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THE EFFECTS OF GRADUATED STIMULUS CHANGE ON THE ACQUISITION OF A SIMPLE DISCRIMINATION IN SEVERELY RETARDED BOYS[1]

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Methods were compared for teaching severely retarded boys to discriminate the position of a 0.75-in. black square and to press the response key closest to it. Seven boys were given trial-and-error training; one learned the task. The six boys who did not learn were presented with a program of graduated stimulus changes. All but one acquired the performance, and he was under appropriate control during the program. When he reached the criterion stimuli, he reverted to a position-based response learned during trial-and-error training. Six similar subjects were presented with graduated stimulus training alone. All six learned the criterion discrimination with few or no errors. Both groups were tested for retention of the criterion performance 35 days after training was completed. Two boys who had near-perfect criterion discrimination performances showed no signs of retention after 35 days. These boys had a history of trial-and-error training.

Recent studies of discrimination learning have indicated that a significant number of severely retarded children fail to learn even simple discriminations, despite carefully programmed contingent reinforcers. Barrett (1965) found no learning in seven of 25 retarded subjects, and deviant response patterns in 11 others, after as much as 16 hr of differential reinforcement. Other studies have reported this finding in the form of subjects who were discarded from experimental samples for failure to learn (Ellis, Girardeau, and Pryer, 1962; House and Zeaman, 1958, 1960; Orlando, 1961).

Errors may be defined as responses to a stimulus not related to the reinforcement contingencies in a learning situation. Spence (1936), Harlow (1959), Krechevsky (1932), Skinner (1948) and others have pointed out that stimuli not specified as "relevant" to the correct response frequently come to control behavior during "normal" discrimination learning. Retardates who do not learn, or who adopt deviant response patterns, may differ from normal in that they continue under the control of some irrelevant property of the experimental situation long after more efficient behavior has been developed by those who learn. Barrett and Lindsley (1962) found "... initial differential responding of a 'superstitious' nature ... and marked response stereotypes ..." (p. 428) in trial-and-error learning by institutionalized retardates.

Errors have long been assumed to be a necessary part of the learning process. However, several experimenters have demonstrated that discriminations can be learned without errors (Schlosberg and Solomon, 1943; Terrace, 1963*a*, 1963*b*; Moore and Goldiamond, 1964). In the above studies, the experimenters initiated training by reinforcing a stimulus-response relation which already existed or which was easily acquired. The controlling stimuli were then gradually changed to approximate more and more closely those appropriate to the discrimination to be taught. By maintaining appropriate stimulus-response relations throughout training, responses based on stimuli not directly related to reinforcement were eliminated.

The present study sought to determine whether a procedure designed to maintain stimulus control throughout training can be effective in teaching severely retarded subjects who have already demonstrated no learning under differential reinforcement conditions.

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Subjects with and without histories of trial-and-error training are compared.

METHOD

Subjects

Fourteen retarded boys, permanent residents of the same ward at the Walter E. Fernald State School, served. Ages ranged from 9 to 16 yr, and duration of institutionalization from 5 to 13 yr. All subjects had been diagnosed as severely retarded with some organic brain disorder. The boys demonstrated little or no verbal behavior. Several were able to respond appropriately to a few simple instructions. Detailed information on individual subjects is given in Table 1. For the purposes of this study, the 14 subjects were ranked according to their current accomplishments by four psychologists and two teachers who had been in close contact with the boys for 18 months or more. The children are identified throughout the study by their rank number. The coefficient of Concordance (Kendall's W) for the internal consistency of the rank-order ratings was 0.85 (significant beyond 0.001). Their I.Q. scores were of little value for differentiating the boys, since the test-retest variation was as great as the variation in score from subject to subject.

Apparatus

The subjects sat in an area approximately 9 by 8.5 by 7 ft, lit by soft, indirect light. The wall facing the subject contained a response and display matrix consisting of three 3.75-in. square Polacoat Plexiglas panels, mounted in an aluminum plate. No dividing strips separated the two response keys from the center display panel (Fig. 1). The two outside panels (keys) were hinged at the top and in contact with heavy-duty microswitches at their lower edge. The center panel was fixed in place. It was occasionally touched by subjects exposed to the programmed sequence, and to minimize feedback, responses to it were not recorded.

The stimulus projection apparatus was a Model 550 Kodak Carousel 35mm slide projector, mounted behind the response panel. A motor-operated shutter interrupted light from the projector during the interval between trials. Each slide contained the stimuli for all three panels for a given trial. Below the panels was a strip of five photocells keyed by holes punched in the lower portion of the slide. These photocells served to decode the correct key position for each trial. Light falling on the

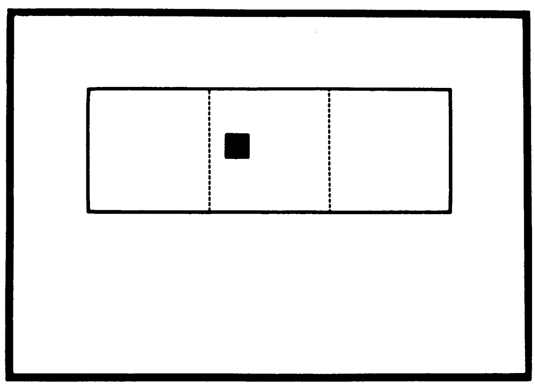

Fig. 1. Experimental apparatus, subject's view.

Table 1
Data on Individual Subjects from Institution Records

Relative rank	*Age (years) at admission*	*Age (years) current*	*Mean I.Q.*	*Diagnosis*
1	1	13	45	Kernicterus
2	3	11	43	Chronic Brain Syndrome
3	4	14	27	Familial Microcephaly
4	4	13	41	Familial Microcephaly
5	1	14	30	Mongolism
6	3	15	31	Neonatal Anoxia
7	7	12	45	Mongolism
8	5	16	27	Mongolism
9	5	13	31	Cerebral Palsy
10	4	9	42	Mongolism
11	6	11	34	Mongolism
12	1	11	42	Mongolism
13	1	14	27	Mongolism
14	1	13	35	Mongolism

photocells was not visible to the subject. A similar apparatus has been described by Hively (1964).

Stimuli for the several programs were manufactured by photographing a mock-up of the apparatus front panel. Kodak high-speed Ektachrome type B film was used. Background colors (including black) were Color-Aid paper. Progressive changes in brightness and color were made by adding or removing layers of Bourges overlays, placed over the stimuli to be photographed.

Pilot data indicated that position-based responses were the most probable type of error pattern. The sequence of correct key-positions was designed so that no more than two consecutive trials required a response in the same position. Repeated presses of the position which was correct on the previous trial would have been reinforced only 35% of the time. Further pilot data indicated that the children did not learn the sequence or portions of it either under trial-and-error or programmed training conditions.

The last slide in the tray of 40 activated a photocell which automatically stopped the session. When this occurred, the slide tray was manually recycled and the session continued until the appropriate number of trials had been given (see below). Recycling the tray by hand rarely took longer than the normal intertrial time of 5 sec.

Responses were recorded on a 20-channel Esterline Angus operations recorder which provided a running account of the onset of trials, location of the correct key, and latency of all responses during and between trials. This apparatus was housed in a plywood container surrounded by sound-insulating materials. "White" noise also helped to mask extraneous sounds.

After every correct response, a Gerbrands M&M dispenser mounted to the right of the stimulus display operated and chimes sounded. The candy dropped into a 5 by 3 by 1 in. Plexiglas tray at the base of the dispenser. During a session the room was dimly lit, but subjects had no difficulty in locating the candy.

PROCEDURES

The initial objective was to determine whether subjects who failed to learn a discrimination under trial-and-error training conditions could be taught that same discrimination by a programmed sequence of stimuli. The preliminary training and criterion discrimination common to all subjects and both training procedures are described first.

Preliminary Training

Before each child was brought into the experimental chamber for the first time, an M&M candy was placed in the tray below the dispenser. All children discovered the candy soon after sitting down to face the matrix of keys. Subsequent operations of the dispenser made sufficient noise to attract their attention to the tray. The procedure of preloading the dispenser with an M&M was continued throughout the experiment. It served to reinforce the child's entering the room, sitting down, and orienting toward the apparatus.

The boys were then taught to press whichever response key was illuminated. The most expedient combination of verbal instructions, demonstration, and guidance was used to get the child to press the key initially. After this initial response, key-pressing was quickly established by the programmed reinforcement contingencies.

At this point, the correct stimulus was a brightly lit red key. The other key and the center panel were dark. In a dimly lit room, the single bright key was the dominating visual stimulus. Once key-pressing had been established, the children were allowed to press the keys while the correct key changed from side to side in a predetermined sequence. A candy was dispensed and a chime sounded after each correct response. Pretraining was considered complete when a child had made eight successive correct responses. All children met this criterion in fewer than 20 trials.

Criterion Discrimination

During each trial, the center (display) panel contained a single black 0.75-in. square. This square was displaced 0.5 in. from either the left or right margin of the panel (see Fig. 2, part E). Proximity to the square determined which outside response key was correct.

A trial began when the display panel and the two keys were illuminated, and ended when the subject applied sufficient pressure to close the switch behind the key closest to the square. Reinforcement (candy, chimes, projector cycle) followed responses to the correct

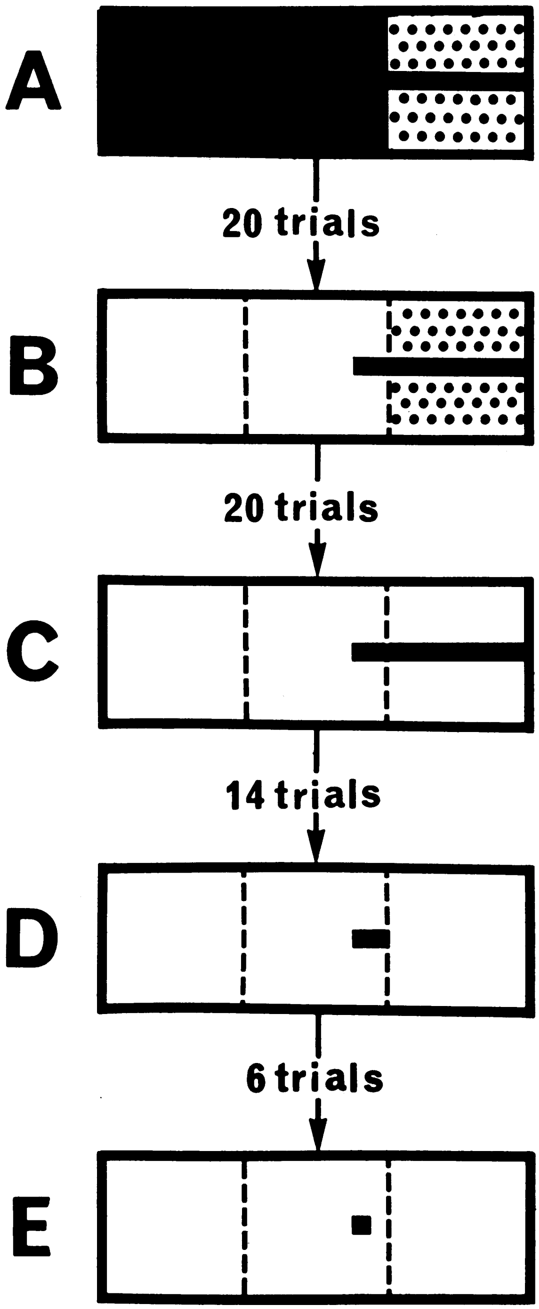

Fig. 2. Schematic representation of the major stages in the programmed sequence of graduated stimuli. Although the correct key is shown on the right, its position actually varied according to a predetermined sequence. The dotted backgrounds in parts A and B represent solid red fields. Transitions from one stage to the next were carried out in small, gradual steps (see text for details).

key. If both keys were pressed simultaneously (within 0.5 sec of each other), the trial was terminated and reinitiated after 5 sec. With the exception of "simultaneous" responses, all trials ended with a correct response. An inter-trial interval of 5 sec, during which the panels were dark, followed each correct response. Incorrect responses were recorded, but produced no contingent event. This correction procedure was used throughout the experiment.

The criterion discrimination with correction served as a teaching procedure for subjects who received trial-and-error training and as a test procedure to assess the effects of the alternate training method described below.

Programmed Stimulus Sequence

The major stages in the programmed sequence of graduated stimuli are presented in Fig. 2. Part A represents the initial training slide. It consisted of a black display panel, a black response key (shown on the left) and a red key containing a black horizontal line. Through the first 20 trials, the black response key and display panel became progressively lighter until they were fully bright, as shown in B. In the next 20 trials, the red background was gradually desaturated until all of the panels were white, as shown in C. In the next 14 trials, the black line was gradually shortened until it was entirely on the center panel, as shown in D. In the next six trials, the line continued to shorten, approximating the 0.75-in. black square which served as the criterion stimulus, shown in E.

Each step followed the preceding step and the sequence was never reversed. A correct response always advanced the next slide in the sequence. The criterion discrimination procedure used the same stimuli on each trial, varying only the position of the stimulus on the display panel.

The empirical procedures used to develop this instructional program were similar to those described by Hively (1962) and Sidman and Stoddard (1966).

Sequence of Training Procedures

Two groups of subjects were each presented with a different sequence of training procedures. The subjects had comparable ratings and I.Q. scores. The objective of this group comparison was to determine what effect, if any, a history of trial-and-error training might have on performance during the programmed sequence, the criterion test, and the retention test.

"Trial-and-Error" Group

Seven subjects (2, 3, 4, 7, 8, 9, 13) were given trial-and-error training on the criterion discrimination. Duration of training was arbitrarily limited to 320 trials (four sessions).

Two subjects (7, 8) were given an additional 320 training trials (a total of 640) to determine the effects of extended practice.

All subjects who had not learned the discrimination after the above training (2, 4, 7, 8, 9, 13) were then given the programmed stimulus sequence to determine if this type of training would affect performance. Immediately after completing the graduated stimulus sequence, the subjects were given 40 criterion trials identical to those which had preceded the programmed stimuli. Thirty-five days later, the criterion discrimination test was applied once again in order to assess retention.

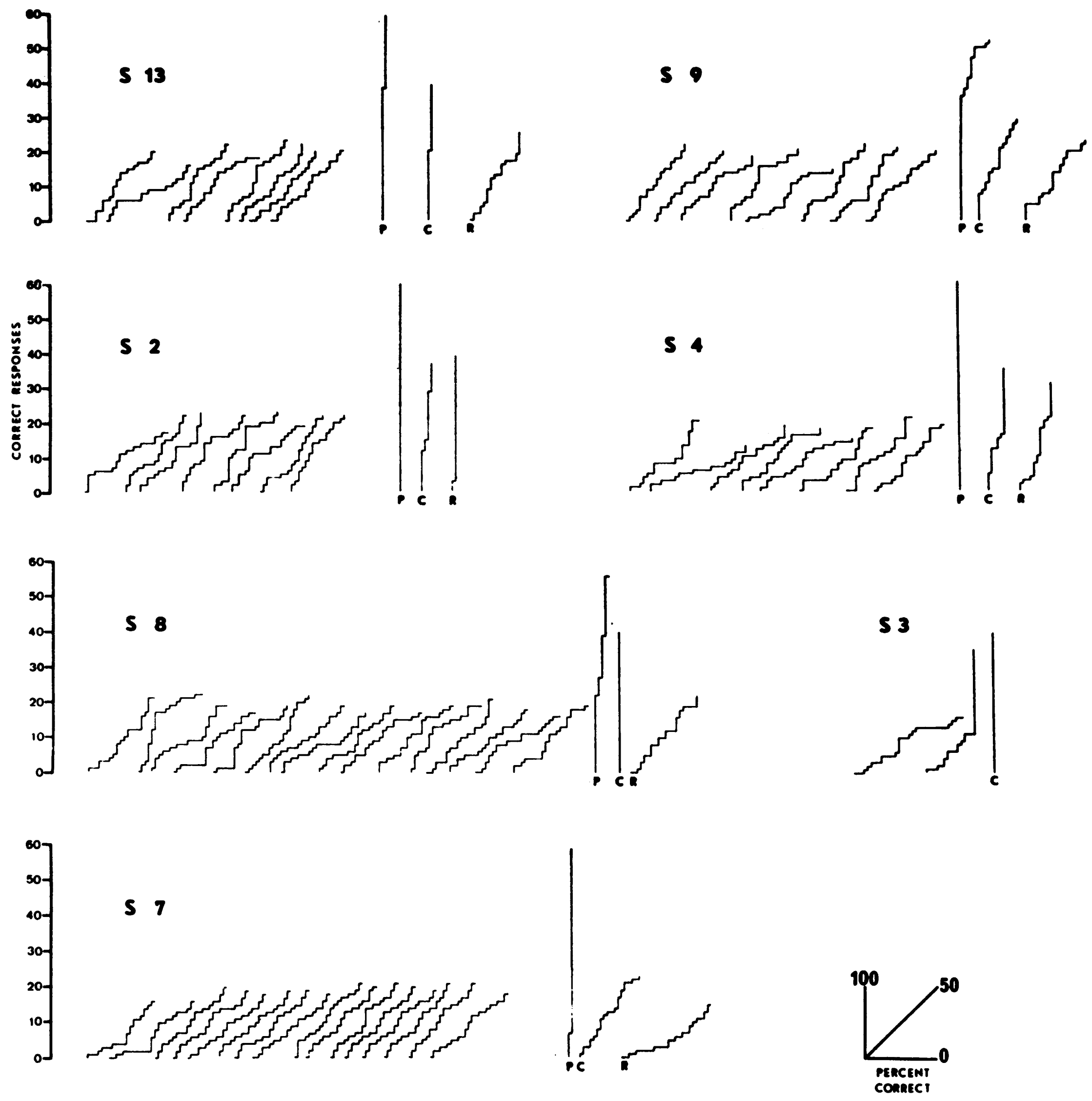

Fig. 3. Cumulative correct responses (each step up) and errors (each step to the right) for each of the 40-trial sequences during trial-and-error training, during the programmed stimulus sequence (P), the criterion test (C), and the retention test (R). Only the first response in each trial is plotted.

"Program" Group

Seven subjects (1, 5, 6, 10, 11, 12, 14) were given the programmed sequence of stimuli directly after preliminary training. Immediately following the programmed sequence, 40 criterion trials were presented. Thirty-five days after training was completed, the criterion test was reapplied to assess retention.

RESULTS

Trial-and-Error Training

The initial experimental question was whether the square, displaced to either side of the center panel, would come to control the key-pressing responses of the severely retarded subjects given trial-and-error training.

Seven subjects were given the criterion discrimination and were rewarded for responses on the key closest to the square. One subject learned the criterion discrimination, six failed to learn. Figure 3 shows the course of training. The left-hand portion of the records in Fig. 3 shows the frequency of correct responses and errors in each of the consecutive 40-trial sequences under differential reinforcement contingencies. In six cases, there was no evidence of learning or any indication that acquisition was imminent after 320 trials.

To appraise the effects of extended practice, two boys (7, 8) were given an additional 320 trials, for a total of 640. They continued to show no significant deviations from 50% correct. No response patterns were related to the repetitive 40-trial sequence of key positions.

One clear error pattern emerged during trial-and-error training. Subject 7 developed a right-key position preference. Figure 4 shows

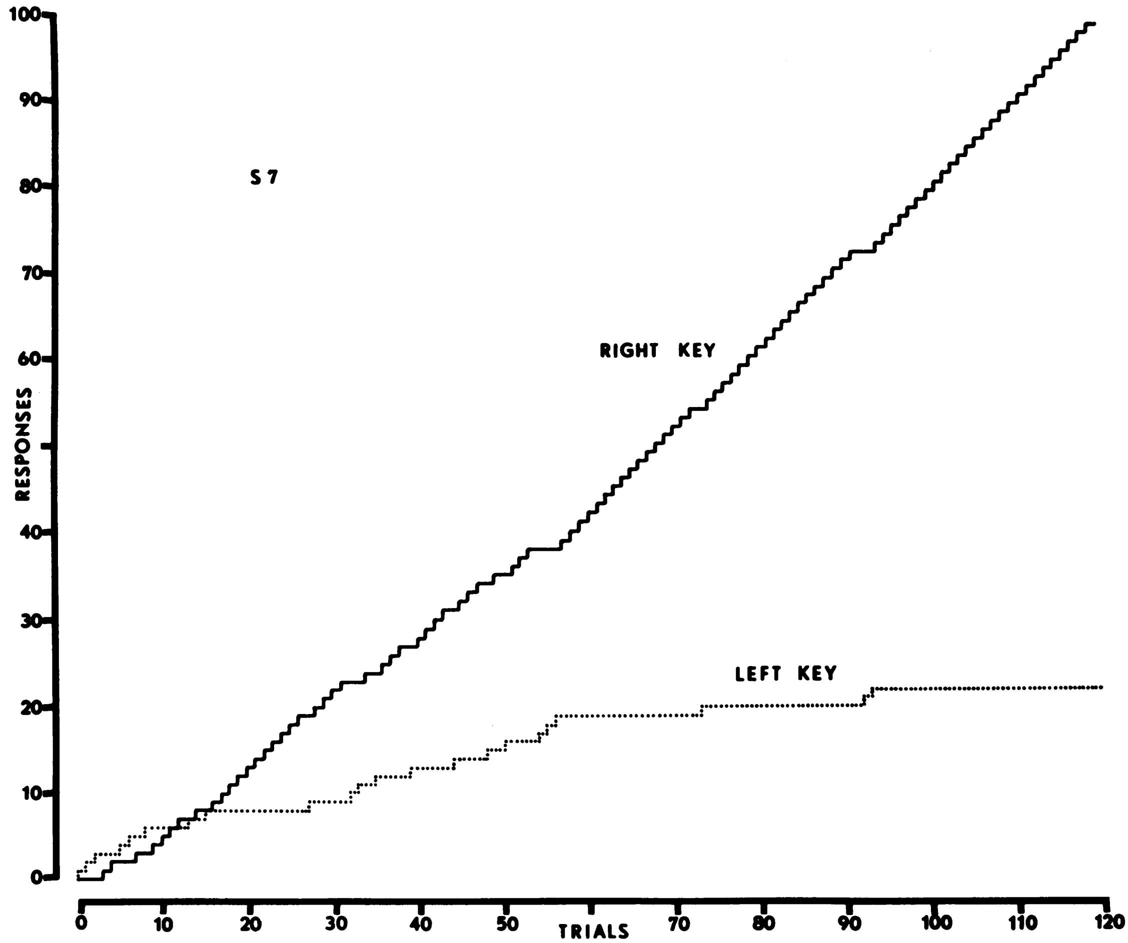

Fig. 4. Development of a position-based response during trial-and-error training, Subject 7.

the development of this preference during the first 120 training trials. No noticeable change occurred during the next 520 trials. Subject 7 continued to initiate more than 90% of the trials with a response on the right key.

Programmed Stimulus Sequence

The trial-and-error procedure provided a group of subjects who had demonstrated no tendency to learn under these conditions. It was thus possible to ask whether the graduated stimulus sequence would affect performance of the "non-learners."

The six subjects who had not learned the criterion discrimination under trial-and-error conditions were given a 60-trial instructional program. The portion of the records designated P in Fig. 3 shows cumulative correct responses and errors during the sequence of programmed stimuli. Five subjects made few or no errors; Subject 9 made several in the latter part of the program. The portion of the records designated C in Fig. 3 represents the frequency of correct responses and errors during the 40 criterion discrimination trials which followed the instructional sequence. Four subjects (13, 2, 4, 8) improved from chance responding to 85% or better accuracy. Subject 9 improved to 72.5% accuracy, while Subject 7 did not show any increase in the number of correct responses emitted during the criterion test.

During the last half of the trial-and-error training, Subject 7 picked the right key first on more than 95% of the trials. During the programmed stimulus sequence, however, there was no evidence of a position preference. He made only one error in these 60 trials. While the programmed visual stimuli successfully maintained control over this subject's responding, the position habit returned when the criterion stimuli were presented after the program was completed.

Program Subjects

Seven boys who had been magazine trained and taught to press a lighted key (1, 5, 6, 10, 11, 12, 14) were presented directly with the programmed stimulus sequence and then the criterion discrimination test.

The objective of establishing a group which received no trial-and-error training was to determine what effect, if any, trial-and-error training might have had on the first group's performance during the programmed sequence, criterion, and retention tests.

Subject 12 was dropped from the experimental group when it was discovered that he was nearly blind. He made only three errors in the first 45 program trials, but exhibited no evidence of control by the programmed stimuli after trial 45. No other child had ever had difficulty with this portion of the program. Similar results were obtained on a second presentation. An opthalmologic examination revealed bilateral mature cataracts, with scars on the left pupil and cornea, the result of surgery performed in infancy. In terms of his behavior on the ward, this nearly blind child was not readily discernible among those with their vision physically intact. He had, in fact, been considered one of the brighter, more alert boys on the ward. This accidental discovery of a severe visual impairment made it clear that the level of visual functioning normally displayed by the subjects in their daily routine was even lower than originally suspected.

Figure 5 includes a trial-by-trial account of the Program (P) and Criterion test (C) performances of the remaining six Program subjects. Only one boy (6) dropped below 90% accuracy during the programmed sequence of stimuli. During the 100 training and test trials, this group's median error frequency was 5, while the maximum was only 11. Thus, the worst subject in this group was 89% correct during training and testing. These records revealed no systematic error patterns across or within subjects. The programmed sequence of graduated stimuli maintained nearly perfect stimulus control while bringing these severely retarded boys under the control of the final stimuli in only 60 trials.

Retention Tests

All 12 boys were retested 35 days after the program and criterion test were completed. The retention test consisted of 40 criterion trials under the same correction procedure used before. Criterion performances may be contrasted to retention test performances in Fig. 5. Table 2 shows the criterion and retention test scores expressed in terms of per cent correct.

Subjects 8 and 13 in the Trial-and-Error group, who had nearly perfect criterion test performances, showed virtually no retention.

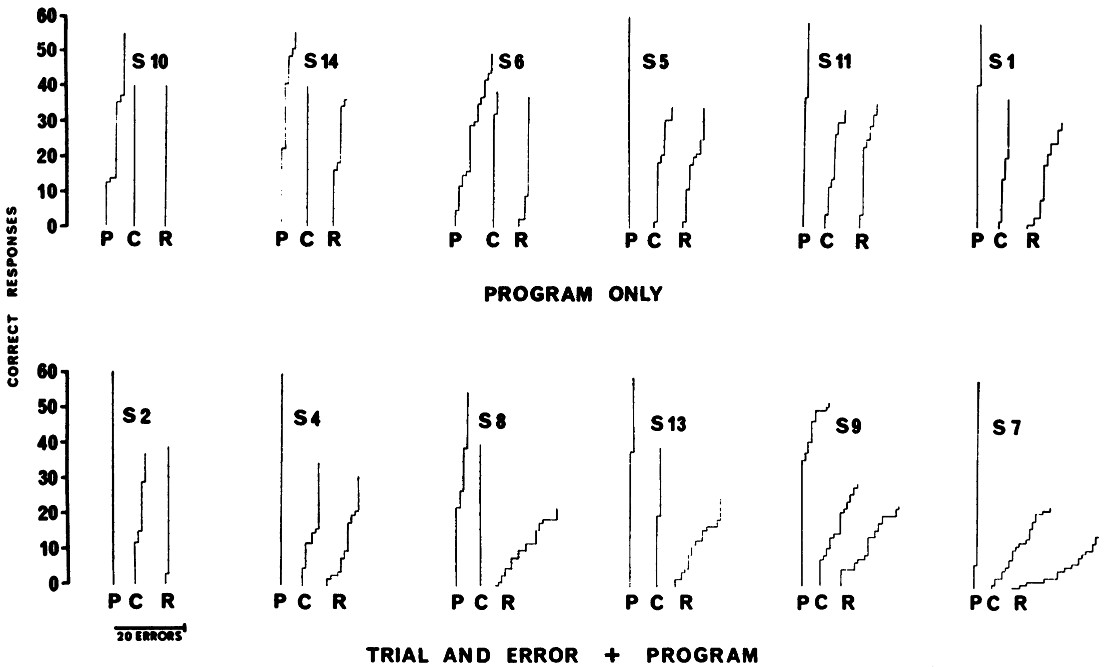

Fig. 5. Cumulative correct responses (each step up) and errors (each step to the right) for both groups during the programmed stimulus sequence (P), the criterion test (C), and the retention test (R). Only the first response in each trial is plotted.

Their retention test performances were not significantly different from chance. Subject 1 in the Program group suffered the largest loss after 35 days, dropping from 92.5 to 75% correct. His retention score was, however, still significantly above a chance performance ($P < 0.001$). Thus, two boys in the Trial-and-Error group lost all that they had learned after near-perfect original performances. In the Program group, all subjects but one showed excellent retention, and that one boy was still demonstrating the controlling relation between the experimental stimuli and his responses. It should be noted that the boys in both groups had learned the discrimination by means of the program, and differed from each other only in their earlier training.

Table 2

Comparison of Criterion and Retention Test Scores

Subject number	*Criterion Test % correct*	*Retention Test % correct*
8	100.0	55.0*
13	97.5	62.5*
2	92.5	97.5
4	87.5	77.5
9	72.5	57.5*
7	57.5*	37.5*
10	100.0	100.0
14	100.0	90.0
6	97.5	92.5
1	92.5	75.0
11	85.0	87.5
5	85.0	85.0

Scores marked with an asterisk were not significantly different from chance (50%) $P < 0.01$.

DISCUSSION

These data indicate that retarded children, who show no signs of learning a discrimination by trial and error, can be taught by a program of graduated stimulus changes. The data further suggest that a history of trial-and-error training may interfere with acquisition and retention of a discrimination. These findings support and extend those of Sidman and Stoddard (1967).

Sidman and Stoddard (1967) reported that retardates, presented initially with a criterion test under trial-and-error conditions, were better able to learn when presented with a programmed instructional sequence. Several subjects in each of their groups (4 of 9 subjects with a history of trial and error, 3 of 10 subjects with no training history) failed to get though the instructional sequence. In this study, subjects similar to those used by Sidman and Stoddard, all completed the program of graduated stimulus changes with few or no errors. A possible reason for this difference lies in the pre-training procedure employed. All subjects were initially taught to discriminate a lighted red key from a dark key to a criterion of eight successive correct responses. This procedure guaranteed that each subject was familiar with the apparatus, had no major topography problems, and was under the control of the stimuli which initiated the instructional program. In contrast, Sidman and Stoddard (1967) presented subjects initially with program slides or criterion trials. They initiated training with a procedure and stimuli which might in no way control the behavior of the subject. Each procedure was then terminated when a criterion of five successive errors on the same slide was met. Thus, it was possible for subjects to get through several procedures without ever having come under the control of the stimuli presented on the keys. If this occurred, and it seems likely that it did, the programmed instructional sequence was doubly taxed. It then became necessary to establish, for the first time, appropriate stimulus control in subjects who were likely to have come under the control of inappropriate aspects of the experimental environment.

Training procedures which do not immediately establish control by appropriate stimuli can result in the acquisition of stimulus-response relations which interfere with the establishment of control by the designated aspects of the experimental environment.

The data from Subject 7 illustrate this point. After pretraining, Subject 7 was presented with 640 criterion trials under differential reinforcement and rapidly acquired a position habit. When he was switched to the program, control by the experimental stimuli was reestablished. He made only one error during the 60-trial program which gradually approximated the criterion stimuli. However, when the stimuli were made identical to those which had been present during trial-and-error training, Subject 7 reverted to his position-based response. This subject responded to the training stimuli by pressing the "correct" key but responded to the criterion stimuli by always pressing the right-hand key. This breakdown of control at the very last step of the program suggests that the subject "recognized" the 0.75 in. square and emitted the response pattern which had been adventitiously reinforced in the presence of this stimulus during trial-and-error training. It seems unreasonable that altering the width of the black area on the key by 0.125 in. would cause such a dramatic change in the subject's behavior, were it not for his previous exposure to the criterion stimuli.

Subject 7's position-based responses might be described as "discriminated errors" in that they signaled his discrimination of the criterion stimuli from the training stimuli. It seems likely that the three Sidman and Stoddard (1967) subjects who went through the initial stages of the instructional program with relatively little difficulty, but returned to making errors as the criterion stimuli reappeared, were making some form of discriminated errors.

The remaining five trial-and-error subjects in the present study did not develop any identifiable error patterns in the presence of the criterion stimuli. This could have been a result of the extreme simplicity of the visual display. The 0.75-in. square was the only stimulus presented on the display-response panels which varied from trial to trial during the criterion procedure. Thus, when this singular visual stimulus did not gain control, the basis for responses was not apparent. There were, however, several indications that these subjects were under the control of some properties of the display-response panels; their continued accurate response topography, and the absence of responses between trials, *i.e.*, when the keys were dark.

In the group of six subjects with a history of trial-and-error training, four showed some difficulty in acquiring or retaining the discrimination. Since none of the members of the group without this training history showed these effects, it seems likely that the trial-and-error training had deleterious effects even in those cases where the adventitiously reinforced response patterns were not obvious. The nature of the interaction between subject and environment in a trial-and-error procedure precludes the accurate specification of historical variables. However, the magnitude of the effects observed in these children suggests that research should be directed to identifying historical variables which effect acquisition, transfer, and retention of stimulus control.

In a visual discrimination problem where "correct" responses are differentially reinforced, the contingencies set by the experimenter do not exclude inappropriate observing behavior. Thus, responses can be reinforced regardless of what the subject is observing. The conditions under which reinforcement is delivered may be sufficient to shape superstitious control. In normal subjects, superstitions frequently appear during discrimination training, but they are replaced by more efficient behavior (Krechevsky, 1932; Harlow, 1959). In the retardate, superstitious controlling relations generated early in discrimination training frequently seem to prevent the development of any appropriate controlling relation. The occurrence of spurious controlling relations cannot be avoided even with the most careful application of reinforcement in a trial-and-error procedure (*cf* Reynolds, 1961). However, if training is initiated by reinforcing a stimulus-response relation which already exists, or is easily established, it may then be possible to shift the stimuli towards those which comprise the criterion discrimination, while maintaining control of responses by specified and appropriate aspects of the training environment.

Tedious though it may be to establish a graduated series of training stimuli which insure the continuity of stimulus control, the startling effectiveness and economy of the program, once perfected, amply justify the work necessary to develop it. Further, some retardates who give the appearance of being untrainable, may in fact be the victims of training techniques which generate perseverative error patterns. For them, a programmed graduated stimulus training procedure may provide the only means for discovering their true potential.

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