APPLICATION OF A GRADED CHOICE PROCEDURE TO OBTAIN ERRORLESS LEARNING IN CHILDREN¹

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A simultaneous, two-choice color discrimination was carried out with three groups of four- to seven-year-old children. For Groups I and II, the opportunity to respond to the incorrect stimulus was controlled (graded) over three different conditions. First, only a red light (S+) and its retractable bar were presented (16 trials for Group I and 316 trials for Group II). Second, a green light (S-) was added with its correlated bar retracted for 14 trials. Third, 40 trials were given with both stimuli on and their correlated retractable bars extended. The opportunity to respond to S- was not graded for Group III children. They experienced only the third condition applied to Groups I and II. Responses to S+ were reinforced for all three groups, while responses to S- were not. Children in the first two groups made from zero to three responses to S-, while the control children emitted 11 to 46 errors. The results demonstrate that fading in S- or presenting S- early in the training procedure are sufficient, but not necessary conditions for errorless learning.

In the establishment of stimulus control, consideration must be given to procedures that not only shape the response in the presence of the correct stimulus, but also eliminate errors or responses to any other stimulus. Terrace (1963) investigated this aspect of stimulus control with pigeons using a fading procedure on two groups of subjects (early progressive and late progressive) and traditional procedures (early constant and late constant) on two other groups. Only those subjects in the early progressive group made the final wavelength discrimination without errors. From these results, Terrace concluded that two conditions were necessary for the development of stimulus control in which no responding occurs to the negative stimulus (S-). First, S- must be introduced immediately after conditioning the response to the positive stimulus (S+). Second, the initial parameters of S- (duration and intensity) must be gradually increased from some minimum value until S- differs from S+ only in respect to wavelength.

The objective of the present study was to demonstrate that in children, at least, an errorless discrimination, with no responses to S-, could be obtained using a method other than fading. A graded choice procedure was em-

ployed in which the opportunity to respond to S- was shifted from a condition allowing only S+ responses to a condition permitting responses to either S+ or S-.

METHOD

Subjects

Twelve children, ranging in age from 4 to 7 yr, were selected and randomly assigned to one of three groups. As the study progressed, one child (S7) was dropped due to a high anxiety level and an enuretic problem, which was manifested in the middle of the experiment. Another child (S8) was then selected and substituted for S7.

Apparatus

The basic test system, an LVE Modular Human Test Panel (520-03), was located in a dimly lit 4 by 5 ft cubicle. Figure 1 is a diagrammatic representation of the panel showing the location of the various stimuli and response modules. An LVE Penny Coin Dispenser (521-74) was located in the center of the middle rack, immediately below a column of lights (283-06). A Nonsense Syllable Panel (521-63), composed of three Industrial Electronic Engineers (IEE) in-line display cells in a row, was centered on the bottom row with a Retractable Rodent Lever (123-07) mounted on either side. An orienting bar (O.B.) was con-

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Fig. 1. Testing console used which consisted of an LVE Nonsense Syllable stimulus protection unit (521-63), two retractable bars (123-07), orienting bar (O.B.), token dispenser (521-74), and six-bulb indicator light panel.

structed from a 905-1202 pushbutton micro-switch supplied by Allied Electronics and mounted in such a way that its 1.5 in. (4 cm) lever protruded 0.5 in. (1.5 cm) in front of the IEE cells. The Nonsense Syllable panel was used to present visual stimuli in the form of a red and/or green light. No geometric stimuli or letters of the alphabet were used. Only the two outside IEE cells were ever illuminated, the center cell remaining dark throughout the experiment. The red and green lights were randomly alternated from side to side with the probability of red on the right side being 0.50. Pennies earned by the child could be saved in two pharmaceutical vials taped together.

Procedure

Initial instructions. At the beginning of Session 1, the child was seated before the console and given the vials. He was then asked to hold the vials in his non-dominant hand, thereby allowing only the dominant hand to be free for responding. After the child had been told he could earn a quarter by filling the vial full of pennies, the experimenter explained how the pennies could be obtained: "The pennies come out here (experimenter points to the dis-

penser and drops a penny in it). Reach in, find the penny, and put it in your penny holder." After doing this, the child's attention was directed to the extended retractable bar beside the red light. "Watch what happens when I push down on this lever" (experimenter presses down and a penny drops from the dispenser). After the child had retrieved the penny, he was directed to watch as the experimenter operated the orienting bar. "When I push down on this it turns on the light so that I can push this lever (experimenter operates the correct retractable bar) and get a penny." The experimenter then assisted the child in doing it himself by pointing first to the orienting bar (which the child pushed); secondly, to the resultant light or lights, and finally, to the correct bar. When the child had operated the correct lever and taken the penny, he was told: "Now, try it by yourself." No instructions were given after the third trial and any questions after that time were answered with: "I've shown you all I can. From now on you'll have to work it on your own." Neither the red (S+) nor green (S-) lights were mentioned specifically by name and the same instructions were given to both control and experimental groups.

All trials began with a depression of the orienting bar and ended with a correct response. Every incorrect response was recorded, although these responses produced no change in the console stimulus presentation. It was, therefore, possible for any child to make from zero to an infinite number of errors on any one trial. Before the start of the experiment, Groups I and II were designated experimental groups and Group III was labelled the control group.

Group I. Each child was given a total of 70 trials divided into three conditions. Condition 1 consisted of the first 16 trials, including the initial instructions, with only one IEE cell and lit and its correlated retractable bar presented. Depression of the orienting bar activated the red light and 1 sec later the bar was extended. When the bar was pressed, a penny was delivered, the bar retracted, and the red light went off.

Condition 2 included Trials 17 to 30. Operation of the orienting bar now activated both the S+ and S- lights followed 1 sec later by the bar. The bar beside S+ was still the only manipulandum presented. A response was fol-

lowed by reinforcement, bar retraction, and the termination of both S+ and S-.

On Trial 31 (the start of Condition 3) operation of the orienting bar resulted in the presentation of both S+ and S-. Both bars were also simultaneously extended on this trial and remained extended throughout the entire condition (Trials 31 to 70). The subject could respond to either S+ or S-. A response to S+ was followed by reinforcement and the termination of S+ and S- while a response to the S- bar produced no stimulus change. Condition 3 was terminated after Trial 70.

Group II. Each child was given a total of 370 trials over four daily sessions. The first three sessions each consisted of 100 trials during which only S+ and its correlated bar were presented (Condition 1). A variable-ratio schedule of reinforcement was used with each child receiving a penny on the average of every fourth response (VR 4). The column of five lights above the token dispenser was flashed on for 0.5 sec every time a correct response to S+ was made, and the bar was retracted after every such response. During the fourth session, the children experienced the same three conditions given to Group I. Pushing the red bar was continuously reinforced (CRF) for the first 16 trials (Condition 1), followed by 14 trials in which S- (without the bar) was added (Condition 2), and concluding with 40 trials where S+ and S- were presented upon operation of the orienting bar and terminated with a correct response, while both retractable bars remained extended continuously (Condition 3).

Group III. Like the first experimental group, the control children were given only 70 trials (one session). For all trials, both S+ and S- were presented when a child operated the orienting bar and were extinguished when a correct response was made. Both bars remained extended throughout the entire 70 trials as in Condition 3 for Groups I and II. Each correct response was followed by reinforcement. A response to S- had no effect on the console stimuli. As with both experimental groups, S+ was randomly alternated from side to side.

RESULTS

The numbers of errors emitted by the subjects in the first two groups were consistently

lower than those in the control group. A majority of Group I and II subjects learned the discrimination errorlessly, while none of the subjects in Group III made fewer than 11 errors. Figure 2 shows the number of errors each subject made during Condition 3. Generally, the control subjects made only one error per trial and then quickly responded to S+. The highest number of errors made on one trial was a burst of seven, by S3 on his twentieth trial. S6 spaced 10 of his 11 errors over the first 18 trials with the eleventh being emitted on Trial 57. The remaining three control subjects spaced their errors throughout the 70 trials with only a slight decline towards the end. Figure 3 shows the mean number of errors emitted by the control subjects over the 70 trials.

DISCUSSION

It is apparent from the results that neither presenting S- immediately in a discrimination task nor varying S- away from S+ along one or more physical dimensions is necessary for obtaining errorless discriminations. Stimulus control can be accomplished where S- is presented late in the training procedure, and at full intensity. Immediacy of presentation and dimensional variation of the negative stimulus appear to be sufficient conditions, however, for obtaining errorless discriminations when Terrace's procedure is employed.

One of the main reasons immediacy and dimensional variation have continued to be accepted as necessary for errorless learning is lack of variation in experimental procedures since Terrace's initial work (1963). Fading procedures have been employed in a matching-to-sample task with three choices (Moore and Goldiamond, 1964) and a simultaneous discrimination with eight choices (Sidman and Stoddard, 1967; Stoddard and Sidman, 1967). Lyons (1969a, 1969b) conducted a study based on a response prevention procedure, which he called an errorless paradigm. Whether he actually obtained errorless learning is somewhat questionable, however. Wildemann and Holland (1973) demonstrated that pigeons trained to discriminate between two circles of different diameters using the blackout method (response prevention) consistently exhibited peak shift in the test for generalization. This finding casts doubt on the validity of the blackout

Fig. 2. Total number of errors emitted by each subject during the conditioning procedure in which there was an opportunity to respond to S—. Groups I and II experienced the graded choice procedure, while Group III did not. The numbers above the bars indicate the exact number of errors made by each subject.

method as an errorless procedure because one of the most notable features of errorless learning in successive discriminations is the absence of peak shift (Terrace, 1964).

An interesting feature of the present results was the high number of errors emitted by the children in Group III. Generally speaking, 4- to 6-yr-old children have already learned to distinguish between the more common colors and have no difficulty in naming them. This would appear to be in contradiction to the performances of the Group III children. It should be remembered, however, that this study was not designed to teach the children the difference between red and green, but rather to condition them to respond differentially to the colors without verbal instructions. The stimulus-response relationship reinforced was the emitting of a particular motor response (depressing the bar next to the red light) to a particular stimulus (red light). A close analysis of the situation reveals more

than one possible stimulus-response relationship that could control responding (*e.g.*, position, time, sequence). A more complete review of these possibilities in child discrimination studies has been presented by Fellows (1968) and White (1958, 1963, 1964*a*, 1964*b*). It is possible, then, to explain the large number of errors in terms of the children having a discrimination situation more complex than simply verbalizing the name of a particular color shown to them or selecting the appropriate hue from an assortment when asked to do so.

One other possible explanation for so many errors by Group III was chaining. The children could have perceived the situation as requiring both bars to be pressed in order to get reinforcement, rather than a response to green as an error. This alternative was not supported by the fact the children occasionally emitted verbalizations such as: "Oh no," "That's wrong," and "It's that one." (pointing to red) after a response was made to S—.

Fig. 3. Distribution of errors for the Group III subjects. Trials are grouped in blocks of 10 with the total number of errors emitted during the block recorded.

These observations, which occurred as early as the fourth trial, also point out the fact that even though the children could say which stimulus was incorrect, they continued to make errors (Figure 3).

The graded choice method offers several advantages over other discrimination procedures. First of all, the procedure is not dependent on

the subject's behavior. Response prevention requires that the experimenter observe the subject's behavior throughout discrimination training. In the graded choice situation, response opportunities are not contingent on the subject's topography and observation of the subject is, therefore, unnecessary. Secondly, since the stimulus can be varied independently of the opportunity to respond, S- may be introduced for any length of time during discrimination training without the occurrence of errors. Thirdly, responses to S- may be controlled by allowing the subject an opportunity to respond to the negative stimulus during some phases of training (response manipulandum present) and not others (response manipulandum withdrawn).

Although the present study has emphasized differences in errorless learning, procedural similarities should also be taken into consideration. For example, in both graded choice and fading procedures, the initial presentation of the negative stimulus is in some way different from the final form of the S- condition. The fading technique gradually reduces difference between S+ and S- in respect to presentation time and physical dimension while always providing an opportunity to respond. The graded choice technique holds physical and temporal characteristics of S+ and S- equal with no opportunity to make an incorrect response. This would suggest that prior experience with some form of S- is necessary for errorless learning to occur.

Past studies have focused mainly on analyzing certain behavioral phenomena (e.g., peak shift and behavioral contrast) that have become apparent through Terrace's efforts. Future research might also be directed toward evaluating various procedures. In this way, characteristics of errorless learning could be extracted and differentiated from stimulus-response relationships that are restricted to specific experimental procedures.

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