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DEFICITS IN ACQUISITION OF OPERANT DISCRIMINATION AND DIFFERENTIATION SHOWN BY INSTITUTIONALIZED RETARDED CHILDREN [1]

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THIS research was undertaken to explore the discrimination abilities of retarded children using controlled laboratory methods with automatic programing and recording devices. The primary goal was the location, automatic measurement, and functional definition of behavioral deficits which are relevant in both clinical and educational diagnosis.

Response differentiation (i.e. making one response instead of another) and stimulus discrimination (i.e. responding to one stimulus instead of another) are two basic component behaviors demanded by complex tasks. To assure a broad range of sensitivity in measuring devices and to conserve valuable experimental time, identification of deficits in differentiation and discrimination should precede investigation of more complicated components.

While there are numerous clinical psychological tests purporting to detect deficits which affect the response of retarded children to the usual formal educational methods, such tests have repeatedly shown themselves to be nonspecific; they do not clearly delineate defects. Furthermore, because of their culture-bound content, they frequently put the child from a deprived environment at an immediate disadvantage. For the severely retarded nonverbal child, they afford only rough estimates which depend upon the judgment and experience of the clinician who administers and interprets the tests. In all cases, they represent poorly controlled testing situations in which observer bias and the interaction of the examiner with the child can have remarkable effects on the test scores. Perhaps most important from a research point of view is the progressive loss of sensitivity of clinical tests with repeated administration.

Educational technology is now in a period of rapid advance in the use of automated methods (Skinner, 1961). Development of these methods is based on principles of behavior generated from laboratory study of the interaction of lower animals with a highly controlled environment. Modifications of the basic methods of free operant conditioning have been used recently to study the behavior of mentally retarded children by Bijou and Orlando (1961), Orlando (1961a, 1961b), Orlando and Bijou (1960), Ellis, Barnett, and Pryer (1960), and Zeaman (1957, 1960). All have shown that the method can be used to obtain fruitful data on retarded behavior. With full environmental control, automatic programing techniques, and adequate reinforcing agents,

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these investigations have demonstrated that the behavior of retarded children may be rapidly brought under stimulus control. Sensitively arranged changes in the programing of discriminative and reinforcing stimuli may readily speed up acquisition of discriminations, and the nature of the stimuli supporting the discriminative behavior may be analyzed within experimental sessions.

While the above findings demonstrate the efficacy of the free operant method for therapeutic and prosthetic purposes in producing apparently "normal" uniformity in a group of retarded children, none has been oriented toward development of devices which automatically measure *behavior deficits.* To date, the only systematic application of free operant conditioning in the area of diagnostic measurement is that of Lindsley (1960, 1962). In his experimental analysis of the behavior of chronic psychotics, Lindsley has clearly shown that some of the most clinically relevant data are produced only through long-term, continuous, controlled observation. To the clinician this is not surprising, for there are obvious parallels in his own training. If he decides, for example, to use a new clinical tool for detecting behavior deviations, he may spend many years using the instrument before he is certain of its value for his purpose.

This report presents some of the findings which emerged during a year of exploratory research with a measurement device never before applied to the study of mentally retarded children.

METHOD

Subjects

Twenty-five institutionalized mentally retarded children, ranging in age from 7 to 20 years and in Stanford-Binet IQ from 33 to 72, were selected from the Walter E. Fernald State School[3] without regard to diagnosis. These children were studied for periods of time varying from 1 to 40 hours. The initial group of seven children, all considered educable, were attending classes regularly. Two children were selected from the extremes of a group on whom there were objective data from a matching to sample automated instructional program on coin recognition.[4] One of these children had little difficulty with the program; the other persisted in random responding irrespective of the stimulus material presented to him. Gradually other children were added for purposes of following leads suggested in the data from the original core group. Seven children were selected because they had a history of seizures. Two children who were incapable of verbal communication and were not attending classes within the institution were added. Sibling groups representing both sociocultural retardation and congenital defects were also included. Since the sensitivity of the laboratory device to varying degrees and types of retardation was considered important, a representative sample was preferred to a "homogeneous" one.

Subject's Enclosure

Each subject was taken to a small room containing only a chair and a sloping wall-mounted panel on which were two lights, each located above a plunger manipulandum.[5] The child

[3] The assistance of Malcolm J. Farrell, M.D., Superintendent, Clemens Benda, M.D., and Benjamin Matzilevich, M.D., of Walter E. Fernald State School is gratefully acknowledged. Without the excellent cooperation of the Fernald School staff and, most importantly, the children themselves, this research would not have been possible.

[4] Personal communication from J. G. Holland, 1961.

[5] This experimental room was described in

could pull these manipulanda either separately or simultaneously, and he could retrieve reinforcements from a tray inset on the right of the panel.

Experimental Design

All children were started on a program designed by Lindsley to locate behavior deficits in psychotic patients (1958a, 1958b, 1962). The design is diagrammed in Figure 1. Each light configuration was presented for one minute (C1 or C2) on a regularly alternating schedule, and either or both manipulanda (M1, M2) could be operated at any time. Thus there were four possible response conditions or reflexes. Pulling the left manipulandum with the left light on (C1M1) was reinforced on a fixed-ratio 10 schedule (every tenth response reinforced) with a penny or piece of candy. The penny to candy ratio was approximately 1:6. Pulling the right manipulandum with the left light on (C1M2), the left manipulandum with the right light on (C2M1), or the right manipulandum with the right light on (C2M2) was never reinforced. Each of these four reflexes was separately recorded on counters and cumulative response recorders. A fifth recorder continuously recorded simultaneous responses (within 125 ms. of each other) on both manipulanda. All programing and recording was controlled by relay circuitry located in a separate room from which one-way observation of the child was possible.

The design permitted independent measurement, within a single subject in a single session, of the three behavior processes which are schematically represented in Figure 2. A significant re-

greater detail by Lindsley (1958b). The conditioning panel is commercially available from Robert C. Dalrymple, 20 Fletcher Ave., Lexington, Mass.

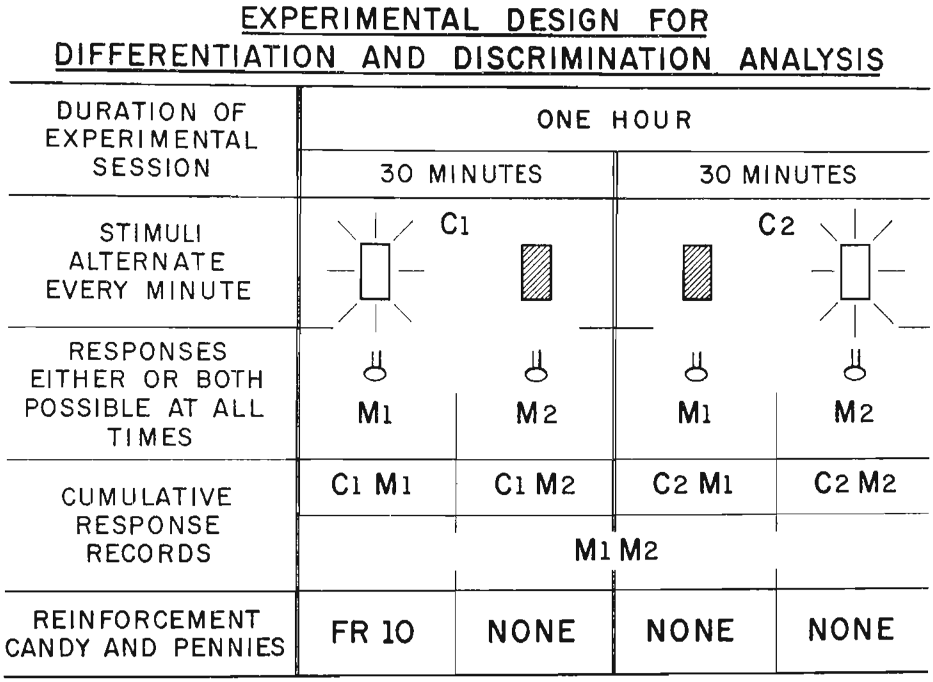

Figure 1. Schematic diagram of experimental design for analysis of response differentiation and stimulus discrimination.

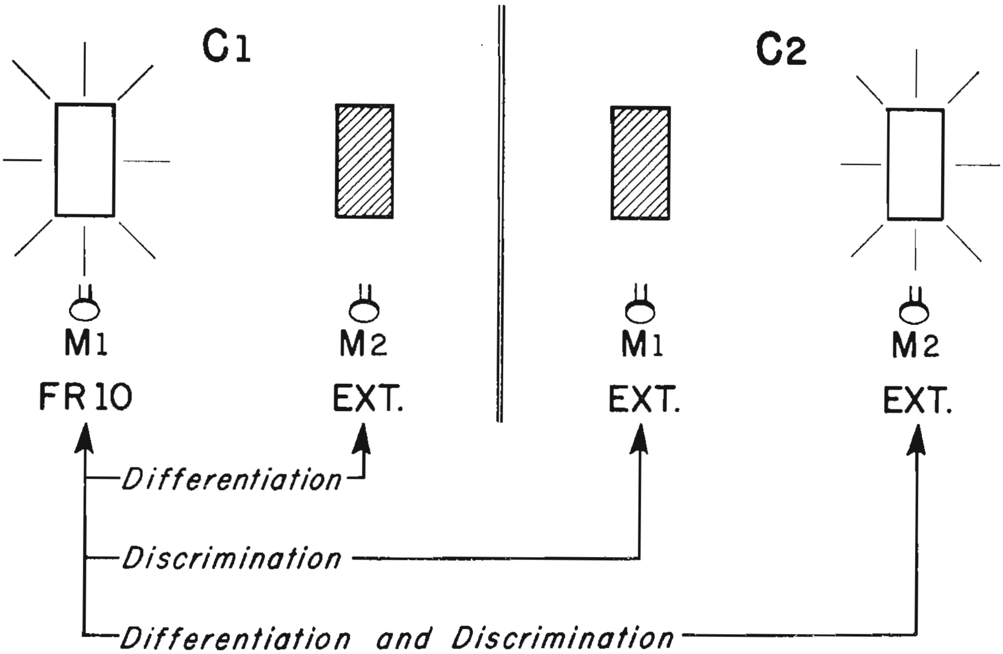

FIGURE 2. Schematic diagram for the functional description of differentiation and discrimination.

duction in the rate of C1M2 reflexes below the rate of the reinforced reflex (C1M1) indicated the formation of response differentiation (making one response instead of another). Reduction in the rate of C2M1 reflexes relative to the C1M1 rate indicated stimulus discrimination (responding to one stimulus and not to another). Reduction in the C2M2 rate below the C1M1 rate indicated formation of both differentiation and discrimination. Maintenance of high rate on C2M2 with concurrent reduction of the C1M2 and C2M1 rates indicated overgeneralization or defective reality testing. The general motivational level of the subject was indicated by the total number of responses per session.

Procedure

Each child was brought from his dormitory at Walter E. Fernald State School to the laboratory at Metropolitan State Hospital for one-hour experimental sessions once a week during successive weeks. Before the start of the first session, each child was introduced to the "machine" by *E* showing him the two knobs and explaining that when the machine was on one of the lights would go on. He was also shown the reinforcement delivery tray and told that he could learn to work the machine so that some of the time he would get a penny or a piece of candy. No further explanation was given. If by the end of 10 minutes the child had not responded on either of the knobs, he was told that he would have to "work" on the machine to get his candies. Only two children failed to respond until given a demonstration of how to pull the knobs. At no time did a demonstration include running off a ratio to obtain a reinforcement.

The number of experimental sessions per child was not preset. The purpose was, rather, to use the apparatus as a vehicle for observing the behavior of each child in this fully controlled experimental environment and to determine whether the method would yield relevant data on the ability of each child to differentiate two responses and to discriminate two stimuli. No experimental changes were introduced until the behavior baselines generated by the previously described pattern of differential reinforcement had stabilized over a number of experimental sessions. The nature of procedural changes was decided on the basis of questions raised by emerging data from each individual.

RESULTS

The patterns of acquisition revealed to date range from rapid acquisition, which is characteristic of the normal adult (Lindsley, 1958a, 1958b, 1962), through delayed acquisition, to no acquisition in adequately motivated subjects in as many as 40 weekly one-hour sessions. Stability in the behavior processes of some children has not been reached in as many as 60 weekly sessions. Initial differential responding of a "superstitious" nature appeared in some of the older children, and marked response stereotypes were immediately shown by others. In those children who eventually reached an optimal level of performance, response differentiation occurred before stimulus discrimination, and the last stage of learning involved the elimination of the overgeneralized response of relatively high rates on C2M2, or "pulling the knob under the light" (Barrett, 1962).

While the above are general summary statements describing the commonalities in the data, the most significant findings are the highly individualized response patterns, many of which were revealed only after months of baseline observation. These deviations from the more general patterns were focused upon in an effort to locate and functionally define specific behavior deficits. Some examples of these specific deficits in discrimination and differentiation are described below.

Initial rapid learning followed by slow loss. Although cumulative records of responses during his first hour showed rapid acquisition (increased rate of the reinforced C1M1 reflex and marked drop in the rates of the non-reinforced reflexes: C1M2, C2M1, and C2M2), one child began to reveal slow sporadic losses in stimulus discrimination through successive hours. This was shown by session to session irregularities in the C2M1 reflex rates relative to the reinforced C1M1 rates and is seen in the irregular decline in the discrimination index from Session 4 through Session 17 in the upper graph in Figure 3.[6] His discrimination losses occurred not only from session to session but frequently within sessions. There were several successive hours when his discrimination failures occurred only at the beginning of each session, suggesting the possibility that forgetting necessitated reacquisition each week.

As this child's experimental history grew, it became apparent that successive reacquisition within sessions was

[6] The rate index was devised (Jetter, Lindsley, & Wohlwill, 1953) to quantify the relationship between two rates of response. It is defined as the difference between two rates divided by their sum. Thus, referring to the rate comparisons diagrammed in Figure 2, a child's discrimination index for a given experimental session is the difference between his C1M1 rate and his C2M1 rate divided by their sum; his differentiation index, the difference between his C1M1 rate and his C1M2 rate divided by their sum; etc. Absence of differential behavior is represented by zero, maximum differential behavior by ± 1.00 Positive values represent higher rates of the reinforced reflex than of the non-reinforced reflex; negative values represent higher rates of the non-reinforced compared with the reinforced reflex.

not sufficient for him to reach a stable performance with respect to this discrimination function. His differentiation of responses (differentiation index: lower rate on C1M2 relative to C1M1) was considerably more stable, although it was subject to occasional temporary loss (Sessions 10, 19, and 23). Nevertheless, this child permanently eliminated the superstitious overgeneralization response (high C2M2 rate) by the third hour.

While there was some fluctuation in his motivational level from session to session (total responses per hour and number of reinforced responses per session in lower graph in Figure 3), his discrimination losses can not be explained on this basis. Intrasession loss, especially when occurring in the middle

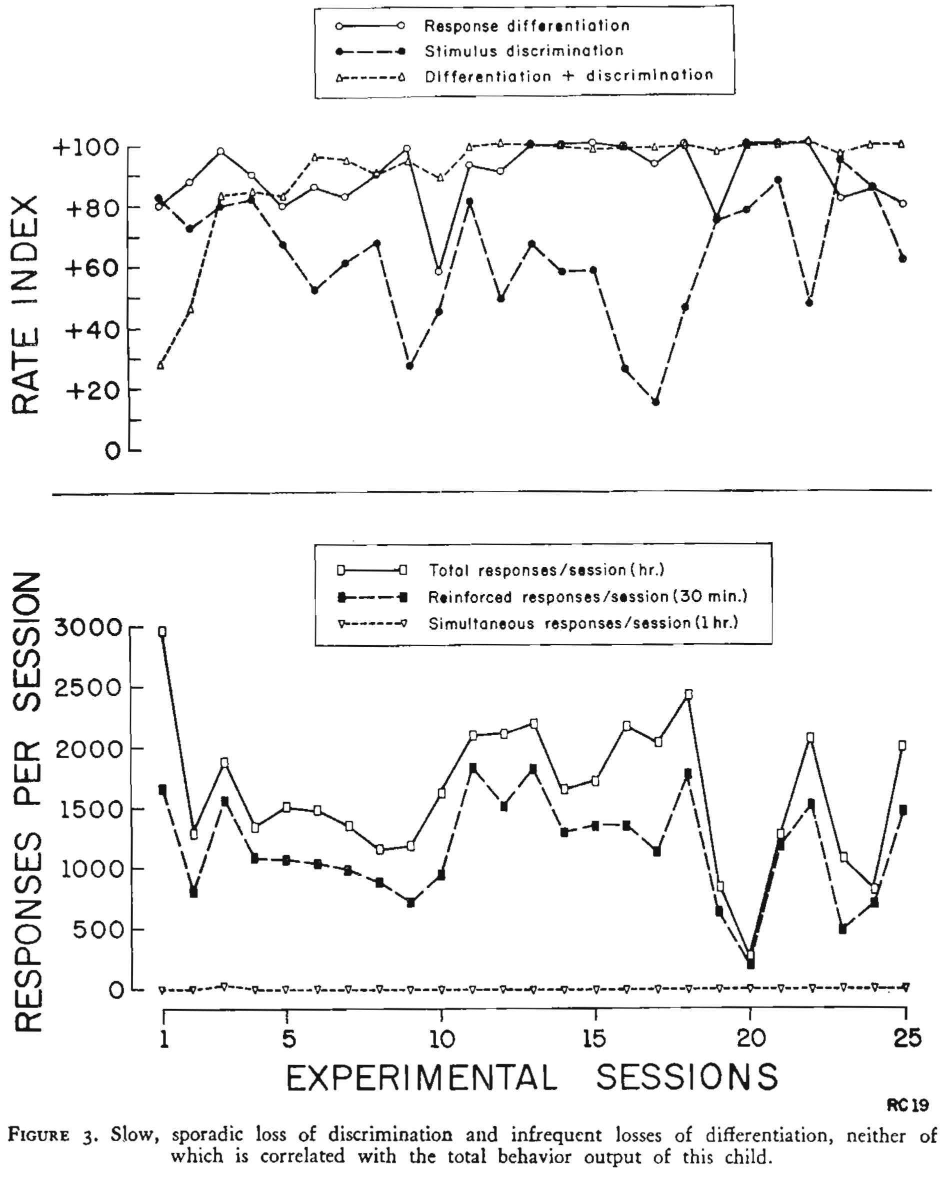

FIGURE 3. Slow, sporadic loss of discrimination and infrequent losses of differentiation, neither of which is correlated with the total behavior output of this child.

of a session within a controlled environment, can be attributed to neither extra-experimental factors nor intersession memory loss. Neither can it be attributed to experimental variables, because they were held constant.

The fact that this was the only child in the group whose mental retardation was attributed to emotional factors may be of considerable significance. Observational data from the laboratory suggest that sharp drops in his discrimination tended to occur on days when clinical symptoms were most obvious. It is clear from these data that, in order to know the range and patterns of variability in this child's baseline behaviors, prolonged controlled observations are necessary. His experimental history to date demonstrates a phenomenon often seen in the clinic, namely that the patient who may appear fairly intact during the first hour may subsequently reveal pathology over a number of months. A one-hour evaluation of this child may be grossly unreliable in predicting his behavior.

Abrupt intrasession loss. After 14 hours of conditioning, one boy proceeded through half of Session 15 in a manner indicating he had learned all the requirements of the task (Figure 4). After approximately 40 minutes, with no change in the apparatus or the experimental enclosure, he suddenly started pulling both knobs simultaneously under the C5 light configuration associated with reinforcement of only one response (see abrupt onset of responding on cumulative records of M1M2 and C5M2 in Figure 4).[7] Within the next 2 minutes, this double responding began to occur under the C6 configuration associated with no reinforcement, though somewhat less continuously (see sudden onset of responding on both C6 records in Figure 4). This abrupt and complete loss of response differentiation rapidly followed by equally abrupt but less complete loss of stimulus discrimination, lasted throughout the remainder of the experimental session. Without continuous functional recording of this boy's behavior, such findings would not have come to light. The implications of these findings in terms of this boy's ability to sustain performance on a learned task are obvious. The fact that he is subject to unilateral focal myoclonic seizures which are barely perceptible clinically, raises a variety of questions which can only be answered experimentally with appropriate devices for simultaneous measurement.

Initial differential responding. The most extreme pattern of initial differential responding was that of pulling only the plunger under the light at very high rates. This apparently prepotent pattern is grossly deviant from the initial undifferentiated responding shown by most subjects. In those children who showed it, the excessive generalization (pulling the plunger under each light when only responses on the left plunger under the left light were reinforced) appeared immediately at the beginning of the first experimental session (see RC 11 in Figure 5). Since it was displayed only by subjects who were among the oldest in the group, it was probably a pattern generated outside of the experimental environment as, for example, by vending machines. This pattern is very resistant to change under differential

[7] In his first five sessions this boy showed little change in his initial differential reflex pattern which was marked by high C1M1 and C2M2 rates with few other responses. Beginning with the sixth session, the stimulus conditions were changed to C5 alternating with C6 as shown in Figure 4. There was no change in the reinforcement contingency. C5M1 responding was reinforced on FR 10 and all other reflexes were programed on extinction.

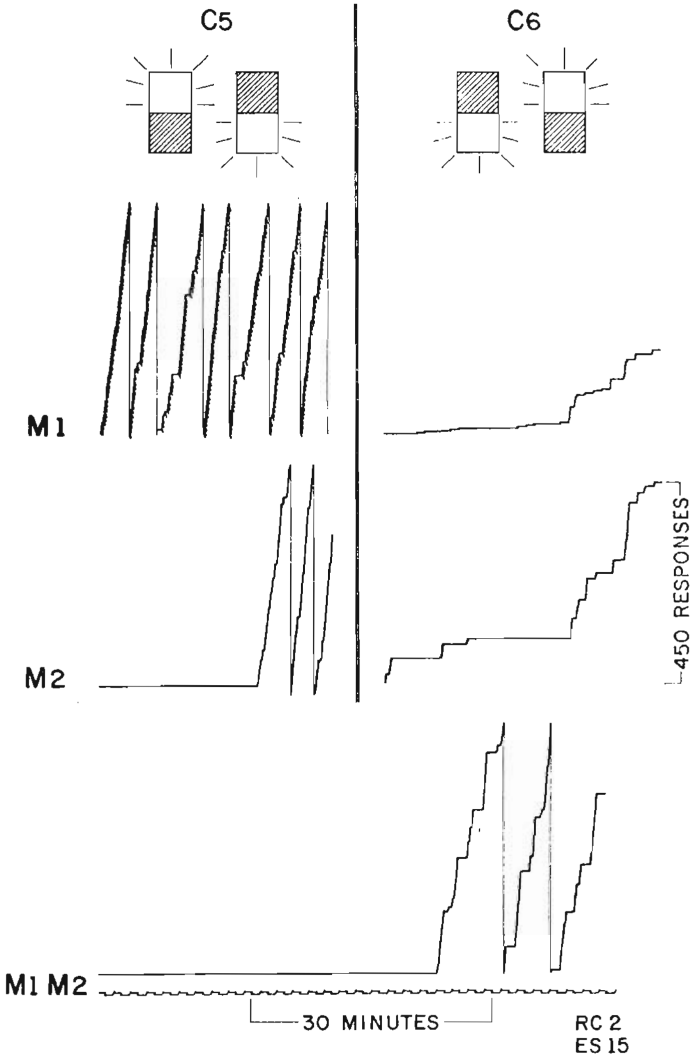

FIGURE 4. Simultaneous cumulative records showing abrupt and complete intrasession loss of differentiation (C5M2) followed by equally abrupt but less complete loss of discrimination (C6M1) and sudden overgeneralization (C6M2) within a single session in a fully controlled environment.[8]

reinforcement, but in some cases it can be broken up by programing different stimulus configurations (such as the C5–C6 alternation shown in Figure 4), though sometimes at the expense of other behavior previously stable in the experimental setting. Experiments in which reinforcement is programed for responses under each of the lights would capitalize on this generalized response pattern which may be independent of the experimental contingency arrangement.

Response stereotypy. Another immediately observable initial pattern which is even more resistant to control

[8] Hatch marks indicate delivery of reinforcement for every tenth C5M1 response. The M1M2 record continuously monitors the occurrence of simultaneous responses (within 125 ms. of each other) on both manipulanda throughout the entire experimental session. The lower event marker on this record is depressed during C5 presentations.

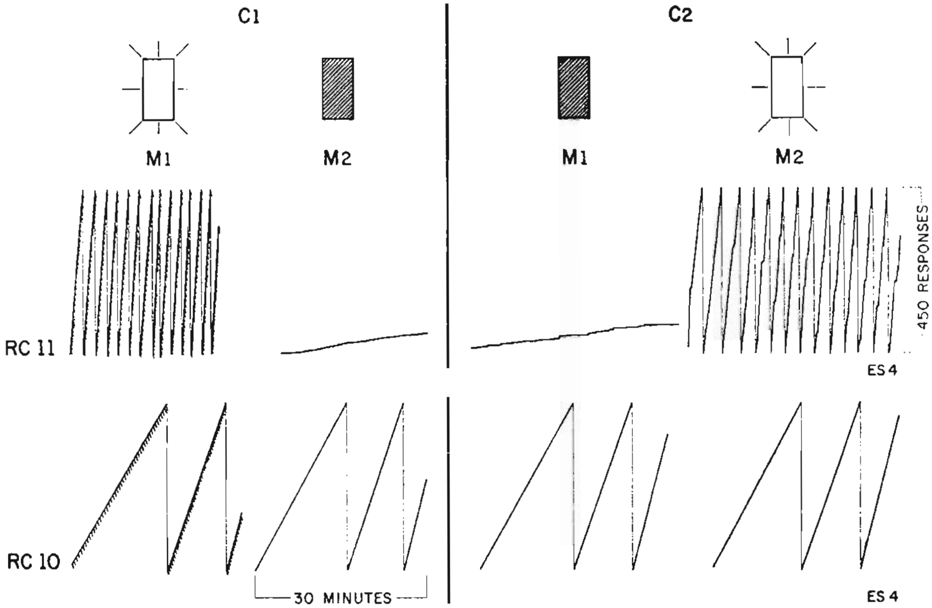

FIGURE 5. Cumulative response records of two children showing two different types of persistent prepotent response patterns.

is that of pulling the two manipulanda in regular single alternation regardless of the stimulus conditions (see RC 10 in Figure 5). While successive discrimination may be brought about eventually by changes in the nature of the C2 stimulus, the single alternation pattern under the C1 condition may remain unchanged even when force is added to the right manipulandum (M2) or when an aversive consequence such as shock is programed for every M2 response. Without the independent and simultaneous recording of all reflexes, such data would not be available for analysis.

Long-term highly variable acquisition. A number of the children provided good examples of long-term acquisition with either temporary or progressive losses in either differentiation or discrimination ability. There is one child, however, whose experimental history reveals a number of surprising facts. This girl carries the diagnosis of congenital cerebral spastic hemiplegia. With decided spasticity of the right hand, she would probably be excluded from other less exploratory experiments involving manual responding. Despite her physical handicap, 80 per cent of this girl's responses during the first experimental session were with her right hand on the right manipulandum (M2), which never produced a reinforcement. During her second hour this dominance reversed to the left manipulandum (M1). However, during this same hour a high rate of simultaneous responding (M1M2) began. The majority of these double responses occurred under the C2 light condition, which is associated with non-reinforcement of both responses. This double responding in a right hemiplegic child predominantly during the extinction component of the schedule did not dissipate until 15 sessions later when response differentiation began to form. It would appear that during periods when no responding pays off, this child expends excessive amounts of energy involving her handicapped limb. This finding suggests that physical therapy procedures with this child which provide prolonged periods of extinction with brief periods of reinforcement would produce greater exercise of the spastic hand than would the opposite arrangement. In addition, it may be that more right hand activity would occur if the opportunity to use both hands together were present. This, of course, is subject to experimental test.

Abnormally low response rates. Three children, all of whom were on anticonvulsants, responded at abnormally low rates. One of these children also displayed clinically evident psychotic symptoms, the second produced higher rates when his medication was reduced, and the third required a lower ratio of reinforcement to maintain sufficient behavior for a differential response pattern to emerge. The plotted data for this third child are presented in Figure 6. Response rates during the first six sessions under fixed-ratio 10 (FR 10) were uniformly low (see lower graph of responses per session for each of the four reflexes), and no differential pattern was shown (see rate index graph). The next three sessions were programed to determine effects of lower ratio requirements. Reinforcement of every C_1M_1 reflex

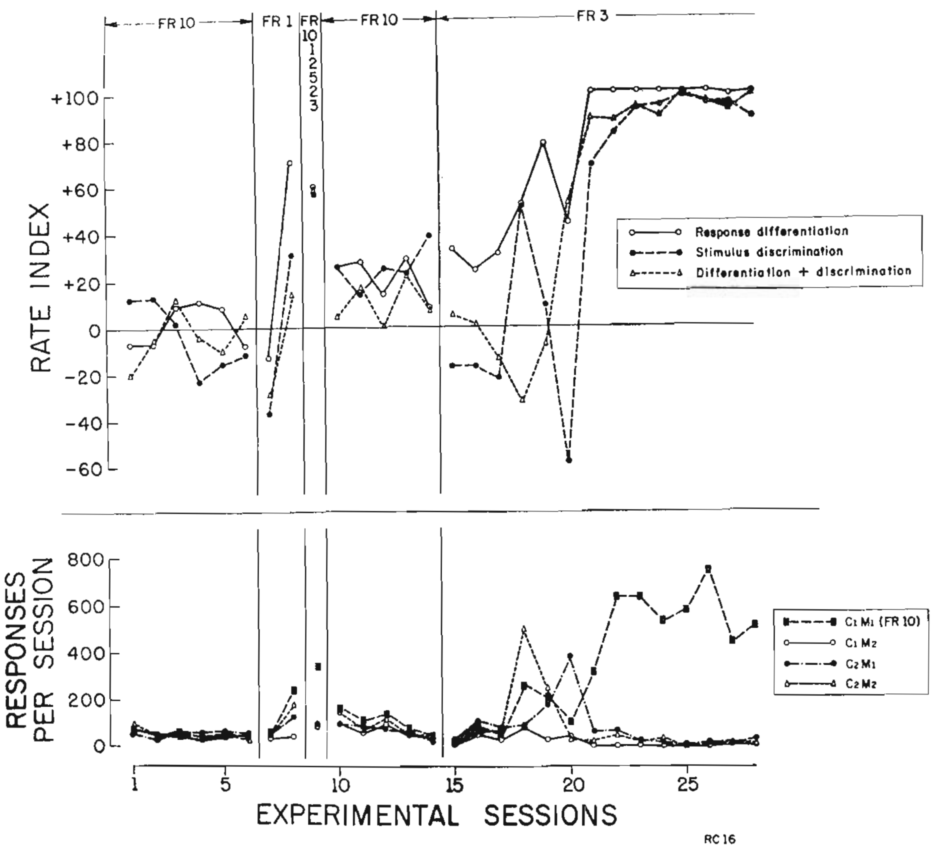

FIGURE 6. The delayed effects of lowered ratios of reinforcement on one child's differential responding and response rates.

(FR 1) took two sessions to show an effect (Sessions 7 and 8 in Figure 6). Return to FR 10 at the beginning of Session 9 produced a drop in response rate to the level shown in the first six sessions. Obviously the effects of two sessions on FR 1 was not maintained. Cumulative records of Session 9 showing effects of successive intrasession ratio changes indicated that this boy responded at higher rates on lower ratios. This is most readily seen in the long range effects of FR 10 during Sessions 10 through 14 followed by change to FR 3 for Sessions 15 through 28 (Figure 6). Under FR 10, rates of all four reflexes progressively declined and the previously shown differential responding disappeared. The change to FR 3 produced a marked facilitative effect both on total behavior output and on differential responding. Note, however, that this effect was quite delayed and was preceded by three sessions of no change followed by disruption, as indicated in the increased rate of first C2M2 and then C2M1, before this child's optimal differential pattern was shown.

It is not surprising that the lower ratio of reinforcements enabled this child to learn the differentiation and discrimination task. Its effect on his rate of responding is unusual enough to have possible implications for his deficit. Higher ratios most often produce faster rates of response, provided the nature of the reinforcement is appropriate. In this case, the behavior deficiency is not attributable to a poor reinforcing agent but may be a function of its intermittent delivery, for he works harder and learns more rapidly when it is delivered more frequently. Also, he may not be capable of "feeling" ratios above 5. The reliability of these findings will be further tested. At this point, however, the data clearly show that, in order to produce best results with this child, training procedures should provide more frequent reinforcement than is practical in most classroom situations.

DISCUSSION

The examples described above are but a few of the more striking deficits shown in the group of retarded children who continue to serve as subjects in the ongoing investigation. The data indicate that the device and the programing are sensitive to individual response patterns. The experimental procedure locates and automatically measures some basic behavioral excesses and deficiencies which interfere with efficient differential response to immediate contingencies in a controlled environment. Because it makes no demands of language comprehension on the part of the subject, it may be used to study the behavior of severely retarded nonverbal children who are often excluded from other experimental procedures and whose deficits are usually beyond the range of sensitivity of current clinical tests. The use of indestructible equipment in sturdily built experimental rooms permits the investigation of extremely disturbed and assaultive patients who are "untestable" by other behavior measures.

The examples described here represent a variety of deficits in the interaction between individual children and the same controlled environment. Except for the prepotent response patterns (shown in Figure 5), none appeared without continuously and functionally measured, controlled laboratory observations over a number of months. Whether similar information could a variety of reliable individual response patterns including a wide range of deficits. Most of these deficits were revealed only through repeated, continuously recorded, controlled observations over many experimental sessions. Individual variability—both intersession and intrasession—is extreme enough in some cases to demand prolonged study. Because of our focus on diagnostically oriented experimental analysis rather than on rapid prosthesis, the nature and amount of individual variability emerges as an important and basic datum rather than as statistical "noise" or therapeutic failure.

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