ANALYSIS OF A GUIDED-RESPONSE PROCEDURE IN VISUAL DISCRIMINATIONS BY RATS

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A guided-response procedure was used to train a visual pattern discrimination by rats in a modified Sutherland box. The method consisted of guiding the animal to the correct choice by means of a retractable bridge that led to reinforcers, followed by gradually removing this prompt. This method was compared to a stimulus-fading procedure, in which the initial differences between discriminative stimuli were gradually faded until they differed only with respect to the critical dimension for discrimination, and to a trial-and-error procedure. Both gradual procedures resulted in fewer errors compared to the trial-and-error procedure. The higher efficiency of the fading procedures was attributed to less aversiveness derived from performance with few errors and to the use of step-by-step requirements relative to the criterion performance.

Key words: guided response, prompt, fading, visual discrimination, choice, rat

A procedure for errorless discrimination training was described by Terrace (1963). It consisted of a gradual modification, or fading, of the negative stimulus (S-) on one or more dimensions, until S- differed from the positive stimulus (S+) only on a single dimension. Since then, the effectiveness of stimulus-fading procedures has been demonstrated in a variety of settings. It has been used with different populations, including adult patients (Barlow & Agras, 1973; Wulbert, Nyman, Snow, & Owen, 1973), normal children (Corey & Sharrow, 1972), retarded persons (Dorry, 1976; Dorry & Zeaman, 1973; Sidman & Stoddard, 1967; Touchette, 1968) autistic children (Ettel & LeBlanc, 1979), and brain lesioned animals (Guic-Robles, Venable, Acevedo, Aramburu, & Pinto-Hamuy, 1982) where visual-pattern discrimination was reestablished with fading procedures after complete removal of all visual cortex.

Within-stimulus prompts (e.g., modifica-

tion of S+, S-, or both) have been studied in children (Schreibman & Charlop, 1981) and rats (Guic & Gormaz, 1976); extra-stimulus prompts (e.g., pointing) have been studied with autistic children (Schreibman, 1975; Schreibman, Charlop, & Koegel, 1982) and with retarded adults (Zawlocki & Walls, 1983). The contributions of such prompts to childrens' learning of conditional discriminations (Schilmoeller, Schilmoeller, Ettel, & LeBlanc, 1979) and to reversal learning in children (Gollin & Savoy, 1968) and rats (Aronsohn, Castillo, & Pinto-Hamuy, 1978) also have been studied. Failures of the fading procedure to establish stimulus control without errors have been reported when such prompts are removed in later stages of the learning process (Anderson & Faust, 1967; Koegel & Rincover, 1976; Newson & Simon, 1977).

Most studies of establishing stimulus control without errors have emphasized modification of the stimulus. As a result, some aspects of Terrace's (1963) demonstration have been neglected. Terrace pointed out that initial changes of the stimulus components were made when "the bird did not seem to the experimenter to be in a favorable position to strike the key" (1963, p. 5), that is, when the response probability was low. However, he initially introduced S- at such a short duration that the animal had no chance to respond. Thus, in addition to using stimulus modification to control behavior, Terrace's procedure directly ma-

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Fig. 1. Modified Sutherland jumping box, with additional bridge.

nipulated the likelihood that a response during S- could occur.

We report a technique in which response fading is considered. Specifically, a bridge initially led the animal to the correct choice. On successive trials, the bridge was shortened gradually until finally the animal chose only on the basis of differences in the discriminative stimuli. To our knowledge, no previous attempt has been made to train animals in a choice situation in which response guidance was faded out without forcing the subject to emit a specific response. The most closely related procedure is found in studies with retarded children where response guidance is provided and then removed gradually while the discriminative stimuli are held constant. For example, Aeschleman and Higgins (1982) gradually increased the time interval between a prompt and the onset of a trial while "all pairs of stimuli were presented at equal and maximal saliency" (p. 283). Richmond and Bell (1982) removed a pointing prompt in several stages. Discriminative stimuli were at criterion level on each trial; the dimension on which the prompt changed was the proximity of the pointing prompt to the center of S+. Neither Aeschleman and Higgins nor Richmond and Bell found that these procedures improved discrimination performance relative to other discrimination learning procedures.

The present study investigated the development of rats' pattern discriminations in procedures in which either a guided-response procedure, a stimulus-fading procedure, or a trial-and-error procedure was used. We asked whether the guided-response procedure was an effective tool in discrimination training and, if so, how efficient was it compared to an already proven fading paradigm.

METHOD

Subjects

Seventeen female gray rats weighing a mean of 270 g were used. They were housed in standard laboratory conditions with water *ad libitum*. Food was restricted to maintain them at approximately 85% of their free-feeding weights.

Apparatus and Procedure

As illustrated in Figure 1, the apparatus was a modified Lashley jumping stand (Sutherland box) that consisted of a roofless wooden box, 107 by 46 by 50 cm, with a central Y-shaped platform 15 cm above the floor of the box. The arms of the Y faced two wooden panels placed at an angle of 130° and with 14 by 14-cm openings. These led to compartments where food was available. Metal plates holding the stimuli could be inserted from above into each opening, in front of which landing platforms were located (Sutherland & Mackintosh, 1971). A 6-footcandle (0.55212 cd/m²) stimulus lamp was illuminated over the visual discriminanda. A correct choice resulted in raising of the sliding doors, which provided access to a chamber where two 45-mg food pellets (Noyes) were available.

The pattern discrimination consisted of an erect triangle (S+) versus an inverted one (S-) on a striped background. For the guided-response and trial-and-error groups the discriminanda remained invariant throughout training.

Procedure

Shaping. During pretraining all subjects were placed in the training box in groups of five or six with the food cups full of pellets. Stimulus doors were removed, thus providing free access to the feeding chamber. After two such sessions, the subjects were divided into three groups: guided-response ($n = 5$), stimulus-fading ($n = 7$), and trial-and-error discrimination ($n = 5$).

For the stimulus-fading and trial-and-error subjects, shaping consisted of establishing a jumping response in front of gray neutral stimuli. The distance between the starting and landing platforms was increased gradually from 0 to 14 cm as a function of the rats' behavior. Walking over the bridge towards either door, covered by plain gray cardboard stimuli, was

shaped in the guided-response group rats (see below).

Training. For guided-response subjects' training, a retractable bridge was inserted between the Y platform and the landing platform on the side where S+ appeared on each trial. The bridge was shortened by 1-cm steps up to Step 11, and then by 0.5 cm on successive steps until it was removed by Step 18.

For the stimulus-fading subjects, the S- area was increased gradually in 17 steps, from 1.44 cm² to 40.8 cm², until it equaled the size of S+. The width of the background stripes was increased simultaneously from 0 to 1.3 cm (See Figure 2).

For the stimulus-fading and guided-response subjects, a criterion of four consecutive correct responses was required to advance to the next step of the sequence. The step sequence for these two gradual procedures was based on empirical data derived from preliminary work. If either three consecutive or a total of four errors occurred on any step, the sequence was taken back one step until the required criterion was met. Once the animals exposed to the stimulus-fading procedure had completed the entire sequence, a final session occurred with the discriminanda at full size. A criterion of 80% or more correct responses was required to end training. The same criterion had to be met by subjects exposed to the guided-response procedure during a final test session when the bridge was absent. If this criterion was not met, further sessions occurred until it was met. For trial-and-error subjects, training was continued until a criterion of at least 80% correct responses was reached.

Throughout training, an incorrect choice resulted in removal of the subject from the landing platform without reinforcement. Each session, which occurred daily, was comprised of 20 trials.

RESULTS

Performance of the subjects trained by the trial-and-error procedure differed from that of the subjects trained by the fading and guided-response procedures. The former committed more errors and required more trials to reach criterion than the other two. Figure 3 shows the total number of trials to criterion and errors during training for each subject. That the type of training affected the outcome was substan-

Steps	Illumination (ft - cd)		Area Δ S- (cm ²)	Area Proportion S+ : S-	Width of Stripes (cm)	S+	S-
	S+	S-					
1	6	0.0	.00	1 : 0.00	—
2	6	0.5	1.44	1 : 0.03	—		
3	6	1.0	2.41	1 : 0.05	0.05		
4	6	1.5	3.22	1 : 0.07	0.1		
5	6	2.0	3.90	1 : 0.09	0.2		
6	6	2.5	4.32	1 : 0.1	0.3
7	6	3.0	6.27	1 : 0.15	0.4		
8	6	3.5	6.63	1 : 0.16	0.45		
9	6	4.0	8.38	1 : 0.2	0.5		
10	6	4.5	9.22	1 : 0.22	0.55		
11	6	5.0	10.10	1 : 0.24	0.6		
12	6	5.5	11.75	1 : 0.28	0.7		
13	6	6.0	14.82	1 : 0.36	0.8
14	6	6.0	23.1	1 : 0.56	0.9		
15	6	6.0	27.8	1 : 0.68	1.0		
16	6	6.0	31.8	1 : 0.78	1.1		
17	6	6.0	33.4	1 : 0.81	1.2		
18	6	6.0	40.8	1 : 1	1.3

Fig. 2. Sequence of training steps for subjects exposed to the stimulus-fading procedure. The following features were systematically adjusted during fading: illumination of S+ and of S- (footcandles); S- area (cm²); proportion of S+:S-; and width of stripes (cm). Samples of discriminanda are shown for steps 1, 6, 13, and 18.

tiated by statistical analysis. A one-way ANOVA was performed for trials to criterion ($F(1, 16) = 29.55, p < .0001$) and errors committed ($F(1, 16) = 48.52, p < .0001$). Multiple comparisons done with the SNK test (Steel & Torrie, 1980) showed that the stimulus-fading and guided-response training did not differ significantly from one another but both yielded significantly fewer trials and errors than did the trial-and-error condition ($p < .005$).

Fig. 3. Total trials to criterion and error scores for the individual rats in each of three groups: GR (guided response), SF (stimulus fading), and TE (trial and error).

Individual performances of rats trained with the guided-response and stimulus-fading procedures are shown in Figure 4, which also shows the total number of trials at each step of the discrimination training task. The last column indicates the total trials required to meet criterion in the final step and the percentage of correct trials (numbers above the bar) in the last session. Comparing the performance of subjects exposed to both procedures reveals that errors committed by stimulus-fading subjects were distributed homogeneously throughout training, whereas errors of the guided-response subjects tended to increase in the last steps of the sequence.

DISCUSSION

The results illustrate the establishment of a visual discrimination in a choice situation by a guided-response procedure. The perfor-

mance of the guided-response subjects presumably was controlled both by visual stimuli from the discriminanda and by proprioceptive and visual cues from the bridge. The low error scores of both the stimulus-fading and guided-response subjects may reflect less aversiveness of the fading procedures, which Terrace (1963) had already proposed as one of the advantages of such techniques.

The data in Figure 4 are useful in understanding the development of the discrimination performance. Errors by subjects trained with a guided-response procedure were most frequent during the last few steps of the sequence, where little response guidance occurred; however, subjects trained under stimulus fading emitted unreinforced responses throughout training. During the early stages of the guided-response procedure, there was virtually no choice involved, because no jumping response was required and there was one path leading

Fig. 4. Individual trial scores for GR (guided-response) and SF (stimulus-fading) subjects on each step. Rightmost bars indicate total trials to reach criterion in the final step and percentage of correct responses in the last session (n/b = no bridge; cr = criterion responses).

to the correct stimulus. This represents a successive-discrimination paradigm where only one option to respond is given at a time. Only during later steps did a functional choice de-

velop, which may explain the increase in errors during this phase. The different distribution of errors suggests that different variables may be involved in the development of discrimi-

native control under the two gradual procedures.

Others who have used a guided-response procedure in which the guidance was faded have reported failures with the method. Aeschleman and Higgins (1982) used a condition in which success depended on a child's response being under stimulus control of a pointing cue. In a "delay" group, a child initially was instructed to touch the correct stimulus simultaneously with the experimenter. An interval was then introduced between the onset of the trial and the cue provided by the experimenter. This delay was incremented by 0.5 s through 10 steps. This situation failed to enhance learning. However, as Aeschleman and Higgins mentioned, children were already responding incorrectly before presentation of the prompt. Aeschleman and Higgins reported that, as in the present fading group, errors occurred across all steps.

Other studies of humans have introduced diverse prompts in which the experimenter initially points to the correct stimulus, a prompt that then gradually disappears. In such studies, a differentiation sometimes is made between within-stimulus prompts that involve emphasizing and then fading stimulus components of the relevant feature of the training stimulus and extra-stimulus prompts such as added cues to the test stimuli. Schreibman (1975) reported no success with autistic children when using extra-stimulus prompts, whereas within-stimulus prompts were more effective in training both auditory and visual discriminations (see also Koegel & Rincover, 1976). The distinction between within- and extra-stimulus prompts seems useful in discussions of the effectiveness of fading procedures involving response or stimulus fading. Schilmoeller *et al.* (1979) attributed the effectiveness of within-stimulus prompt procedures to the similarity between criterion-related cues appearing in the initial and the ultimate discrimination. Schreibman (1975) successfully used manual prompts in which the prompt stimulus was incorporated into the training stimulus, which might be considered a type of within-stimulus prompting. In our study, the guided-response procedure also incorporated the response into the prompt. We believe that this feature led to successful results. Further, the response requirements arranged by the prompt were part of the criterion response.

In summary, the guided-response procedure permitted learning with few errors. The efficiency of this procedure may relate to the fact that it is less aversive than discrimination learning with errors. The clear presentation of the situation to the animal is also a factor, because the bridge constitutes the prompt that leads the way to the stimulus correlated with reinforcement.

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