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EFFECTS OF ERROR AND ERRORLESS DISCRIMINATION ACQUISITION ON REVERSAL LEARNNG[1]

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The effectiveness of trial-and-error, graded-choice, and verbal-instruction procedures on the acquisition and maintenance of a two-choice simultaneous color discrimination in an intradimensional double-reversal learning situation was studied using 18 first-grade children. After acquiring a red-green discrimination during one 70-trial session, the discriminative roles of the stimuli were reversed for 30 trials, followed by a second reversal for 30 trials. Children in the graded-choice and verbal-instruction groups acquired and maintained the discriminations with fewer errors than children who learned by trial and error. The importance of the results in terms of two-stage discrimination learning theories is pointed out and similarities between errorless learning and overtraining are discussed.

Key words: errorless learning, reversal learning, verbal instructions, lever press, children

During the last quarter century, the area of discrimination learning has been strongly influenced by the application of two experimental procedures, stimulus reversal and stimulus fading, which have resulted in two significant findings—the overlearning reversal effect and errorless learning. In 1953, Reid trained rats on a stimulus black-white discrimination in a Y maze. His investigation included two groups of rats that learned the color discrimination under a trial-and-error procedure. One group was trained to a nine out of 10 criterion; another group received 150 overtraining trials, past the nine out of 10 criterion. After completing initial training, each group learned the reversal of the original problem. Two aspects of Reid's findings have had great theoretical significance. First, during the first reversal trial, the overtrained rats perseverated much more than their nine out of 10 criterion counterparts in responding to the original S+, now S−. Second, the overtrained rats required substantially fewer trials to reach the nine out of 10 criterion in the reversal condition than the rats trained just to criterion on the initial discrimination. In response to these findings, several two-stage discrimination theories (*i.e.*, Goodwin and Lawrence, 1955; Lovejoy, 1966; MacKintosh, 1962; Reid, 1953; Sutherland, 1959; Thomas, 1970) were proposed to explain what was occurring during overtraining to produce these results.

In 1963, Terrace produced a second major finding in discrimination learning when he compared the acquisition of successive, two-choice color discrimination by pigeons experiencing a trial-and-error conditioning approach to a stimulus fading procedure. Using a free operant paradigm, Terrace (1963*a*) conditioned one group of pigeons to respond on a VI 60-sec schedule to a red key (S+), then introduced S− (a green key) at full intensity and duration. For a second group of pigeons, S− was faded in. By fading in S− early in the training condition, Terrace demonstrated that a discrimination could be acquired with few if any responses being made to S− (errorless learning).

Just as overtraining produced certain byproducts (overlearning reversal effect) when compared to trial-and-error learning, so have certain byproducts been observed with errorless learning that distinguishes errorless discrimination learning from discrimination learning that is acquired through extinction of responding to S−. Byproducts, which have been reported, and refuted in some cases, include differences in behavioral contrast (Terrace, 1963*a*), peak shift (Terrace, 1964), speed of learning (Storm and Robinson, 1973; Terrace, 1963*a*), and the emission of errors as the task continues (Terrace 1963*a*). While Terrace's (1963*a*) demonstration of errorless learning has not produced, as yet, any new theories

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explaining discrimination learning, it has caused a reassessment of certain issues in these theories, such as the role of inhibition (*e.g.*, Sutherland and MacKintosh, 1971, pp. 37-38).

To date, only one investigation has attempted to study the effects of abruptly reversing the roles of S+ and S− after the initial discrimination is acquired errorlessly. Marsh and Johnson (1968) were unsuccessful in obtaining reversal learning with pigeons after a successive color discrimination was acquired errorlessly. Only one of five pigeons responded even to a small extent to the new S+ (previously S−). The other four perseverated in their responding to the original S+ for four sessions, at which time the experiment was terminated. One objective of the present study was to determine whether reversal learning could be obtained with children who acquire the initial discrimination errorlessly, and if so, whether the advantages of acquiring the initial task errorlessly were lost once errors occur.

A second purpose was to identify, if possible, an alternative means of obtaining errorless learning. Before this investigation, errorless discriminations had been acquired using one of the three procedures. The most common was initiated by Terrace (1963*a*) and involved gradually "fading" in S− along more than one dimension (time and intensity). Storm and Robinson (1973) used a graded-choice procedure, in which the S− stimulus was initially presented at full intensity while the ability to respond to S− was restricted. Autoshaping has also been used to produce discriminations without errors (*e.g.*, Wessels, 1973; Wilkie and Raimer, 1974).

A fourth procedure, by which a discrimination may be obtained with few or no errors, has been somewhat overlooked. By informing a person as to which stimulus is S+ and which is S−, it was anticipated that one might obtain an errorless discrimination. While the role of instructions has been addressed in trial-and-error discrimination situations (*e.g.*, Fellows, 1965; Hively, 1962; Luria, 1961; Reese, 1962) no previous studies have addressed the role of instructions in errorless learning situations. The present experiment entailed comparing the effectiveness of trial-and-error, graded-choice, and verbal-instruction procedures on the acquisition and double reversal of a simultaneous color discrimination. We were interested in determining whether verbally informing the children as to which color was S+ would produce behavior similar to that obtained using a graded-choice procedure, and if so, to what extent.

METHOD

Subjects

Eighteen children, 11 boys and seven girls, were enrolled in first grade. No children were dropped from the experiment because of an inability to obtain errorless learning with them. The children were randomly divided into three groups of six each.

Apparatus

The basic test system, a BRS/LVE Human Test Console/Triple Level (HTC-603), was located in a dimly lit 1.3- by 1.5-m cubicle. Figure 1 is a diagrammatic representation of the panel, showing the location of the various stimuli and response modules. In the middle level, an orienting bar (O.B.), two Industrial Electronics Engineers (I.E.E.) inline display cells, and two BSR/LVE Retractable Rodent Levers (123-07) were mounted. The orienting bar, constructed from a pushbutton microswitch (905-1202) supplied by Allied Electronics, was centered on the middle level. The shaft of the switch of the orienting bar protruded from the panel and had a strip of metal 1.77 cm wide by 3.81 cm long at the end, forming a "T" with the shaft. The I.E.E. cells,

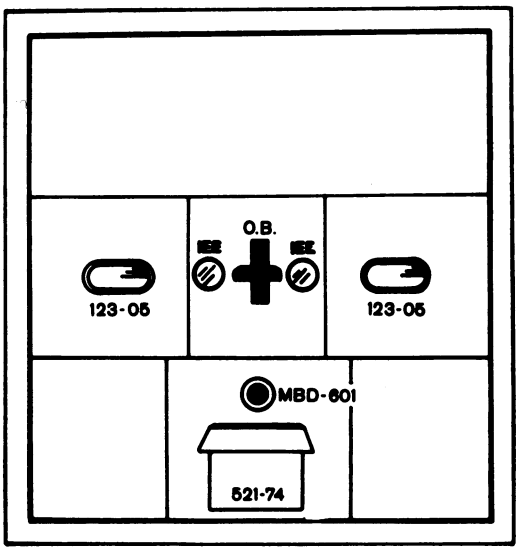

Fig. 1. Test console.

used to present a red or green stimulus light, were located 5.08 cm on either side of the orienting bar. Presentations of the red and green stimulus lights were alternated from side to side with the probability of the red light on the right side being 0.50. A retractable lever was located 4.13 cm from each I.E.E. cell. Directly below the orienting bar, at the center of the bottom level, the delivery magazine of a BRS/LVE Dispenser (MBD-601) was located. When a correct response was made on one of the retractable levers, a marble was delivered. The experimental apparatus was controlled by solid-state and electromechanical circuitry located in an adjoining room, and connected by a cable through the wall of the cubicle to the test console.

Procedure

The experiment consisted of two daily sessions, each session terminating after 70 trials of a simultaneous two-choice color discrimination. Each trial basically consisted of (1) a child pushing the orienting bar; (2) presentation of the stimulus light(s) and its (their) correlated retractable bar(s); (3) termination of the stimulus light(s) and retraction of its (their) correlated bar(s) when a correct response was made.

At the beginning of the first session, each child was seated before the console in such a manner that the orienting bar was approximately at eye level. While handing the child a cup, the experimenter explained that marbles could be earned and exchanged for packages of gum at the end of the session. Pointing to the marble dispenser, the experimenter indicated that a marble would appear there whenever the child made the response to be demonstrated by the experimenter. The child's attention was then directed to the orienting bar, and the child was told: "When I push down on this (orienting bar) it turns on the lights so that I can push this lever (correct retractable bar) and get a marble." When the child and the experimenter had completed the sequence, the child was told: "Now try it by yourself." No additional instructions were given. Questions after that time were answered with "I've shown you all I can. From now on, you'll have to work on your own." Neither the red (S+) nor green (S−) stimulus lights were mentioned specifically by name for two of the three groups. These basic instructions were given to both the trial-and-error and graded-choice groups; the third group was told to push the bar next to the red light.

All trials began with a depression of the orienting bar and ended with a correct response. Every response to S− (defined as an error) was also recorded, although these responses produced no change in the console stimulus presentation. This made it possible for any child to make any number of errors on any one trial, while only one correct response per trial was possible. Previous experimenter experience in such situations indicated that the children should be required to hold a cup for their marbles in one hand during the experiment. When both hands were left "free", the children occasionally pressed both retractable bars simultaneously.

Group I (graded-choice). The children in Group I were conditioned using a graded-choice procedure (Storm and Robinson, 1973) consisting of the following steps. During the first 20 trials, only S+ was presented. The sequence of events for these trials was as follows: (1) the orienting bar was pressed, (2) the S+ stimulus light immediately came on one of the two sides, (3) 1 sec later, the retractable bar next to S+ was extended, and, (4) a response on the retractable bar next to S+ delivered a marble and retracted the bar. On Trial 21, S− also appeared at the same time in the sequence as S+. However, the bar next to S− was not extended. This condition continued until Trial 41. On Trial 41, the S− bar was extended simultaneously with the S+ bar. Both bars then remained extended for the duration of the session. Responses on the S− bar were recorded as errors.

The next day, the children were again given 70 trials (Trials 71 to 140). The first 10 trials employed the same stimulus and response contingencies that were in effect on the last 30 trials of the previous day. On Trial 81, the reversal learning phase of the experiment was put into effect (green became S+ and red became S−). Only responses to green were reinforced during this part of the investigation (Trials 81 through 110); responses to red were recorded as errors. Trial 111 marked the start of the second reversal condition. At this time, the contingencies were again reversed, so that red again became S+ and green S− for the remaining 30 trials. At no time during the experiment were any of the children told that

the contingencies would be or had been changed.

Group II (trial and error). The instructions given to the trial-and-error group were exactly the same as the graded-choice group. The experimental procedure for the trial-and-error group differed from that of the graded-choice group in the following manner. During the first 20 trials of the discrimination acquisition session, S+ was the only stimulus light presented after a response on the orienting bar. The two retractable bars were extended throughout the session. During the acquisition session, no more than two responses were made by any one child to either bar when no stimulus light was illuminated. Responses on the nonilluminated side were recorded as errors. On Trial 21, and for the remainder of the 70 trials, both the green (S−) and the red (S+) lights were presented after a response on the orienting bar. Responses to S− were counted as errors. The trial-and-error group experienced the two reversal conditions in the same manner during the second session as the graded-choice group.

Group III (verbal instructions). The instructions given to the verbally informed group differed from those given to the other two groups in the following manner. It was specifically stated that "to get the marble you press the bar next to the red light". This was repeated for the first two trials. After the second trial, the children were told to respond on their own. For all 70 trials of the first session, both S+ and S− were presented after each response on the orienting bar. Both bars were extended and never retracted at any time during the session. The informed group did not experience any trials in which S+ and its bar were presented without S− and its bar. The second session had the same contingencies and reversal sequences as for the other two groups.

In summary, the experiment was divided into two sessions. The first session consisted of training three different groups of children to acquire a red-green discrimination by responding to red (S+) and not to green (S−). Group I was trained with a graded-choice procedure, Group II used a trial-and-error method, and Group III children were verbally informed which response was correct. The second session entailed two stimulus reversals. On Trials 81 through 110, green became S+ and red became S−; red was again defined as S+ on Trials III through 140.

RESULTS AND DISCUSSION

Although the behaviors of both the graded-choice and instruction groups were similar, they were quite distinguishable from the trial-and-error group in terms of both acquisition and reversal. Figure 2 shows the total number of responses each child made to S− during acquisition of the discrimination. A Scheffe multiple-group comparison test showed no significant difference between the graded-choice and verbal-instruction groups ($F < 1$). The Fs ($df = 1, 10$) obtained when comparing the trial-and-error group to the graded-choice and instruction groups were 55.99 and 59.76 ($p < 0.001$) respectively. It is apparent that instructing the children as to which stimulus was S+ can help them to acquire a discrimination with few, if any, errors, and therefore can be used to develop errorless learning. It is interesting to note that the use of verbal instructions in the past has often not led to immediate acquisition of a discrimination. In a two-choice simultaneous matching-to-sample task, Hively (1962) gave verbal instructions to 6-yr olds. Although they did eventually establish a stable baseline of matching behavior, it was not acquired immediately. Baron, Kaufman, and Stauber (1969) placed three groups of college students on a multiple fixed-interval (FI) schedule of reinforcement. The first group was told what the reinforcement contingencies were at the start of the training and exhibited the appropriate patterns of behavior almost immediately. The second group was never told

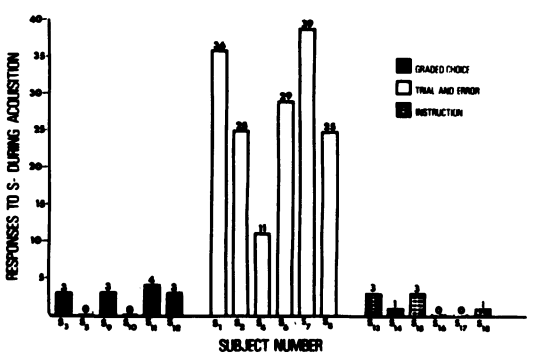

Fig. 2. Number of responses to S− emitted by each child during discrimination acquisition phase of the experiment (Session 1).

about the specific schedule being used and acquired the typical FI response patterns over time. The third group was told what the schedule was about halfway through the experiment. The response pattern of this third group did not immediately change after instructions but was acquired over time in a manner similar to the second group. Kendler and Kendler (1961) instructed children to verbalize the relevant dimension on a reversal learning task, and in doing so, noted that the performance of 4-yr olds was enhanced but the performance of 7-yr olds was not. The rôle of instructions in discrimination learning is still unclear and is a worthy subject for future investigations.

A milder position preference than commonly seen when animal subjects are used was observed with the children. This might not be as much due to species differences as to the use of a relatively dark conditioning room, which intentionally accented the importance of color of the choice stimuli over position.

The number of errors each child emitted during the reversal conditions in the last 70 trials is presented in Figures 3 and 4. Several differences between the three groups of children are apparent. All three groups differed in the number of errors emitted on the first trial of the reversal, Trial 81. The *F*s ($df = 1, 10$) obtained when comparing the graded-choice group to the trial-and-error and instruction group were 3.11 ($p > 0.10$) and 5.84 ($p < 0.05$) respectively. The *F* obtained when comparing the instruction group to the trial-and-error group was 9.98 ($p < 0.05$). When compared to the graded-choice and instruction groups, the trial-and-error group made a significantly ($p < 0.05$) higher number of errors as the first reversal continued, Trials 82 to 110, ($F = 24.76$ and 7.35 respectively). No significant difference was obtained ($p > 0.1$) between the graded-choice and instruction groups. No significant difference ($p > 0.1$) was found between any of the groups on the first trial of the second reversal, Trial 111. As the second reversal continued, Trials 112 to 140, the trial-and-error group again emitted a significantly higher ($p < 0.05$) number of responses to S− than either the graded-choice or instruction groups ($p > 0.1$). Frequently, the effect of the variable(s) being studied in a reversal learning investigation is not the same direction for all or most of the subjects. As a result, averaged or summarative data are required for the overlearning reversal characteristics (*e.g.,* perseveration on first trial of reversals) to show up adequately. The effect of the different procedures for acquiring the discrimination in this investigation were so consistent from one child to another that differences between the groups are as easily revealed by comparing almost any subject from one group to any subject in one of the other groups.

Figures 3 and 4 reveal the following. First, the children who acquired the discrimination with few or no errors perseverated in their responding to the original S+ on the first trial after reversal; children acquiring the discrimination with a relatively large number of responses to S− showed little perseveration. This tendency of subjects acquiring a discrimination errorlessly to perseverate on the initial S+ trial after reinforcement contingencies are either removed or reversed is also consistent with previous reports (*e.g.,* Terrace, 1966; Marsh and Johnson, 1968; Wilkie and Raimer, 1974). Second, the children who acquired the initial discrimination with errors emitted a substantially larger number of errors after the first reversal trial than did the children who learned errorlessly. These results are consistent with Terrace's (1963*a*) contention that errors made during acquisition of a discrimination beget errors as the discrimination continues. The present results suggest that that relationship holds true, even when the roles of the stimuli in the initial discrimination change. Third, none of the groups displayed perseveration when the roles of the red and green stimuli were reversed a second time. Only one or two responses to the new S− were made by most of the children before switching to the correct stimulus. Fourth, the children acquiring the original discrimination errorlessly continued to make fewer errors after the second reversal than those learning the discrimination with errors. It is important to note that in every respect the behaviors of the children in the graded-choice and the instruction group were almost identical but were in sharp contrast to the children who acquired the discrimination with errors. Although the instruction group had a tendency to perseverate to a greater degree than the graded-choice children on Trial 81, that difference is most likely due to the exact instructions given, and would probably vary, depending on what is specifi-

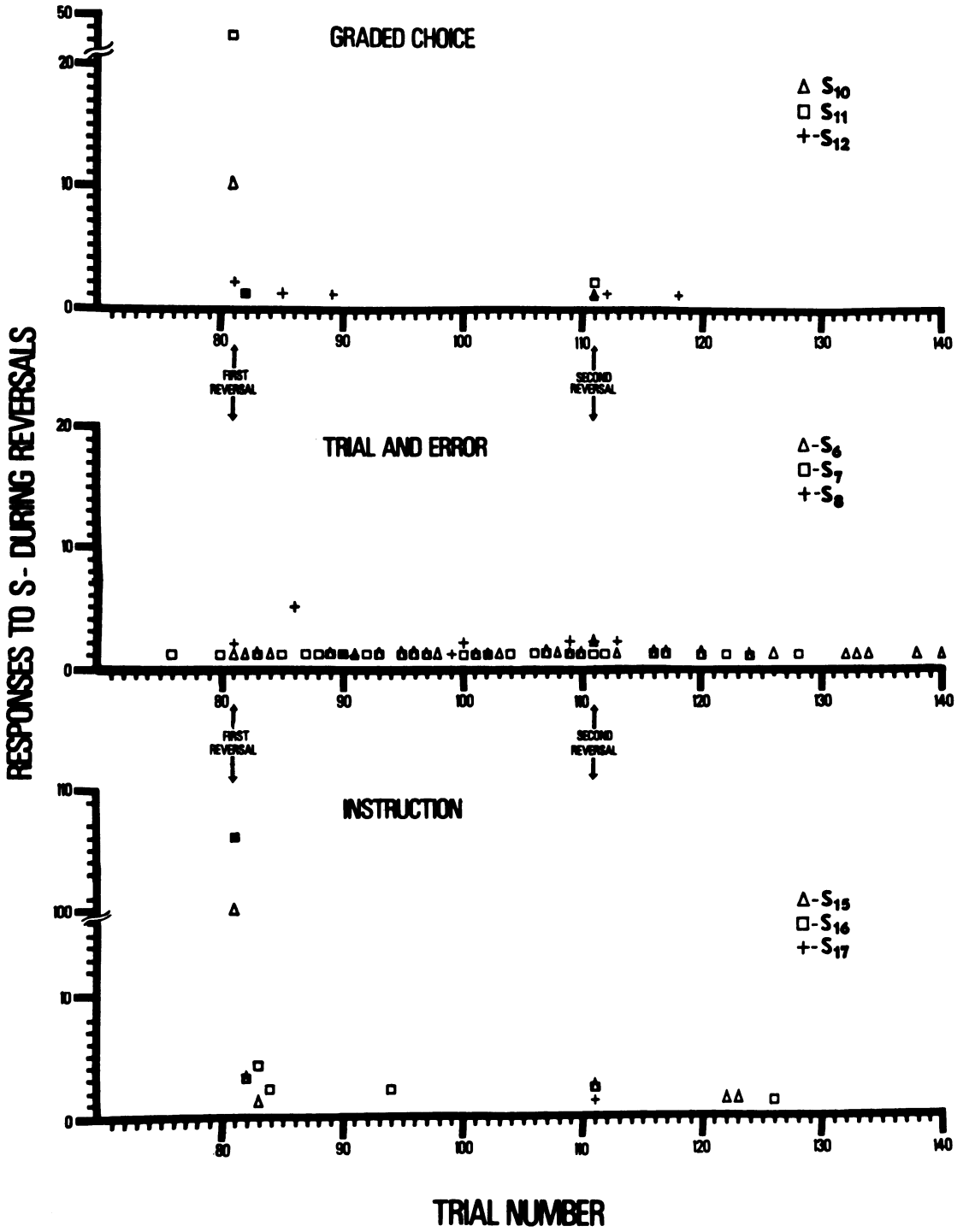

Fig. 3. Number of responses to S— per trial each child emitted during the reversal conditions according to which type of discrimination acquisition procedure was employed: graded choice, trial and error, or verbal instruction.

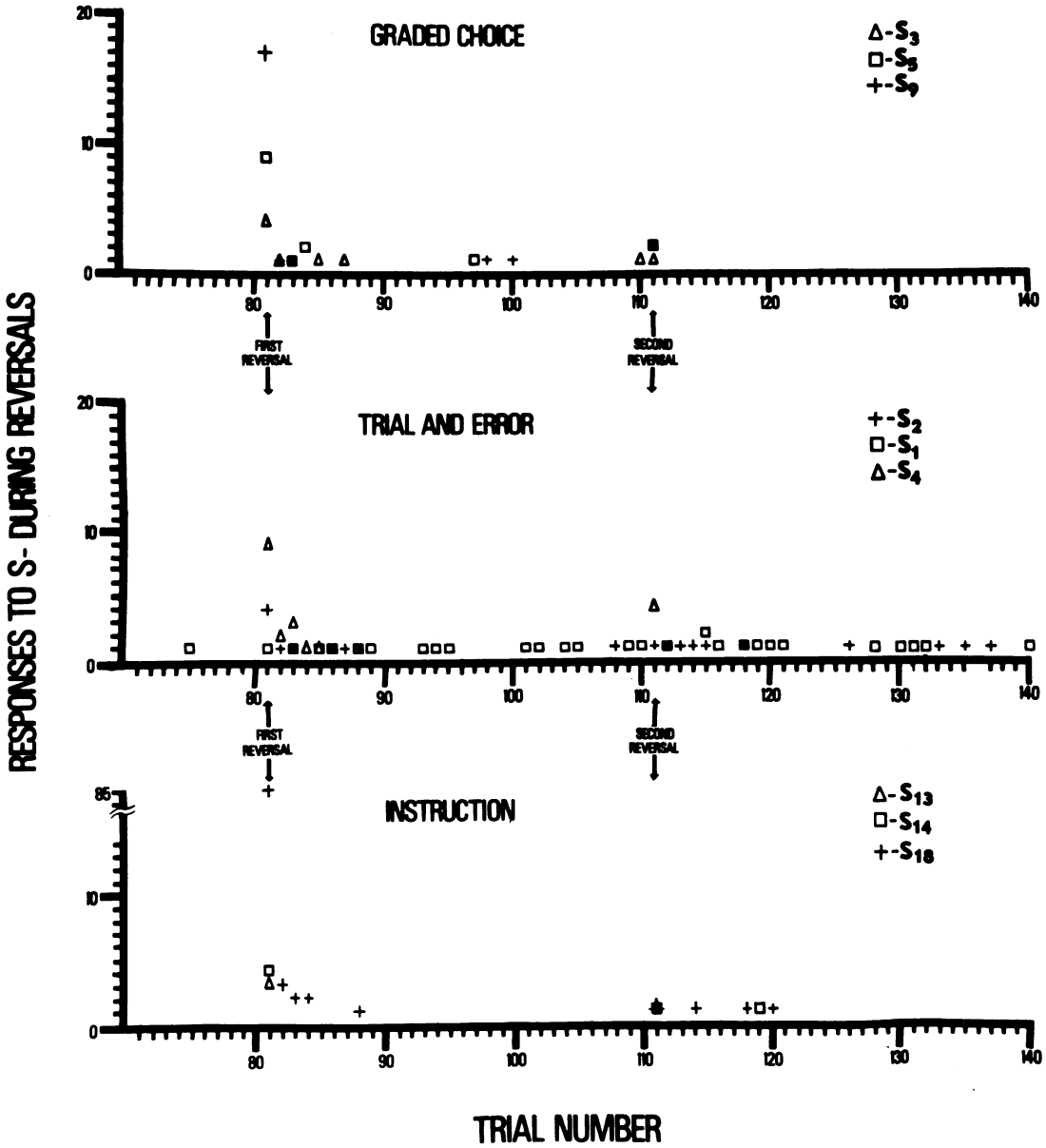

Fig. 4. Number of responses to S— per trial each child emitted during the reversal conditions according to which type of discrimination acquisition procedure was employed: graded choice, trial and error, or verbal instruction.

cally said. This conclusion is consistent with the results obtained by Fellows (1965), when the verbal instructions given children were varied.

Several conclusions may be drawn from these results. First, while the errors made after the first reversal trial (Trials 82 to 110) were not determined to any great extent by the number of responses made to S— on that first trial (Trial 81), they were highly related with the number of errors made during acquisition. While the present results support Terrace's (1963) contention that errors beget errors, they also indicate that *when* responses to S— are made, and not just *how many* are made, is important. By the time all the children had experienced Trial 81, on which the reinforcement contingencies had been reversed for the first time, most of the children in the instruction group had emitted nearly three times the

number of errors made by those children who had learned by trial and error, yet the children in the instruction group made fewer errors as the discrimination task continued, Trials 82 to 140.

Besides demonstrating that the advantages of acquiring a discrimination errorlessly are not necessarily lost once errors are made, and that errorless learning can be obtained through verbal instructions, the results of this study reflect on several issues of discrimination learning in general. For example, the reversal results obtained from the children who acquired the task errorlessly are consistent with the results obtained from subjects who are overtrained (training past a given learning criterion) before experiencing reversal conditions.

In 1953, Reid reported two important effects of overtraining on reversal learning which have been replicated many times since. First, overtrained subjects initially perseverate in their responding to the original S+ after it becomes S−. Then, once subjects do switch their responding to the new S+, they make fewer errors as the reversal condition continues. Errorless acquisition of the discrimination also produces these same results. However, errorless learning procedures produce these results without increasing the number of trials during training. This raises the question of what is the role of the overtraining phase in obtaining the overlearning reversal effect. In response to the results of overtraining, several two-stage discrimination theories were proposed (Goodwin and Lawrence, 1955; Lovejoy, 1966; MacKintosh, 1962; Reid, 1953; Sutherland, 1959) to explain what was occurring during overtraining to produce these results. According to these theories, an organism has two things to learn in a discrimination task. First, it must learn to attend or focus on the relevant stimulus dimension; second, it must learn to approach S+ and avoid S−. It is generally agreed that the overtraining phase most specifically helps the organism focus on the relevant cues in the situation. Sutherland and MacKintosh (1971) proposed that this focusing must occur slowly, thereby explaining the need for the extended overtraining. Errorless learning, however, apparently also produces that focusing in a relatively short time, without the need for extended training.

One possible explanation for the relatively quick development of the ORE with the errorless learning groups is generalization of previous stimulus-response relations to the present situation. Due to the fact that all reports on errorless learning had involved either adult nonhumans (*e.g.*, Terrace 1963*a*, *b*, Wilkie and Ramer, 1974) or human subjects at least 4 yr of age (*e.g.*, Sidman and Stoddard, 1967; Storm and Robinson, 1973; Terrace, 1974), Robinson, Foster, and Bridges (1976) developed errorless learning in newborn chicks to support their contention that generalization from prior experience is not necessary and sufficient to explain how a discrimination can be obtained with no responding to S−. The present results, and indirectly those of Robinson, *et al.* (1976), suggest that extended training is neither a necessary nor a sufficient condition to produce perseveration and a reduced number of errors in a reversal learning situation. It is apparent that the behavioral results commonly referred to as the overlearning reversal effect are determined by some other condition in the reversal learning situation, a condition that can be influenced by both extended training and errorless discrimination acquisition procedures.

Sutherland and MacKintosh (1971) and Goodwin and Lawrence (1955) distinguish themselves from other two-stage discrimination theorists by suggesting that an organism may in fact be learning about more than one stimulus dimension at one time. The difference in responding on Trials 81 and 111 supports this idea. The lack of perseveration on the second reversal demonstrates that some other relations were also learned. Although future investigations are necessary to discover what these other relationships are, it seems reasonable to propose that something analogous to Harlow's (1949) learning sets is involved.

The present results, demonstrating perseveration and faster reversal similar to ORE, support the two-stage attention models of discrimination learning (*e.g.*, Goodwin and Lawrence, 1955; Sutherland and MacKintosh, 1971; Zeaman and House, 1963), but raise questions regarding the explanation of discrimination learning with two-stage attention models.

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