influence of stimulus labeling, established by either the experimenter or the subject, has been well documented. Stimulus generalization may be attenuated when the stimuli are readily labeled (e.g., line lengths, colors; Thomas & Thomas, 1974) and potentiated when they are not (e.g., pure tones; Baron, 1973). That is, when subjects are trained to label the stimuli, gradients tend to be steeper than when labeling is not trained. Future studies could determine the influence of stimulus labeling on the present results by directly training it and by using stimulus dimensions that are more difficult to label than line length.

Although the role of verbal processes in the present study remains unclear, it is clear that generalization was limited with most subjects. In 5 of the 8 subjects, generalization was limited to stimuli closest to $S_p^D$, and, as noted, for 2 subjects punishment effects eventually dissipated. These results suggest that the generalization of punishment effects will need to be programmed explicitly if that is a desired outcome (see also Azrin & Holz, 1966; Lovaas & Newsom, 1976), and that generalization technology does not yet have an adequate foundation of basic research.

Most laboratory work on punishment has involved unconditioned positive punishers. A complete understanding of the punishment process requires knowledge of conditioned punishers, including conditioned negative punishers. Conditioned negative punishers (e.g., timeout, token loss, loss of money, and fines) are the aversive events used most often to reduce undesirable behavior with children, persons with developmental disabilities, and society in general (e.g., fines and incarceration). Furthermore, these events frequently are delayed. Thus, knowledge gained about the effects of conditioned punishers may be more relevant for application than are effects of unconditioned punishers. We may not be able to simply assume functional similarity of conditioned and unconditioned punishers and extrapolate findings from unconditioned punishment to situations using conditioned punishment.

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## APPENDIX

This is a situation in which you can earn money by pressing and releasing a lever or pulling a plunger. Sometimes a small yellow box will appear in the top right corner of the screen. If you move the mouse cursor into this box and press the left mouse button, you will hear a tone and points will be added to your score, and the box will flash then disappear. If you do not move the cursor into the box and press the mouse button within 5 seconds the box will disappear, and points will not be added to your score. Sometimes you will hear a tone and points will be subtracted from your score. Throughout the experiment your point total will be shown in a box at the top of the screen. At the end of the experiment you will receive 12 cents for every 1,000 points in your score (e.g., 100,000 points equals $12).

It is very important that you come to every session. If you come to all scheduled sessions you will receive a bonus of $50. If, however, you miss a session without first informing an experimenter, you will not receive the bonus, and furthermore, you will lose $5 for missing the session.

Do not touch anything on the computer,

keyboard, or screen because this may crash the program and lose your points. Press the lever or pull the plunger, do not hit it! If you hit the lever or plunger you may damage the equipment and lose all your points.

Sometimes throughout the session, you will see a gray horizontal line in the center of the computer screen. Before you can begin pressing the lever or pulling the plunger and earning points, this line must be red. You can change the color of the line by doing the following: (1) Position the mouse cursor over the LEFT end of the line; (2) Press the LEFT mouse button until the line flashes briefly; (3) Position the mouse cursor over the RIGHT end of the line; (4) Press the LEFT mouse button until the line changes color. You can press the lever or pull the plunger to earn your points only if the line is red. Repeat the above instructions whenever you see a gray line until the line is red. Remember to click on the LEFT side of the line first, then on the RIGHT side, and always to use the LEFT mouse button.