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STIMULUS GENERALIZATION, DISCRIMINATION LEARNING, AND PEAK SHIFT IN HORSES

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Using horses, we investigated three aspects of the stimulus control of lever-pressing behavior: stimulus generalization, discrimination learning, and peak shift. Nine solid black circles, ranging in size from 0.5 in. to 4.5 in. (1.3 cm to 11.4 cm) served as stimuli. Each horse was shaped, using successive approximations, to press a rat lever with its lip in the presence of a positive stimulus, the 2.5-in. (6.4-cm) circle. Shaping proceeded quickly and was comparable to that of other laboratory organisms. After responding was maintained on a variable-interval 30-s schedule, stimulus generalization gradients were collected from 2 horses prior to discrimination training. During discrimination training, grain followed lever presses in the presence of a positive stimulus (a 2.5-in circle) and never followed lever presses in the presence of a negative stimulus (a 1.5-in. [3.8-cm] circle). Three horses met a criterion of zero responses to the negative stimulus in fewer than 15 sessions. Horses given stimulus generalization testing prior to discrimination training produced symmetrical gradients; horses given discrimination training prior to generalization testing produced asymmetrical gradients. The peak of these gradients shifted away from the negative stimulus. These results are consistent with discrimination, stimulus generalization, and peak-shift phenomena observed in other organisms.

Key words: stimulus generalization, peak shift, discrimination learning, circles, lever press, horses

"There is definitely something wrong with the way the horses are handled," wrote Skinner (1983, p. 82) after making several visits to a horse barn. "Their control is almost exclusively aversive. I am going to talk to the teacher in charge of the horses and unless she thinks it likely to 'spoil' the present training, I'll try to . . . shape some behavior" (p. 82). Armed with a frying pan and a bicycle horn, Skinner began to shape the behavior of a horse named Mama. Using the frying pan to feed small amounts of oats or hay to Mama and the horn's sound as a conditioned reinforcer, he shaped Mama to turn her head to one side. Later, Skinner could hold Mama's head so that a bridle could be placed on her head and a bit placed in her mouth. But soon his investigation was halted after a rider in the barn informed him that he had violated a fundamental rule of horse training: "You must not be nice to a horse." By positively reinforcing desired behavior, he was found guilty of "spoiling" (p. 83) the horse. He abandoned his investigation. These observations, presented in Skinner's autobiography, well characterize the attitudes of horse handlers today: Few types of behavior are controlled by positive reinforcement.

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Equally surprising, considering the millions of dollars spent in the horse industry each year, is that few researchers have systematically investigated the control of the behavior of horses by contingencies of reinforcement. Gardner (1933, 1937a, 1937b) began a series of experiments in 1931 to study horses' acquisition of a simple choice discrimination task. These studies were large, involving more than 60 horses and several breeds. In each of these experiments, horses were required to choose one of three covered feed bins; a black cloth's position signaled in which bin a grain reinforcer was available. Gardner recorded the number of trials required to learn the different discriminations. His results indicated that horses were capable of learning simple choice discriminations. Years later, Myers and Mesker (1960) conditioned a single horse to nudge a lever horizontally; the researchers then collected cumulative records under several fixed-ratio and fixed-interval schedules. Their records revealed patterns similar to those of rats and pigeons. Others, although not specifically interested in operant behavior, have successfully shaped and maintained discriminated operants to examine horses' hearing abilities using both water as a positive reinforcer and shock in an avoidance procedure (Heffner & Heffner, 1984, 1986).

This lack of operant research and the observation that trainers and riders infrequently ask about the role of positive reinforcement in the control of horse behavior led us to the present investigation. In this investigation, we studied three aspects of the stimulus control of positively reinforced responding and determined whether horses were controlled by environmental stimuli in a manner similar to other species. Three basic phenomena—stimulus generalization, discrimination learning, and peak shift—were chosen because they have been thoroughly documented and reflect a widespread yet subtle environmental influence.

Stimulus generalization is said to have occurred when behavior that is first conditioned to a specific stimulus also occurs in the presence of other similar stimuli. The stimulus used during conditioning is referred to as the positive stimulus (S+). The similar stimulus, which is correlated with extinction, is referred to as the negative stimulus (S−). From generalization testing procedures, a gradient is obtained that reflects the extent to which behavior is controlled by a stimulus that sets the occasion for a reinforcer.

Guttman and Kalish's (1956) classic study is probably the most well-known generalization experiment. Using 11 wavelengths of light, they demonstrated that pigeons show orderly generalization gradients. Many other investigators have explored generalization using other stimulus dimensions, including auditory intensity (Pierrel, 1958), visual intensity (Blough, 1959), light-flicker rate (Sloane, 1964), line orientation (Bloomfield, 1967; Thomas & Lyons, 1968), and object size (Brush, Bush, Jenkins, John, & Whiting, 1952; Grandine & Harlow, 1948; Grice & Saltz, 1950; Jenkins, Pascal, & Walker, 1958), and other species, including rats (Grice & Saltz, 1950; Pierrel, 1958), goldfish (Fay, 1970), monkeys (Grandine & Harlow, 1948), ducks (Tracy, 1970), and humans (Gulliksen, 1932; Kalish, 1958; McKinney, 1933; Rosenbaum, 1953). These generalization experiments have typically found that the modal frequency was recorded at the S+, with fewer responses being recorded to the other stimuli as the interval between the S+ and each successive stimulus became greater.

But the modal frequency does not always lie at the S+. After discrimination training, in which the subjects learn to discriminate between an S+ and a selected S−, a subject's modal frequency on the stimulus generalization gradient can lie at a novel stimulus. This is the peak-shift phenomenon introduced by Hanson (1959; see Purtle, 1973, for a review). Hanson trained pigeons to discriminate between wavelengths of light projected on a response key. In the presence of the S+, pecking was reinforced on a variable-interval (VI) 60-s schedule; in the presence of the S−, pecking was never reinforced. Groups of subjects differed in the difficulty of the discriminations they were required to make. After pigeons successfully discriminated between the S+ and S−, a stimulus generalization gradient was collected. Discrimination training had a systematic effect on the generalization gradients: It shifted the peak of the generalization gradient to a novel stimulus. Furthermore, subjects' generalization gradients occupied more area on the side opposite the S−, compared to a control group receiving no discrimination training. The distance of the gradient's shift was determined by how close, along the generalization dimension, the S− (used during training) had been to the S+. An inverse relationship existed: The closer the S+ and S− were, the farther the peak shifted.

Since Hanson's (1959) experiment, the peak-shift phenomenon has been observed using many stimuli and many species. Researchers have successfully used the following stimulus dimensions: wavelengths of light (Blough, 1969; Thomas, 1962), visual intensity (Ernst, Engberg, & Thomas, 1971), auditory stimuli (Migler & Millenson, 1969; Moody, Stebbins, & Iglauer, 1971; Pierrel & Sherman, 1960; Thomas & Setzer, 1972), line-tilt dimensions (Bloomfield, 1967; Thomas & Lyons, 1968), floor-tilt dimensions (Riccio, Urda, & Thomas, 1966; Thomas, 1969), and object size (Brush et al., 1952; Jenkins et al., 1958). Most of this research has used rats and pigeons, but other organisms, including humans (Doll & Thomas, 1967), guinea pigs (Thomas & Setzer, 1972), goldfish (Ames & Yarczower, 1965), chickens (Rudolph & Honig, 1972), and monkeys (Moody et al., 1971), have also shown peak shift.

The present experiment provides new information about horses by systematically investigating stimulus generalization and peak shift and expands the generality of stimulus control principles to include horses.

METHOD

Subjects

Four quarter horses, Bud Dark, Lady Bay, Bubba, and Scarlet, participated in the experiment. The subjects' ages, sex, and weights varied: Bud Dark was a 26-year-old gelding weighing 431 kg; Lady Bay was a 25-year-old mare weighing 408 kg; Bubba was an 8-year-old gelding weighing 522 kg; and Scarlet was a 14-year-old gelding weighing 499 kg. All weights were estimated from girth measurements. These horses remained housed together in a barn, each in a separate stall, when not participating in the experiment.

Apparatus

Horses were tested in their own rectangular stalls, which served as the experimental chambers. The front and back walls measured 3.7 m and the side walls measured 2.7 m. All walls were wood and extended 2.4 m above the sod floor. A door to the stall, 1.5 m in width and 2.4 m in height, was positioned in a corner along the front wall. Two overhead lights, each 125 W, plus daylight provided general illumination in the stall. During experimental sessions, an experimental panel was mounted in the doorway; the panel was 127.0 cm above the floor (measured from the bottom of the panel).

A stimulus projector, a lever, and a food dispenser were positioned on the experimental panel, which was 55.9 cm long by 43.2 cm wide. The stimulus projector was mounted on a 17.8-cm square opening, centered in the panel, 10.2 cm from the top. Bolted on the front side of this opening was a 6.4-mm-thick shield of transparent Plexiglas. On the back of the panel, a frame held 20.3-cm-wide Plexiglas panels, on which stimuli were mounted. Directly behind this frame was a 40-W bulb that illuminated the stimuli. The lever was a Gerbrands rat lever (G6312) that required 0.40 N of force for operation. This lever was centered 45.7 cm from the top of the panel and 12.7 cm from the left side. The lever itself was 5.1 cm wide, 1.3 cm thick, and protruded 17.5 mm from the surface of the lever housing. A grain dispenser released grain from behind the panel; the grain fell through a 12.7-cm by 6.4-cm opening in the panel into a feed tray. The grain chute, 27.9 cm in length, was attached to the back of the panel and sloped at a 45° angle. A flap was constructed near the top of the chute to hold a charge of grain; this flap released grain with the use of a solenoid, which was controlled by the experimenter. The opening in the front side of the panel was centered 61.0 cm from the top and 12.7 cm from the right side of the panel.

Nine stimuli were used. The stimuli were solid black circles ranging from 0.5 in. (1.3 cm) to 4.5 in. (11.4 cm) in diameter, increasing in 0.5-in. increments (i.e., 1.3, 2.5, 3.8, 5.1, 6.4, 7.6, 8.9, 10.2, and 11.4 cm). The circles were printed on plain white paper, laminated with clear plastic, and mounted on 20.3-cm-wide panels of Plexiglas. These panels provided nine durable and rigid stimuli that could be slid into the frame of the stimulus projector and illuminated from behind the panel.

The lever and food dispenser were connected to a 28-V control panel, which counted responses and reinforcements and allowed the lever to deliver grain when the experimenter held a circuit closed.

Procedure

An oat-molasses mixture and hay were available in quantities normally received prior to the experiment; during a feeding approximately 2 quarts of grain and a quarter of a bale of hay were given to each horse. The grain used during each experimental session was taken from each horse's daily ration. All horses were fed twice each day, once in the morning and once again in the evening after participating in the experiment.

The method of successive approximations (Ferster & Skinner, 1957) was used to train all horses to press the operant lever. One-quarter cup (60 mL) of grain, a highly preferred food, was delivered to reinforce desired behavior. A maximum of 7.5 cupfuls (1.8 L) of grain were given in a single session.

On the day following successful shaping of the operant response (pressing the response bar) preliminary training began. Continuous reinforcement (CRF), VI 15-s, and VI 30-s schedules were used to maintain responding. Subjects participated in four sessions on the CRF schedule and three sessions on each of the interval schedules. All sessions were performed at the same time each afternoon.

Each horse was assigned randomly to a condition. Two horses, Bud Dark and Lady Bay, were assigned to the first condition, which included a stimulus generalization gradient procedure followed by a peak-shift procedure. Two horses, Bubba and Scarlet, were assigned to the second condition, which included only the peak-shift procedure. Both procedures were similar to Hanson's (1959), except for a few modifications to meet the horses' and equipment's needs.

For all subjects, participation began with a minimum of 5 days (including the three preliminary training sessions) on a VI 30-s reinforcement schedule. During this time the S+ (the 2.5-in. circle) was presented 30 times for 60 s (the stimulus-on periods); each of these periods was separated by a 10-s stimulus-off period. During the stimulus-off period, the stimulus projector remained dark and responses were not reinforced; the intervals did not include the stimulus-off period. The intervals used were derived from Fleshler and Hoffman (1962) progressions (using 60 intervals). All subjects remained in this VI 30-s procedure until they met a 250-response per session criterion.

Stimulus generalization procedure. Ten testing blocks, each block containing a random presentation of all nine stimuli, were given. Testing was performed using an extinction procedure: No reinforcers were given during the test blocks. Each stimulus was presented for 60 s, separated by a 10-s stimulus-off period that allowed time to change the stimuli. Each block was preceded by a pretest series consisting of three 60-s S+ presentations (each separated by a 10-s stimulus-off period) during which a total of six reinforcers was given on the VI 30-s schedule. The pretest series and test series were alternated until both had been administered 10 times. By the end of the test session, 60 reinforcers had been delivered, and each of the nine stimuli had been presented 10 times. Responses were recorded for each of the stimuli presented. Without intervening training, this test procedure was repeated on the next day, concluding the stimulus generalization procedure.

Peak-shift procedure. The peak-shift procedure began with discrimination training. After the horses met the 250-response requirement in the preliminary training procedure, the S− was introduced. For all subjects the S− was a 1.5-in. circle. Sessions were divided into six blocks. Each block contained 10 stimulus presentations: The S+ and S− were each presented five times. The order was determined by a random number chart, with the exception that no stimulus occurred more than three times in a row. During S+ presentations, subjects received grain reinforcement on a VI 30-s schedule. Each presentation was 60 s, separated by a 10-s stimulus-off period, with one exception: Responses made during the S− extended the duration of the S− for an additional 30 s. This exception prevented accidental reinforcement of responding during the S− by the appearance of the S+. The criterion for successful discrimination training was the completion of a block (of 10 presentations) with no responses occurring during any S− presentations. Two days of stimulus generalization testing followed; testing was identical to that in the stimulus generalization procedure.

RESULTS

All subjects were quickly shaped to press the response lever. Bud Dark, Scarlet, and Bubba were successfully conditioned in one session and Lady Bay in two. The elapsed time between the beginning of the conditioning procedure and the first recorded response was short, and the reinforcers required were few: 21 min and four reinforcers for Bud Dark, 8 min and five reinforcers for Scarlet, 25 min and nine reinforcers for Bubba, and 53 min and 35 reinforcers for Lady Bay (across two sessions).

The topographies of the response differed among subjects. Both Bubba and Scarlet pressed the lever with their lips. Bud Dark used his nose to depress the lever; he usually rubbed his nose on the left hand side of the apparatus, moving it vertically from the top of the apparatus to the bottom. Lady Bay held the lever between her teeth, moving it up and down with vertical head movements. After acquiring the operant, subjects rarely left the vicinity of the apparatus and completed most preliminary training sessions in the shortest time possible.

All subjects met the 250-response criterion in the first five sessions. Mean rates of responding on the VI 30-s schedule varied considerably: Bud Dark averaged 14.1 responses per minute, Scarlet averaged 20.0 responses per minute, Lady Bay averaged 31.7 responses per minute, and Bubba averaged 78.6 re-

Table 1
Rates of responding (responses per minute) for each horse during the 5 days of VI 30-s preliminary training.

	Session					
Subject	1	2	3	4	5	$\bar{x}$
Bud Dark	12.3	14.9	15.1	13.4	15.0	14.1
Lady Bay	44.9	28.3	26.0	22.2	37.2	31.7
Bubba	79.6	71.3	76.8	83.5	81.7	78.6
Scarlet	16.1	20.1	21.5	21.1	21.0	20.0

sponses per minute. Rates of responding for each horse during each session of the VI 30-s schedule are presented in Table 1. These five (VI 30-s schedule) sessions completed the preliminary training procedure.

Stimulus Generalization

Preliminary training for Bud Dark and Lady Bay was immediately followed by two consecutive sessions of stimulus generalization testing; their generalization gradients are shown in Figure 1. The total number of responses made to each of the nine stimuli during both test sessions were summed. The two gradients were similar in that both gradients' modal response frequency was located at the S+, and both gradients were symmetrical. The percentages of total responses contained under the gradients, on each side of the S+, were nearly identical for the 2 subjects: Bud Dark's gradient contained 48% of the total number of responses on the left side, and Lady Bay's gradient contained 52% of the total number of responses on the left side. The 2 horses also emitted a similar number of responses during testing: Lady Bay emitted 2,634 responses, and Bud Dark emitted 2,236 responses. Lady Bay's stimulus generalization gradient was broader than Bud Dark's gradient.

Discrimination

The peak-shift procedure began with discrimination training and was followed by stimulus generalization testing. During the early stages of discrimination training, Lady Bay's Scarlet's, and Bubba's responding came under the control of the S+ (2.5-in. circle) and the S− (1.5-in. circle). The number of responses made during the S− periods rapidly declined during the first few sessions, as can be seen in Figure 2. The number of sessions required to meet the discrimination criterion (zero re-

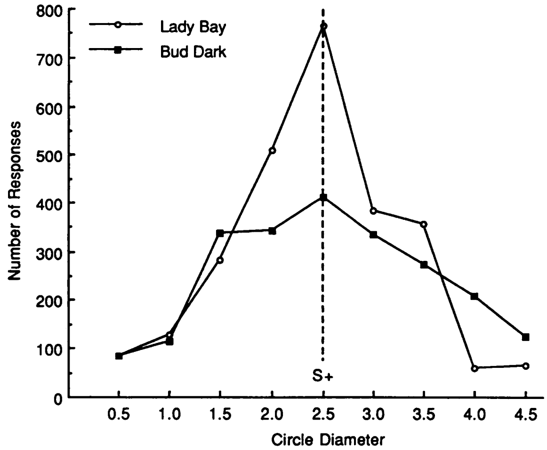

Fig. 1. Number of responses made by Lady Bay and Bud Dark during 2 days of stimulus generalization testing. Both horses made more responses to the positive stimulus (2.5-in. circle) than to any of the other eight stimuli.

sponses to the S− in a block containing five S− and five S+ presentations) varied. Lady Bay, Bubba, and Scarlet, acquired the discrimination after 7, 11, and 15 sessions, respectively. Lady Bay, who had previously been in the generalization procedure, met the discrimination criterion in only 7 days. Bud Dark, who had also previously been in the generalization procedure, was dropped from the experiment when his rate of responding during the 15th session fell to near zero. Why Bud Dark ceased responding is unclear; it may have been related to his advanced age.

Peak Shift

After completing the discrimination training, Lady Bay, Bubba, and Scarlet were tested for stimulus generalization. The results from the generalization testing are shown in Figure 3; all gradients show a peak shift. Lady Bay and Bubba's gradients both peak at one stimulus above the S+; their modal frequencies are located at the 3.0-in. circle. Scarlet's gradient, on the other hand, peaks even farther away from the S+; his modal frequency is located two stimuli above the S+, at the 3.5-in. circle.

Besides a peak shift, these generalization gradients also show area shifts. Less area was under the gradients on the side where the S− was located. The percentages of the total number of responses located on the left side of the S+ for Lady Bay's, Scarlet's, and Bubba's gra-

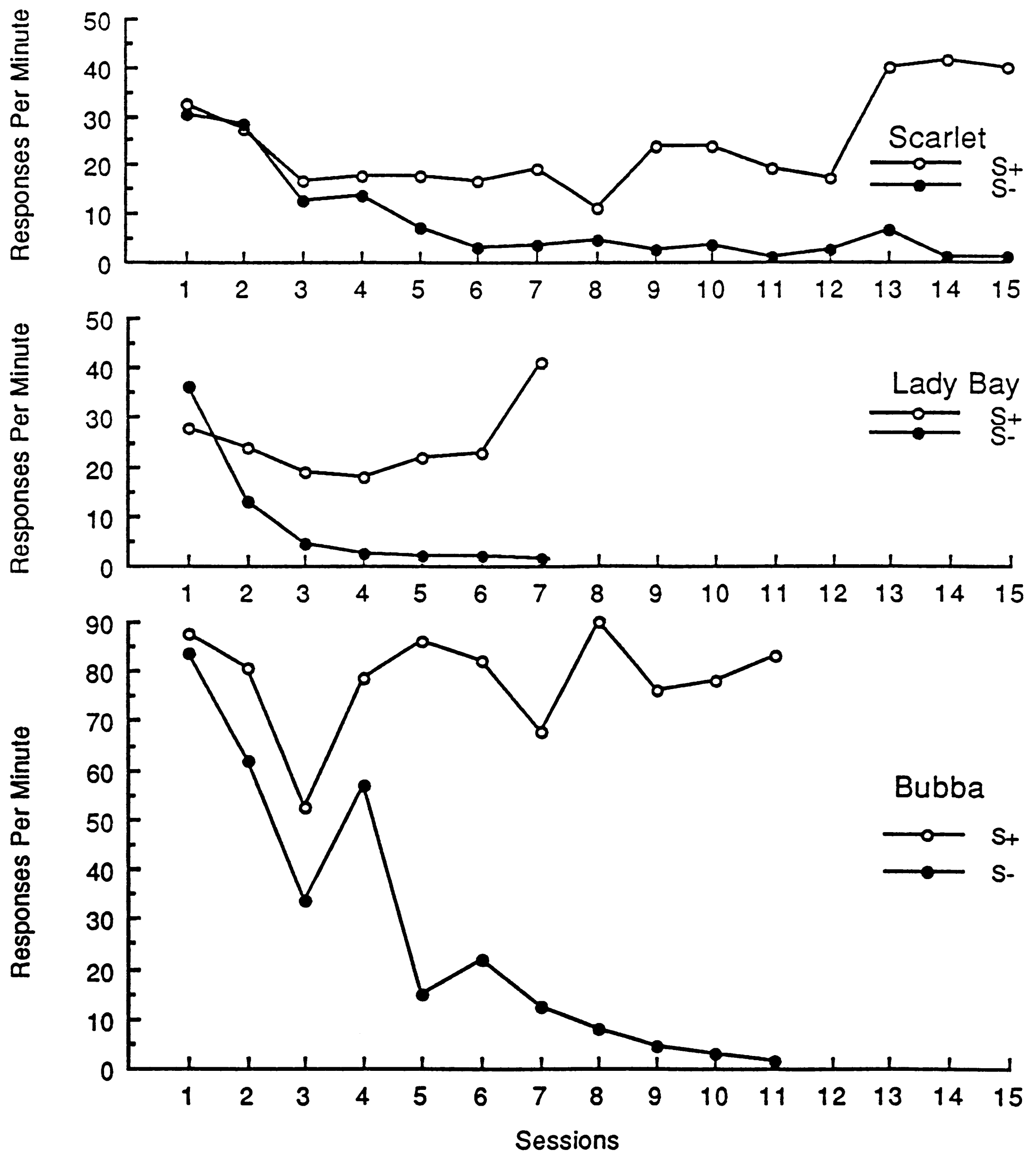

Fig. 2. Rates of responding for Scarlet, Lady Bay, and Bubba during positive stimulus (S+) and negative stimulus (S−) presentations during each session of discrimination training. The S+ was a 2.5-in. circle; the S− was a 1.5-in. circle. During the S+, a grain reinforcer was available on a VI 30-s schedule. All 3 subjects acquired the discrimination criterion of zero responses to the S− throughout a block of stimulus presentations, which consisted of five S+ and five S− stimuli given in a random order. This criterion was met by all 3 subjects within 15 sessions.

dients are 37%, 37%, and 40%, respectively. The total number of responses emitted during generalization testing for Lady Bay, Scarlet, and Bubba were, 1,722, 1,816, and 3,604, respectively.

DISCUSSION

Results of the present experiment were straightforward: Lever pressing was controlled by environmental stimuli in a manner similar to that of other organisms. The stimulus generalization procedure produced gradients with a modal frequency lying at the S+. The peak-shift procedure, which included a period of discrimination training, produced shifts in the modal frequency with the modal frequency lying at a novel stimulus. Although these results are consistent with previous findings, several specifics of the data are worth mentioning.

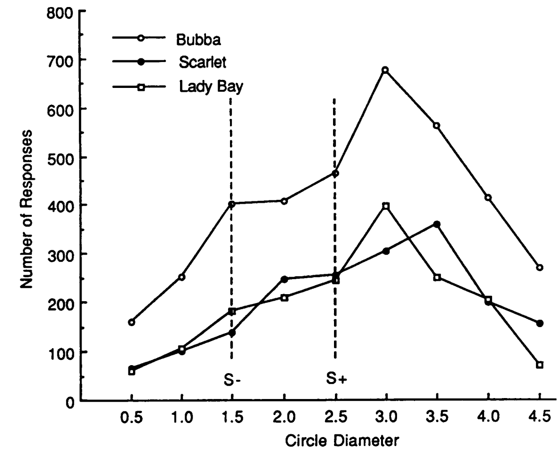

Fig. 3. Stimulus generalization gradients obtained from Bubba, Scarlet, and Lady Bay immediately following discrimination training. Subjects were first trained to discriminate between an S+ (a 2.5-in. circle) and an S− (a 1.5-in. circle) and were then given 2 days of generalization testing. Discrimination training produced gradient shifts. Horses made more responses to a novel stimulus located opposite the S−; Bubba's and Lady Bay's gradients peaked at the 3.0-in. circle, and Scarlet's gradient peaked at the 3.5-in. circle.

The shaping of the horses' lever press proceeded in a manner similar to the shaping of responses in other research organisms. This shaping procedure, described by Ferster and Skinner (1957), includes three steps: (a) adaptation to the experimental apparatus, (b) magazine training, and (c) the conditioning of the operant. Adaptation to the experimental apparatus occurred rapidly. As soon as the apparatus was placed in the stall's doorway, all horses began to explore the apparatus, usually by licking the food bin mounted directly below the apparatus. While the animals were near the apparatus, magazine training began; it, too, went quickly. Magazine training began with a delivery of grain. All horses consumed the grain immediately. Their rates of consumption were slow at first, taking many minutes to consume the small amount of grain delivered, but their rate increased sharply after the first few deliveries. Soon horses would take no longer than 30 s to consume the grain. The sounds of the solenoid and of the falling grain controlled approach behavior. No matter what the horse's orientation (rarely did a horse leave the proximity of the apparatus), it would go to the feed bin immediately after the grain dispenser was operated. Conditioning of the lever press also went quickly, taking only minutes in a couple of cases. During the shaping period, horses frequently swayed from side to side in front of the response panel. Also, after the first few grain deliveries, all horses spent a lot of time licking the feed bin and the opening from which the grain was delivered. In all cases, the first lever press was associated with licking the response lever. This licking response drifted during the first few sessions to other stereotypical responses specific to each horse. Also during the shaping procedure, and later during the experimental procedures, other recurrent types of behavior were observed. Among these were pawing, kicking, and nudging at the apparatus, especially during long interreinforcement intervals. At other times, horses would either nudge the feed bin with their noses or grasp the feed bin with their teeth and shake it.

Another interesting result was the shape of the generalization gradients: They were symmetrical. Other researchers, using circles of varying diameters, have found generalization tending to be greater on the side of the gradient with the larger stimuli (e.g., Brush et al., 1952; Jenkins et al., 1985). For example Brush et al. found pigeons' rates of responding higher at the larger end of the stimulus dimension. Because the two experiments in which asymmetrical gradients were observed both used pigeons, the difference between those experiments and this one may reflect a difference between the behavior of horses and pigeons.

Together, the present experimental results strengthen the generality of behavioral analysis by extending the principles of stimulus control to include horses. In the future, it would be interesting to explore the extent to which positive reinforcement could be used in both research and applied settings: To what extent can the behavior of horses be controlled by using positive contingencies? Behavior of horses is controlled by environmental stimuli in a manner similar to other organisms.

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