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A Comparison of Differential Response Rates with Children under Two Schedules of Reinforcement and Extinction Using Programmed Mathematics Instruction

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A COMPARISON OF DIFFERENTIAL RESPONSE RATES WITH CHILDREN UNDER TWO SCHEDULES OF REINFORCEMENT AND EXTINCTION USING PROGRAMMED MATHEMATICS INSTRUCTION

By

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There is considerable evidence to indicate that a major controller of behavior is the consequence of that behavior (Skinner, 1948, 1953, 1958, 1961, 1963; Lawrence and Festinger, 1962). The particular stimulus event that follows a response largely determines the likelihood that the response will occur again in the future. We have knowledge of three types of consequences: reinforcers, which increase the frequency of the response they follow; punishers, which decrease the frequency of the response they follow; and neutral stimuli, which have no effect on the response they follow.

Animal research has shown that reinforcers influence response rates differently depending upon their schedule of presentation (Skinner, 1938; Ferster and Skinner, 1957; Dews, 1964). Ferster and Skinner (1957) devoted one hundred pages to the discussion of fixed-ratio (FR) schedules and over two hundred pages on the influences of fixed-interval (FI) schedules. In summarizing these effects, Lundin (1961) states, "Generally, high rates of response occur under ratio schedules, and low but stable rates occur under interval schedules..." (p. 65).

Studies of animal behavior under FR and FI schedules are numerous and yield rather consistent patterns of performance. With fixed-interval schedules, the typical response pattern that emerges is wave-like or scalloped on a cumulative recorder. Because reinforcement is followed by a period of non-reinforcement, an extensive history with these schedules results in the animal's pausing for an appreciable time following reinforcement. This response pattern, consisting

of post reinforcement pauses followed by a gradual positive acceleration until the next reinforcer is programmed, has been examined in great detail (Morse and Herrnstein, 1955; Hearst, 1958; Cumming and Schoenfeld, 1960; Dews, 1962).

Performance on fixed-ratio reinforcement schedules is quite different (Sidman and Stebbins, 1954; Weiner, 1964; Ferster and Skinner, 1957; Morse, 1966). These studies, also with animals, have yielded a number of principles which may be summarized from Ferster and Skinner (1957): (1) higher rates of response tend to be developed under this kind of schedule than under fixed-interval schedules; (2) as in FI conditioning, a discrimination is built up. There is a break after the reinforcement, followed by a rapid rate until the next reinforcement; and (3) the length of the pause is a function of the size of the ratio requirement. Once the response begins following a pause, it assumes a rapid rate until the next reinforcement (Chapter 4).

Reported attempts to study the performance of human subjects under various reinforcement schedules are relatively rare compared to the kind of animal research described above. However, in one study, mental patients were conditioned to respond by pulling a lever for candy and/or cigarettes on FR schedules (Hutchinson and Azrin, 1961). Response rates increased from fewer than six per minute under FR-1 to more than one hundred per minute under FR-25 and FR-50. These results are similar to those reported by investigators in work with normal humans (Long, Hammack, May, and Campbell, 1958; Holland, 1960), mental defectives (Ellis, Barnett, and Pryer, 1960) and with psychotic children

(Lindsley, 1956). In another study, infants were conditioned to respond in a characteristic FR manner for food after short periods of deprivation. The infants did pause for prolonged intervals, however, following the presentation of reinforcers (Weisberg and Fink, 1966).

Unfortunately, success in establishing schedule control in humans is the exception rather than the rule. This is particularly true when two or more schedules are studied together, as in a multiple FR-FI-Ext. One researcher (Long, 1962) expressed this problem as follows: "Anyone who has ever run pigeons and children on a mult FI-FR schedule cannot help being impressed by the relative ease with which the pigeon is brought under stimulus control and the great difficulty encountered in the child" (p. 455).

Among the causes for the discrepancy between animal and human behavior on multiple reinforcement schedules may be the motivational differences involved in deprivation and the type of reinforcers used. Rats and pigeons are brought to 80% of their free feeding weight by deprivation before conditioning. This, of course, is not feasible with children. It has further been hypothesized that perhaps the major uncontrolled variable in human studies is the history of the child before he comes to the experiment (Long, 1962). This hypothesis was supported in a study which provided an experimentally produced conditioning history (Weiner, 1964). Normal humans were conditioned to either an FR-40 or a DRL-20 sec schedule. They were then placed on an FI-10 sec schedule. Those with an FR-40 history continued to respond at high rates during the FI schedule, while those with a DRL-20 sec history continued their low rate of responding.

Despite the failure to achieve reliable schedule control with human subjects, it does seem clear that similar contingencies do operate in everyday human affairs. Students who attend classes at certain hours and frequent the dining hall when meals are served are behaving in accordance with FI contingencies. The factory worker on piecework payments is under a type of FR schedule.

Perhaps no area of human endeavor carries as much potential for the application of reinforcement schedules as does the contemporary educational system. The role of operant conditioning in the classroom is made clear by Skinner (1968) who states, "The application of operant conditioning to education is simple and direct. Teaching is the arrangement of contingencies of reinforcement under which students learn. They learn without teaching in their natural environments, but teachers arrange special contingencies which expedite learning, hastening the appearance of behavior which would otherwise be acquired slowly or making sure of the appearance of behavior which might otherwise never occur" (p. 64-65). From the framework of operant conditioning, then, the teacher is viewed as a behavioral engineer who arranges discriminative stimuli (S^D's) and provides proper consequences for student behavior so that appropriate behaviors are developed to an optimum. It is anticipated that from scientific research will come the necessary skills which will enable the teacher to perform these functions competently.

Experimental success in modifying children's behavior in the classroom has been repeatedly demonstrated (Birnbrauer and Lawler, 1964; O'Leary and Becker, 1967). Many investigations have been related to

social or discipline problems in the classroom, while other studies have attempted to modify behaviors which might be designated "academic", such as reading rates (Staats, Findley, Minkes, and Wolfe, 1964; Hawkins, 1967; Lovitt and Curtiss, 1968). There remains, however, a distinct shortage of research in which academic behaviors are examined under controlled laboratory conditions.

The present study is an attempt to demonstrate control of such behavior in normal children under fixed-ratio and fixed-interval schedules of reinforcement. The major purpose of the research is to investigate the interaction of a meaningful human response with schedules which have been shown to differentially influence animal behavior in a reliable manner. The dependent variable is the rate of correct responses on programmed instruction in mathematics. It is assumed that this measure correlates with the amount of learning that occurs, for a child who makes many correct responses on programmed materials should learn more than a child who makes few responses. In addition, relative constancy of the criterion response is essential to the study of reinforcement schedules if reliable results are to be expected. This is achieved in animal studies by using a bar press (with rats) or a key peck (with pigeons) and humans have been required to make similar responses for reinforcers (Hutchinson and Azrin, 1961; Weisberg and Fink, 1966). In the present study, the choice of a response to programmed instruction provides a meaningful learning sequence comprised of individual responses that are roughly equivalent.

One of the more difficult problems in human research is the discovery of effective reinforcers. According to Michael (1963) in a dis-

cussion of animal research and the mentally retarded, "...the reinforcers usually available to the mentally retarded learner are social approval, advancement in some series of learning tasks, candy or similar non-essential edibles, trinkets and toys of various kinds, and escape or avoidance of mild social disapproval. The reinforcing effectiveness of these events for a particular child is often not known, and in many cases varies from moment to moment" (p. 7). Hersheyettes, M & M's, candy corn and Payroll mint coins have been suggested for experimental studies with children (Bijou and Sturgis, 1959). Gerwirtz and Baer (1958a; 1958b) report two studies in which social rewards served as reinforcers. These may not be the kind of events, however, that will maintain high response rates over extended periods of time.

Since one cannot deprive children of food extensively, and since many of the most appropriate reinforcers cannot be readily dispensed systematically, there has emerged in the literature a growing usage of token reinforcement systems (Ayllon and Azrin, 1968). This is a system whereby certain desired objects or privileges are obtainable only through the exchange of tokens which, in turn, are obtainable only contingent on some behavior that is to be developed or maintained. Token reinforcement programs have been used with considerable success with the mentally retarded (Birnbrauer and Lawler, 1964); in school adjustment classrooms (O'Leary and Becker, 1967) and even with lower animals (Cowles, 1937; Wolfe, 1936). The current study utilized points on a counter as token reinforcers which were exchangeable for a variety of items desired by the subjects.

In summary, this experiment was designed to investigate the dif-

ferential effects of FR and FI contingencies (along with extinction procedures) on a important type of human operant behavior, responses to programmed mathematics instruction. These responses have the advantages of being relatively equivalent and easily recorded. The study is a logical extension of research with sub-human organisms in which the effects of FR and FI schedules on response rates are rather well established.

METHOD

Subjects

Ten sixth-grade boys were selected from four public school classrooms. These students were chosen by their teachers on the basis of a serious deficiency in elementary mathematics achievement. Such deficiency was determined by school marks in the subject. The ability to read on at least a fourth grade level was also necessary to insure that each boy could read and understand the questions presented in the programmed materials.

This group of ten was administered a pre-test of simple multiplication and division problems and the four boys with the lowest scores on this test were selected as experimental subjects. One boy was terminated as a subject after the first week of the study because of habitual truancy. The other three boys are designated here by the names Ed, Bill, and Tom. These boys were described by their teachers as lazy, unmotivated, and disruptive in the classroom, particularly during mathematics instruction. Their marks in other school subjects

were "C" or better with the exception of music for Bill and Tom. Throughout the ten week duration of the study the subjects continued to participate in regular class activities, including mathematics instruction, and no attempt was made to relate the work received from the experimenter to that assigned by their classroom teachers.

Instructional Materials

The TMI-GROLIER Programmed Instruction for Elementary Mathematics was selected as the stimulus materials because it is suitable for children who read on a fourth grade level (and has even been used sucessfully with educable mentally retarded children; Rainey and Kelley, 1967).

The entire program includes Part I: Addition and Subtraction, Part II: Multiplication and Division, Part III: Fractions, and Part IV: Decimals. Only Parts II and III were employed for the study, however, because the subjects were too advanced for Part I and because the experiment was terminated by the closing of school before Part IV was reached. Each Part of the program consists of approximately ten units with about two hundred problems per unit. The material is organized on standard 8½ x 11 inch paper with five questions on each side of each page. One complete unit can be placed in the Mini-Max teaching machine built by TMI-GROLIER. In this machine the program can be advanced with a roller that is geared to go forward only. The subject views each problem separately, pencils his answer on the program through a small opening in the window of the machine, advances far enough to see the correct answer, and proceeds to the next problem.

Since the program is a linear one, advancement is made to the next frame regardless of the outcome of the previous response.

In the upper left-hand corner of each frame is the number of the problem being presented and at the bottom of each page is the unit and page number. All of these are visible to the person as he advances through the material. Early in the study it was necessary to black out the numbers because the boys were receiving extraneous reinforcement by competing to see who could work the most problems in a session (point "b" Fig. 2,3,4,5,6, and 7).

Data and Apparatus

The experiment was conducted in a specially designated classroom in the subjects' school. The room was not used for regular school activities but was similar to other classrooms in the building except most of the desks and chairs had been removed.

The laboratory, located at one end of the room, contained two tables that were positioned together with a plywood partition separating the subject's side from the experimenter's side. Another partition separated the laboratory from the remainder of the room. The teaching machine was on the subject's table, and behind the teaching machine was a large display panel with two press buttons located within easy reach of the subject. The button on the right was labelled the "wrong" button and the left-hand button was marked "right". The subject recorded the accuracy of his response by pressing the appropriate button after viewing the correct answer to each problem. Two identical red lights were located between and just above these

press buttons on the panel. The lights were positioned one above the other. During the Experimental Phases these lights functioned as external stimuli that were paired with the FR, FI, and Ext contingencies. The top light was on during fixed-ratio reinforcement, the bottom light was on during fixed-interval reinforcement, and both lights were off during extinction. Also mounted on the panel was a small counter which recorded points automatically with an audible clicking sound. Points were presented immediately contingent upon certain correct responses, depending on whether FR or FI conditions were in effect.

The two red lights and the counter were operated by an electrical relay system located on the experimenter's side of the partition. The relay rack was positioned beside the experimenter's table and contained the necessary components to program the various contingencies. A small timer regulated the time interval under FI, and a response counter, which recorded only correct responses, was used during FR to maintain ratio requirements. Three on-off switches were also mounted on the relay rack, and each of these controlled one of the three experimental conditions--FR, FI, and Ext. This made it possible to change conditions instantly without stopping during a session. A stop watch was used to control the length of sessions and was stopped when adjustments were necessary in the apparatus or when the subject indicated the need for a new unit in the program.

Two timers were located on the experimenter's table. One of these was running while the subject worked. When either button was pressed by the boy to record a response, the timer stopped and the second timer began. This allowed the experimenter to take a direct reading

of the time between responses (to the nearest 0.1 second) and reset the timer. A small white light near the timers flashed when the "wrong" button had been pressed. The experimenter was thus able to record their times separately on the data sheet (see Appendix A). A daily check of the completed program materials indicated that all three boys consistently reported honestly (by pressing the proper button regarding the correctness of their responses).

The manual operations performed by the experimenter, then, included the changing of the switches, the resetting of the two timers, and the recording of data. The primary data consisted of an interresponse time (IRT) for each response made representing the time between button presses. Separate data sheets were kept for each session and a mean IRT was computed for each session during Baseline and for each component of the multiple schedules during the appropriate Experimental Phases. Interresponse times were used, rather than merely recording the number of responses per session, because they provide a detailed response-by-response record of performance.

Since incorrect responses were recorded as such, it was possible to determine the degree of accuracy achieved. The number of correct responses divided by the total number of responses provided an accuracy index for each of the sessions.

Procedure

Each subject reported at his assigned time every school day for a thirty minute session. They were told that they had been chosen to be part of a special class in mathematics, but that their performance

would not be used as a basis for grading in their regular mathematics classes. They were further advised that no reports would be given their teachers concerning their performance or general behavior during the special class, and that they were free to work at their own speed. Instructions were given for operating the teaching machine and the means for recording the correctness of each problem worked.

The door to the room was closed, and when a boy arrived, he waited his turn outside. When admitted to the room, he entered the laboratory area and was seated on the subject's side of the partition. The boys began each session at the point in the program where they had stopped the previous session. Verbal interactions during a session between the subject and the experimenter were minimal and, with few exceptions, were initiated by the subject. However, talking was not made to seem out of place nor was any other normal activity such as walking about, opening and closing windows, or writing on a blackboard adjacent to the subject's table.

Data were taken for four separate parts of the study. The first fourteen sessions comprised a Baseline, the next twelve sessions represented Experimental Phase I, the next six sessions were designated Experimental Phase II, and the final sessions comprised Experimental Phase III.

Baseline

The Baseline (sessions 1-14 for Ed and Bill, 1-12 for Tom) covered a total interval of five weeks. Included in this period was a ten-day spring vacation as well as an orientation procedure. During

these sessions the subjects responded without receiving points and the two red lights remained off. However, it is likely that certain reinforcers were operating consequent to the boys' responses to the programmed material. For each response they received feedback as to the correctness of the response by advancing the program and exposing the correct answer. Holland (1960) suggests that the only reinforcer needed to maintain behavior on programmed instruction is the correspondence between the learner's response and the answer which is immediately given. In addition, the advancement to the next frame of the program may be a reinforcer for all responses, correct and incorrect. These characteristics of programmed instruction precluded the possibility of achieving true extinction, procedurally, during Baseline. But if the answers had been removed from the program the subjects could not have responded properly to the two press buttons and would have been hampered in answering subsequent problems. It was hoped that the effect of the token and backup reinforcers used during the Experimental Phases would be powerful enough to influence the subjects' behavior despite the existence of the feedback intrinsic to the programmed materials.

During Baseline, IRT's were recorded for each response and a mean IRT was computed for each session by dividing the total number of seconds in the session by the number of correct responses. Because interresponse time is the interval between correct responses, the occurrence of incorrect responses produce large IRT's. They take time to work but do not meet the criteria of a response (see Appendix A).

Baseline was terminated when the subjects' response rates began to stabilize.

Experimental phase I

Following Baseline the daily sessions of Experimental Phase I were comprised of multiple schedules with various arrangements of three components--FR, FI, and Ext. Each of the components operated for ten minutes during the thirty minute sessions, but the order of their presentation was varied from one session to the next. Extinction was defined procedurally as the same conditions present under Baseline.

The initial values of the FR and FI components for Experimental Phase I were determined following the last Baseline session. Since a comparison of response rates during these components was of interest, it was essential to consider the relative frequency of reinforcement under the two conditions (Reynolds, 1961; Shettleworth and Nevin, 1965). With very small FI contingencies, such as FI-5 sec, responses which require an average completion time of 10 seconds will produce the equivalent of continuous reinforcement. One could not compare response rates under FI-5 sec and FR-4 meaningfully under those conditions because the comparison would actually involve continuous reinforcement and FR-4. For this reason care was taken to establish the FR and FI requirements using the results of Baseline performance so that the initial frequency of reinforcement would be approximately equal under the two conditions.

The mean IRT's for Ed and Bill through Baseline were about 15 seconds or four correct responses per minute. Requirements for Ed and Bill during the mult FR-FI-Ext schedules of Experimental Phase I were therefore set at FR-4 and FI-1 min. For Tom, FR-2 and FI-1 min were

used because his base rate had been about two correct responses per minute. His requirements were changed to FR-4 and FI-1 min at session twenty because he was receiving more points than the other two boys for doing less work (point "c" Fig. 6 and 7).

The token reinforcement system was in effect during FR and FI. The system included the presentation of points, the accumulation of points in a "bank account", and the exchange of points for desired items. Under FR a point registered when the specified number of correct responses was completed, so that with FR-4 a point would be earned following every fourth correct response. Under FI-1 min a point was delivered after the first correct response following an interval of one minute since the last reinforcement. Responses made during the one minute interval did not affect the availability of reinforcers at the end of the interval.

A systematic record of the "wealth" for each boy was maintained in a daily "bank" transaction. The boys were instructed to tell the experimenter in advance what they would like to buy with their points. Sometimes the desired items were brought to the laboratory to be displayed until enough points had been earned. Sometimes a boy would earn many points before deciding what to buy. They were encouraged, though, to choose articles with a wide range of value so that small items would be available when work was primarily directed toward more valuable reinforcers requiring several days' work. The actual value of merchandise varied from five cents to two dollars with a total cost of $17.58 for the study. The exchange price was based on the cost of each item with a point equal to a penny (see Appendix B). In addition to these

backup reinforcers, designed to make the points more powerful reinforcers, a game was established at session 18 to see who could earn the most points. The winner was awarded a special five hundred point bonus at the end of the study for his total earnings.

Experimental phase II

The first Experimental Phase was designed to investigate possible differences in response rates under three different conditions within sessions. Experimental Phase II provided an opportunity to examine performance when one contingency was continued throughout the session.

Experimental Phase II was comprised of six sessions for each boy and all three boys began this Phase on the same day. Each of the thirty minute sessions involved either FR, FI, or Ext. The same values were used for the FR and FI sessions that were established during the preceeding Phase. There were two FR sessions, two FI sessions, and two Ext sessions. At the beginning of Phase II the boys were told that the red S^D lights would not change during or within sessions.

On the 29th session Bill was informed that he could leave the room briefly for a drink or to use the bathroom whenever he wished for the remainder of the class (point "d" Fig. 4 and 5). This was done to see if available alternative responses (leaving the room) would influence his performance.

Experimental phase III

Experimental Phase III was a return to the same multiple scheduling which had been presented in Phase I. It was believed that per-

haps the lack of desirable alternative responses might be partly responsible for the fact that moderate rates had continued to occur even under "extinction" in Experimental Phases I and II. It was thought that the boys could be following an implied instruction to keep working or at least to remain seated in the "working position". For these reasons, one new variable was introduced during Phase III. A space maze and a target game were made available on the subject's table along with the teaching machine. No directions were offered except the explanation, "I thought perhaps you might like these". Two of the boys asked if they could play with the toys and were told that it was their decision. The final Phase of the study was terminated by the closing of school for the year.

RESULTS

Baseline

The Baseline data are shown in the left-hand portion of Figures 2,4, and 6. It will be observed that the rate of responding was increasing over the first seven to nine sessions for all boys, as is indicated by a decline in the mean IRT. At this point the experimenter discovered that at least two of the boys (Tom and Bill) were competing daily to see who could work the more problems. Bill reported that they were doing this "to make the class a little more exciting". To remove this uncontrolled social consequation, all numbers for frames and pages in the program were blacked out with a crayon beginning at point "b".

For this session and the one immediately following, the experimenter was also absent from the laboratory, although he did remain in the room. This two-session probe (absence of E) was an attempt to determine the possible effect of the experimenter's presence at the recording table (probe "a"). Of course IRT's could not be taken for individual responses during these two sessions; however, a mean IRT for each session was computed by dividing the total session time by the number of correct responses made. The number of correct responses was determined by checking through the program material after the boys had completed their work for the day. Following the probe, the experimenter returned to the laboratory, but the page and frame numbers remained blackened for the duration of the study.

The combined effects of the probe and the removal of program numbers appears clear for the competing boys, particularly for Tom. His mean IRT changed from 25 seconds during session seven to 46 seconds during session eight. Bill's mean IRT for the session prior to the probe, 10.9 seconds, was followed by a mean IRT of 17 seconds. Ed, who was thought not to be a part of the competition, showed no change in performance between these sessions. The single continuing influence of removing the program numbers is not clear from the data.

Baseline accuracy data are shown in the left-hand portion of Figures 3,5, and 7. It is apparent that the accuracy level was often less than 100 per cent for all subjects. Tom's performance stabilized at perfect accuracy in his final five Baseline sessions, while Bill and Tom showed no improvement.

Because later comparisons were to be made between the three ten

minute segments of the thirty minute experimental sessions, it was desirable to determine whether the subjects produced consistently longer or shorter IRT's during Baseline as a function of segment order. Table 1 contains mean IRT's for the first, middle, and last segments of the last four Baseline sessions. Generally, the range from highest to lowest mean IRT among each boy's segments was from two to eight seconds. Every boy had at least one session in which the difference exceeded eight seconds and Tom had one segment in his last session with a much higher mean IRT than the other two segments. The combined total mean IRT's of all three boys for each of the three segments during these four sessions are shown in Fig. 1. On the basis of the individual data in Table 1 and the combined data in Fig. 1, it appears that a tendency to respond differentially as a function of the segment order does not exist.

Table 2 contains the results of a lowest to highest ranking of the three segments during the same four Baseline sessions. This information shows the number of times that each segment had a mean IRT that was lowest, second, and highest for its session. The totals in Table 2 show that the first ten minutes of the sessions had the lowest mean mean most often, the third ten minutes of the session had the highest mean most often, and the second ten minutes had an intermediate mean most often. This suggests the possibility of differential order effects among the segments during Baseline. Information regarding order effects are presented later for Experimental Phases I and III.

Experimental Phase I

Session	Ed 1st 10 min.	2nd 10 min.	3rd 10 min.
11	14.0"	22.0"	18.3"
12	21.8"	24.2"	22.4"
13	27.5"	29.0"	26.0"
14	17.2"	22.1"	29.0"
Total Mean	20.1"	24.3"	23.9"
	Bill		
11	10.9"	9.5"	10.4"
12	16.2"	20.7"	21.3"
13	11.3"	9.9"	13.9"
14	21.3"	21.3"	34.0"
Total Mean	17.4"	15.3"	19.9"
	Tom		
9	21.0"	22.6"	32.0"
10	22.0"	39.0"	21.3"
11	39.3"	38.4"	36.0"
12	60.0"	16.6"	20.3"
Total Mean	35.6"	29.2"	27.4"

Table 1. Mean IRT's during the first, second, and third segments of the final four Baseline sessions.

Mean IRT	Ed 1st 10 min.	2nd 10 min.	3rd 10 min.
Lowest	3 times	none	1 time
Second	1 time	2 times	2 times
Highest	none	2 times	1 time
	Bill		
Lowest	2 times	2 times	none
Second	1 time	2 times	2 times
Highest	1 time	none	3 times
	Tom		
Lowest	1 time	1 time	2 times
Second	1 time	2 times	1 time
Highest	2 times	1 time	1 time

Table 2. Lowest to highest ranking of the three ten minute segments during the final four Baseline sessions.

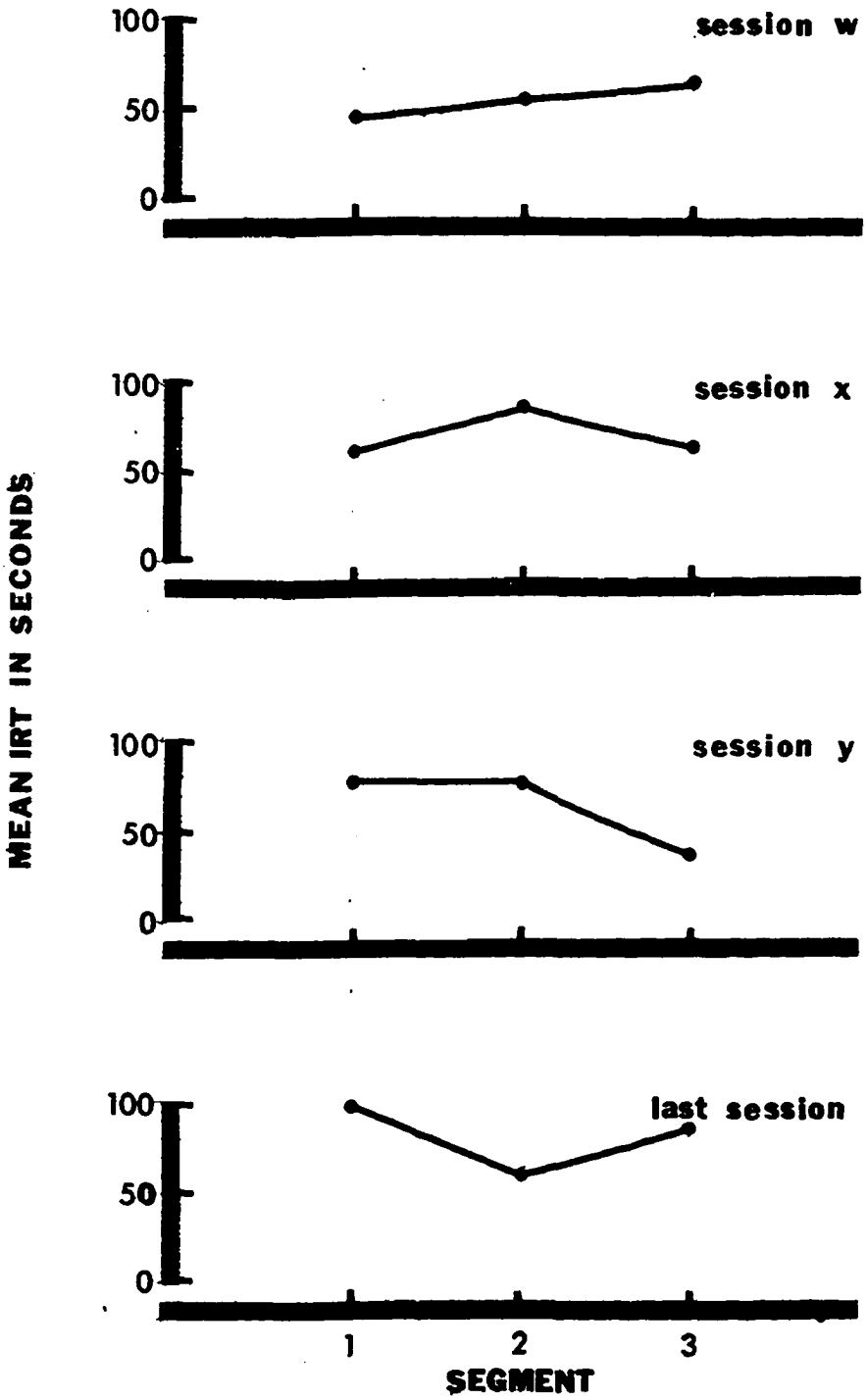

Fig. 1. Total combined mean IRT's for the first, second, and third segments of the final four Baseline sessions

The results of Experimental Phase I, expressed in mean IRT's for each component of the multiple schedules, are shown in Figures 2,4, and 6. All subjects displayed considerable variability within schedules from session to session and a rather consistent failure to discriminate between the FR and FI contingencies until the final few sessions of the Phase.

Figure 2 represents Ed's performance. There is much variability among all components (FR, FI, and Ext) of the multiple schedules from one session to another with greatest variability occurring in FR and Ext. Discrimination seems to have developed during the last six sessions except for session 20. Response rates are consistently higher under FR than under FI or Ext in these six sessions and, although the differences are not large, Ext is usually lowest of the three components. Statistical analysis of the data using t tests of dependent measures for the last six sessions showed that FR mean IRT's were significantly lower than under Ext ($df=5$, $p \leq .01$), but no significant differences were found between FI and Ext or between FR and FI.

The data from the Ext components show much more variability between sessions during Phase I than during Baseline when the same "no reinforcement" conditions were operating. However, the combined IRT's for all Ext components resulted in a mean IRT of 17.7" during Phase I compared with 18.4" for all Baseline sessions. This represents very little overall change in rate from Baseline performance to Experimental Phase I performance under the Ext condition. The mean IRT for all FR and FI components during Phase I was 14.8" and 15.8" respectively. The mean IRT for all responses in Phase I was 16.1" compared to the

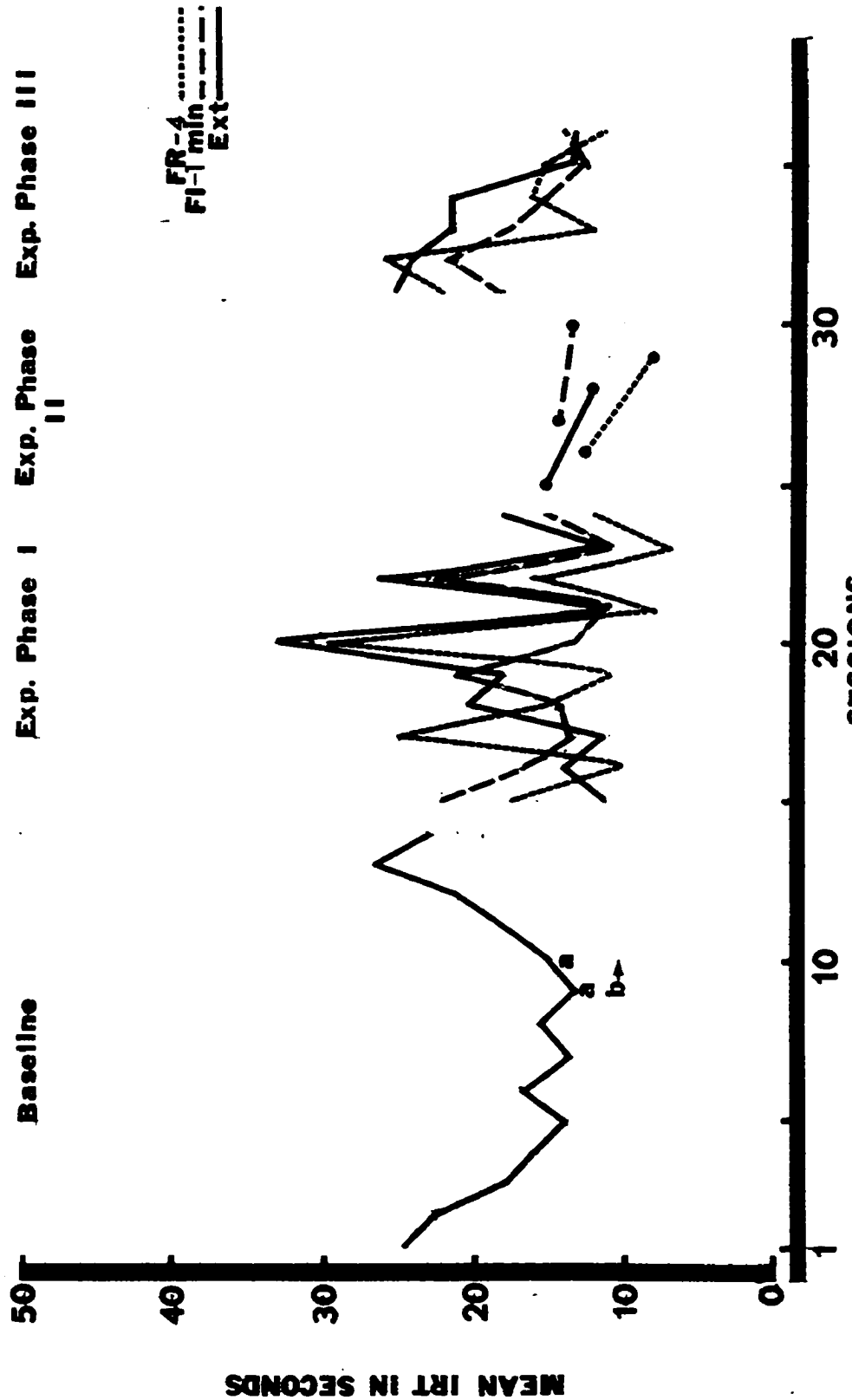

Fig. 2. ED

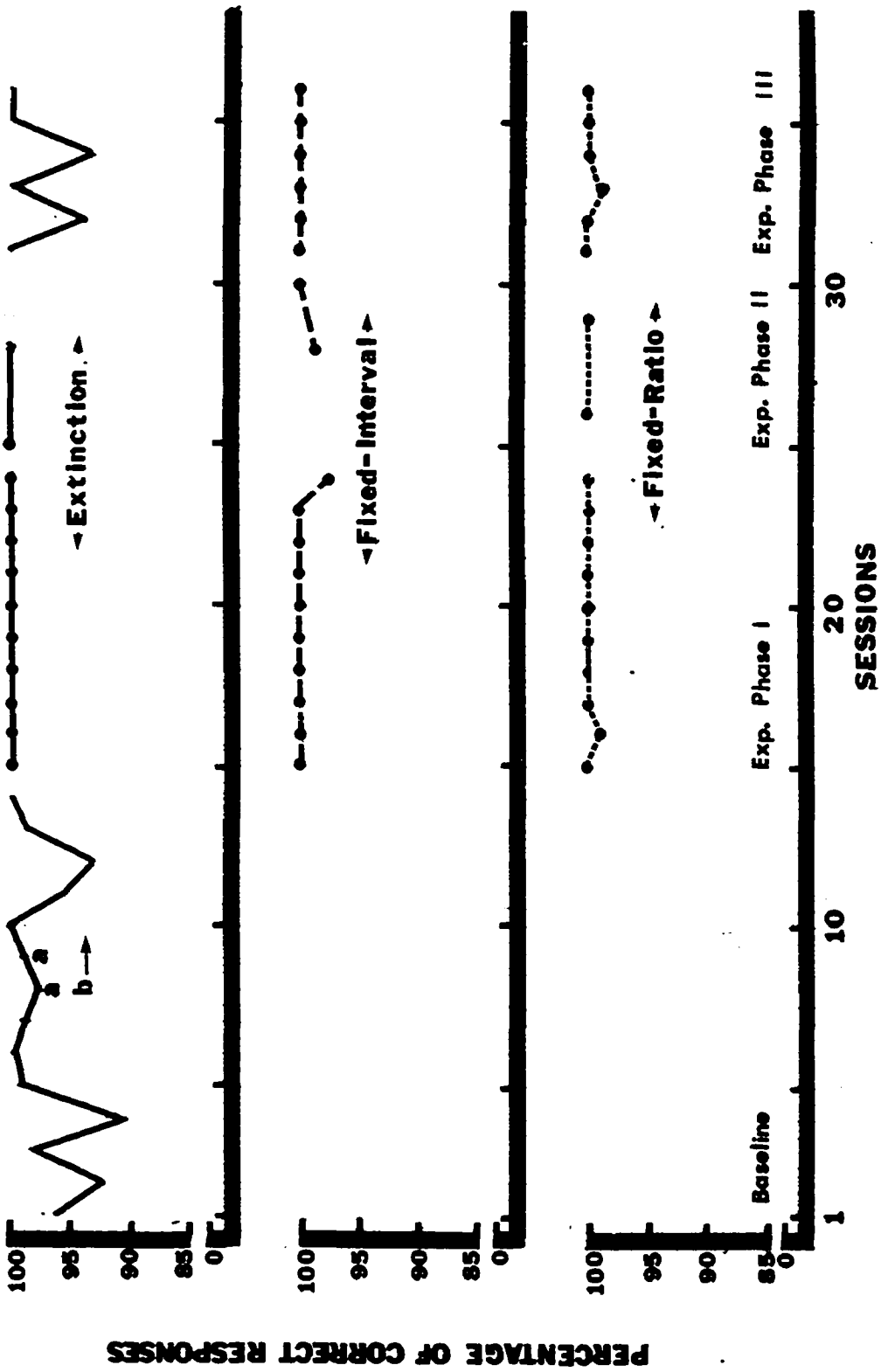

Fig. 3. ED

18.4" mean IRT during Baseline.

The accuracy index for Ed is plotted in Fig. 3. His accuracy improved from sporadic performance in Baseline to nearly perfect percentages throughout Phase I.

Figure 4 shows Bill's response during Phase I. Again, there is much variability in all three components throughout sessions. A distinguishing feature of his pattern is that the direction of change in the mean IRT's from one session to the next is generally the same for all three components. Bill apparently responded rapidly or slowly through a session without developing any appreciable discrimination of contingencies. This characteristic pattern also occurred with Ed but not until he began to show a discrimination within each session (sessions 19-24). Bill's mean IRT's under Ext were highest for four of the last six sessions. Mean IRT's under FR were lowest four times while FI produced the lowest mean twice during these six sessions. Statistical t test analysis showed that FR IRT's were significantly lower than Ext IRT's (5 df, $p \leq .02$), but no significant differences were found between FI and Ext or between FR and FI in Bill's data dur- Phase I.

The combined IRT's for all Ext components yielded a mean of 22.0" which was identical to the mean IRT for the entire Baseline. The mean IRT for all FI components was 18.5" and for all FR components, 17.3". The combined responses of all Phase I sessions resulted in a mean IRT of 19.3".

Bill's accuracy is plotted in Fig. 5 which indicates that his percentage of correct responses did not improved much following Baseline

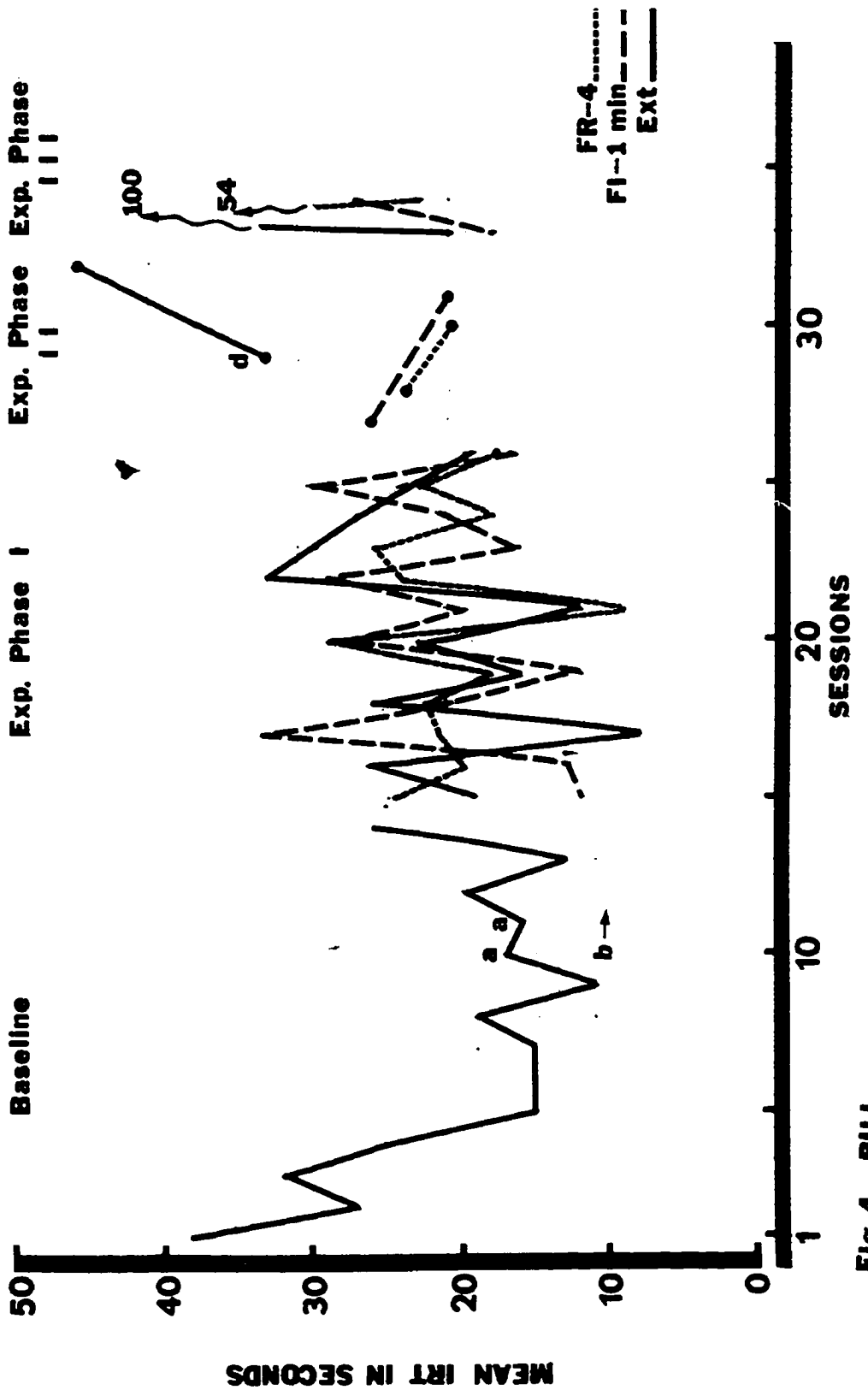

Fig. 4. BILL

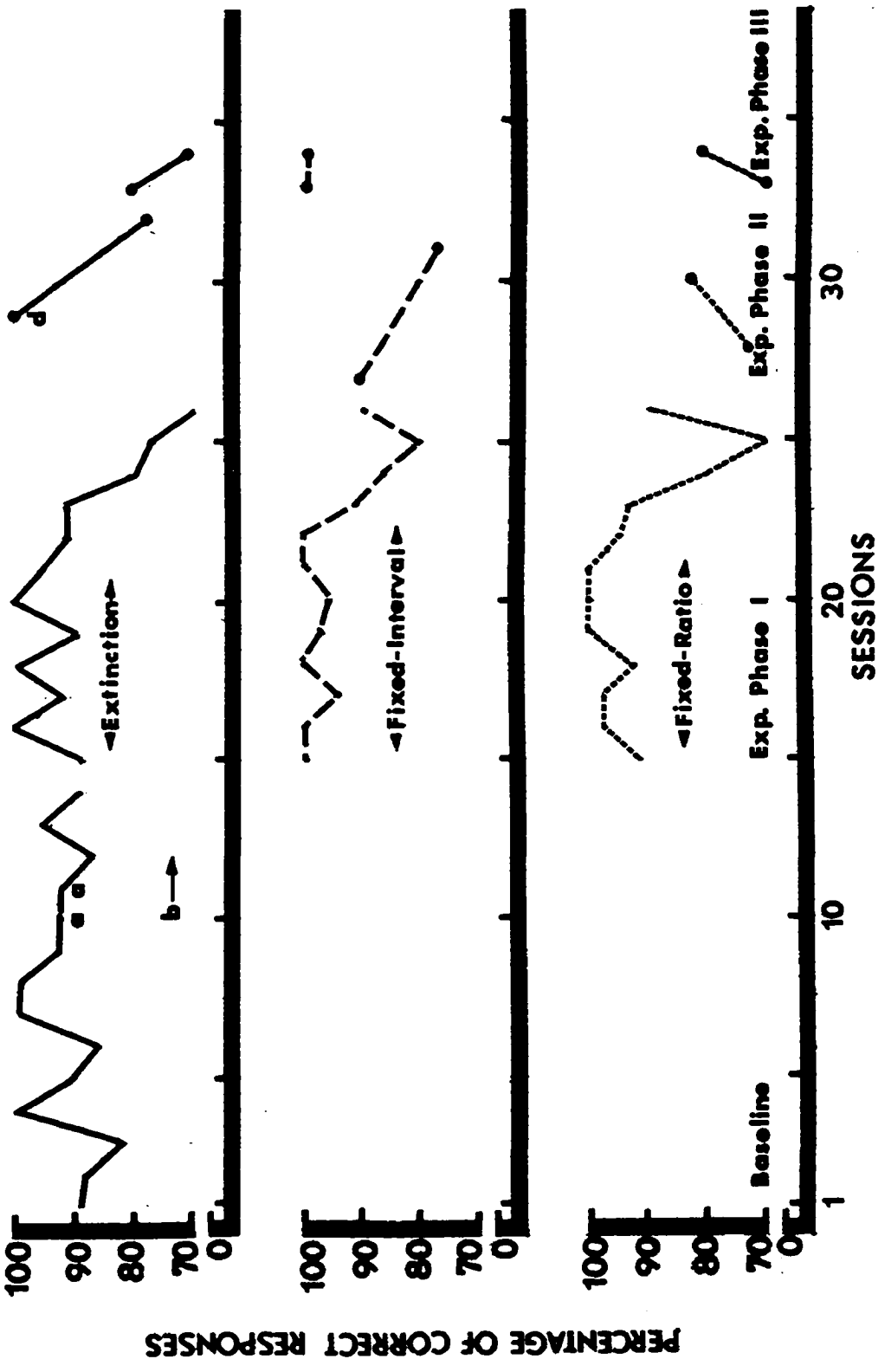

Fig. 5. BILL

and, in fact, declined after session 22. It is not known why this occurred.

Tom's performance during Phase I is presented in Fig. 6. His pattern reflects the greatest instability from one session to the next. The graph indicates large changes almost daily in the Ext components and similar, though smaller, changes in the other two components.

Tom responded under FR-2 for the first seven sessions of Phase I. At session 20 his FR component was switched to FR-4 and this occassioned lower IRT's, not only under FR, but also under FI. The peculiar aspect of the change was a daily reversal between FR and FI components in producing the lowest mean IRT for each session. As discussed later, this apparently cannot be explained on the basis of the order of component presentation within these sessions.

The apparent discriminations between Ext and consequated components was rather consistent throughout Phase I. Only once after the first session was Tom's mean IRT during Ext lowest for its session, and the Ext mean was highest for the session on nine of the thirteen days. However, t tests of statistical analysis failed to yield any significant differences between the three contingencies for Tom. This is likely due to unusual variability in the data and the limited number of observations tested (6). For all sessions with the FR-2 condition the following results were found: mean IRT for all FR components, 21.1"; mean IRT for all FI components, 23.5". The means for all FR and FI components while the FR-4 condition was in effect (sessions 20-25) were 13.3" and 17.5". The mean for all Ext IRT's during Phase I was 30.9".

The accuracy percentages for Tom are shown in Fig. 7. They show

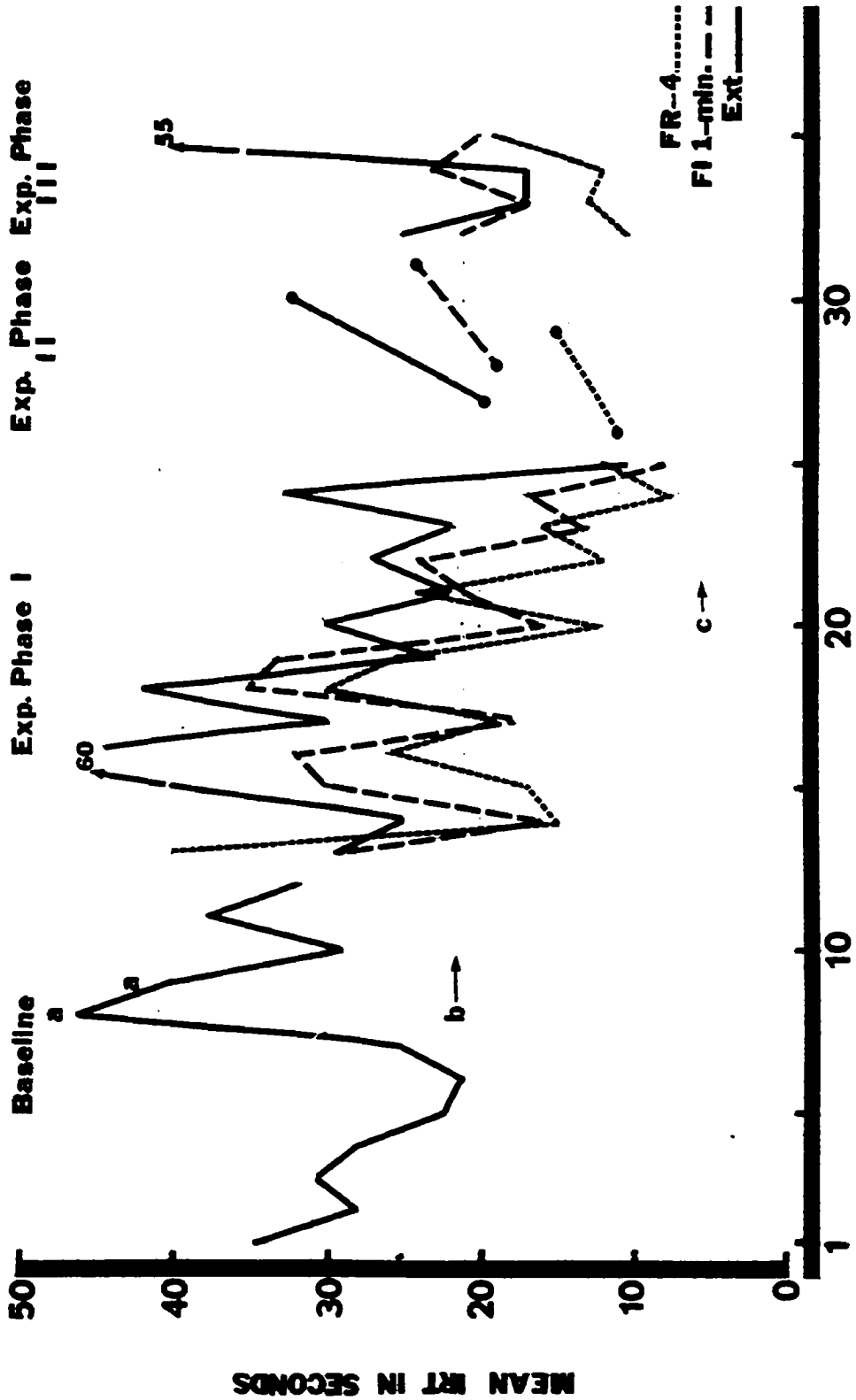

Fig. 6. TOM

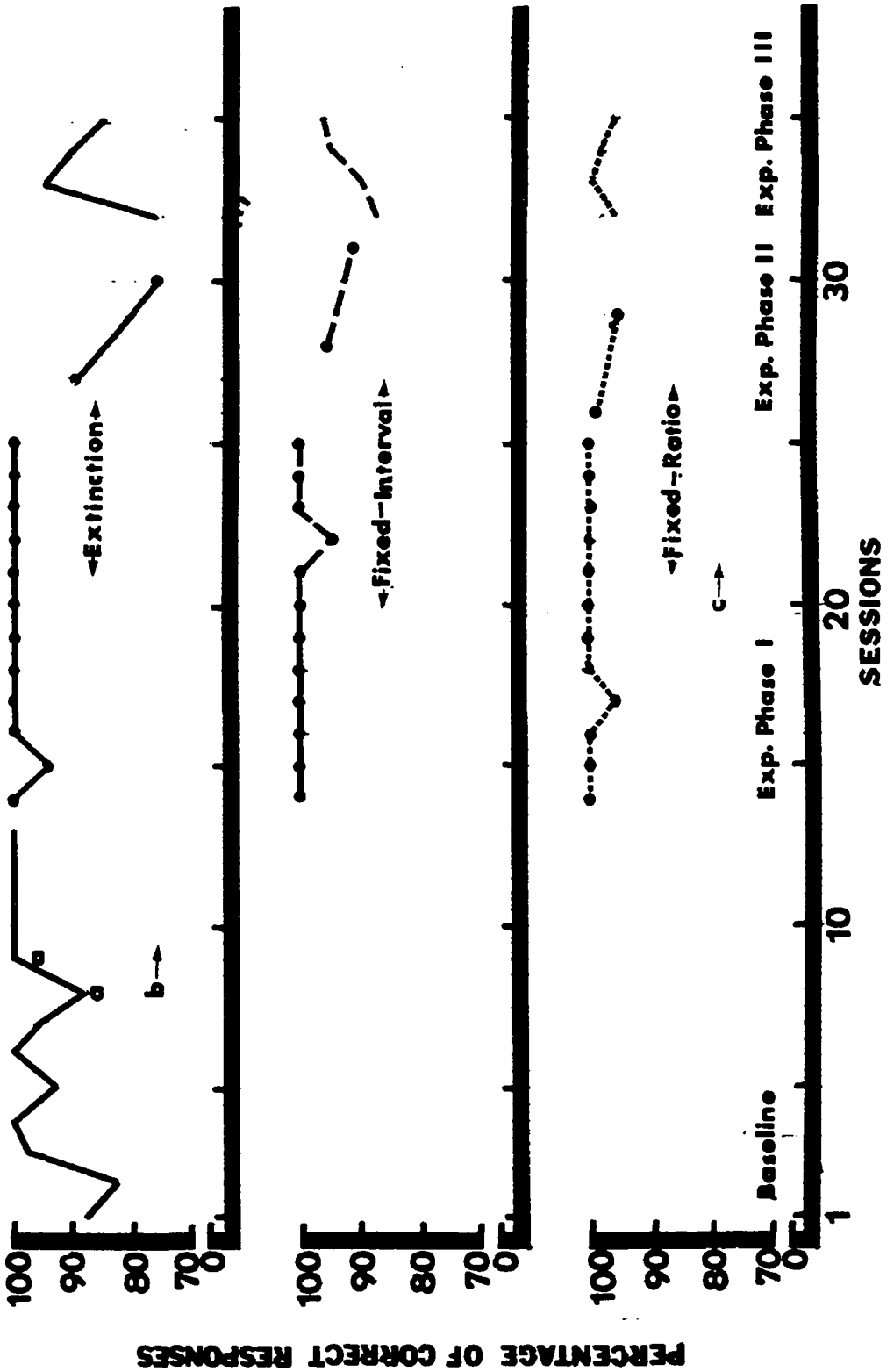

Fig.7. TOM

that accuracy remained very high throughout Phase I.

Experimental Phase II

The results of Experimental Phase II are presented in the third sections of Fig. 2,4, and 6. As expected, all subjects tended to produce their lowest mean IRT's under FR and their highest mean's under Ext. The increased evidence of some schedule discrimination was especially apparent for Tom during Phase II.

Accuracy remained very high for Ed. Bill continued to make many mistakes and Tom, who had previously made few errors, dropped in accuracy (Fig. 3,5, and 7).

Beginning with his 29th session (labelled "d" in Fig. 4), Bill was casually told he could leave the room for short trips to the restroom or the drinking fountain whenever he desired during his remaining sessions. During this session, in which an Ext schedule was in effect, Bill left once for 2½ minutes. He did not leave during subsequent sessions even though an Ext schedule was in effect again on session 32. Ed and Tom were not given this above information and did not leave the room during sessions.

Experimental Phase III

The results of Experimental Phase III are presented in the right-hand section of Fig. 2,4, and 6. Ed's responding seemed somewhat disrupted during this Phase. His IRT's at first increased considerably, then declined again the same level they had shown during Phases I and II. He did not demonstrate a recognizable discrimination among the

three components.

Bill's performance was also clearly disrupted in both of his sessions. Tom's mean IRT's during Phase III, however, were about the same as during his last Phase I sessions and suggested a clear discrimination among session components. His FR components were always the lowest in mean IRT and his Ext components were always highest. The t tests showed Tom's IRT's under FR to be significantly lower than his IRT under Ext ($df=5$, $p \leq .05$). There were no other significant differences found between performances on the three components, perhaps because there were only 4 sessions of each component. Probably for similar reasons, no significant differences were discovered among the various components for either Ed or Bill.

Figures 3,5, and 7 show that accuracy declined for all three boys, although the only sizeable drop in Ed's accuracy was in the Ext component on two of his six sessions.

DISCUSSION

The attempts made at various points in the study to control possible irrelevant variables were at least partially successful. For example, early in Baseline it became apparent that the response rates were higher than would typically be expected under conditions of feedback only. The program manual indicated that one minute was the average time required per frame, and the subjects were responding in one third to one half this time. The competitive race between Bill and Tom was probably an influential variable for them. It was also likely that Ed was competing with himself on the basis of total problems worked in

a session. This was suggested by the very serious and determined approach which he seemed to take toward his work. The necessity of controlling this variable was twofold. First, it was essential to achieve conditions of extinction as closely as possible in order to contrast the effects of consequated versus unconsequated behavior. Second, in order to examine the effects of the two reinforcement schedules, it was necessary to make reinforcers contingent upon the different schedule requirements. Competition during the Experimental Phases should therefore have been on the basis of points earned rather than on the number of problems completed. Removing the page and frame numbers (condition "b") almost certainly eliminated this variable since progress could not be calculated accurately by the boys.

The probe (point "a" Fig. 2,3,4,5,6, and 7; absence of E) conducted during the first two sessions with blackened numbers may also have played a role in producing the initial rise in Baseline IRT's for Bill and Tom. However, it was not possible to separate the effects of the experimenter's absence from those of blacking out the numbers.

Although no clear discriminations were demonstrated in any of the three Experimental Phases, Fig. 2,4, and 6 do suggest that some rough discriminations were beginning to emerge among the three contingencies. The t tests of statistical analysis also revealed significant differences between FR and Ext components during the last six sessions of Phase I for two of the boys. It is likely that the limited number of observations prevented additional significant differences. This can be supported by t tests using the combined data of all subjects for the same six Phase I sessions which revealed significant differences be-

tween FR and Ext (df=16, $p \leq .01$) and between FI and Ext (df=16, $p \leq .05$). No significant differences were found between FR and FI.

There are other possible sources which may help to explain the lack of clear and visible discriminations. One problem, of course, was the amount of inter-session and intra-session variability evident in the data. This may have been the result partly of differences in the level of difficulty encountered in the program as a person moved from the beginning of a unit, to the middle, to the end of that unit, and on to a new one. The use of programmed materials to equalize response requirements may have been only partially successful.

The order of presenting the schedule components is another place to look for an answer to the problem of variability. Table 3 contains data regarding such order effects. Table 2, presented earlier, contained similar information for the last four sessions of Baseline and indicated the possibility of order effects. The data in Table 3, however, do not suggest that order effects were an important source of variability. The first, second, and third positions have about the same frequency of long, medium, and short mean IRT's except that seldom did the second component have the shortest mean. It should be noted also that FR did not occupy the second position very often.

A technique which is often used to help build up schedule discrimination is the provision of training sessions under one particular contingency to give intensive learning periods with that schedule (Long, 1959; 1963). This has become a standard practice in many animal studies and probably could have been helpful in the present experiment. It often appeared the FI was functioning as a variable-ratio

FIXED-RATIO

Relative Mean IRT Within Sessions	Order of Presentation Within Sessions: First	Second	Third	Total
Longest	5 times	1 time	5 times	11
Medium	5 times	5 times	3 times	13
Shortest	9 times	2 times	11 times	22
Total	19	8	19	46

FIXED-INTERVAL

Relative Mean IRT Within Sessions	Order of Presentation Within Sessions: First	Second	Third	Total
Longest	3 times	3 times	2 times	8
Medium	6 times	10 times	4 times	20
Shortest	8 times	4 times	6 times	18
Total	17	17	12	46

EXTINCTION

Relative Mean IRT Within Sessions	Order of Presentation Within Sessions: First	Second	Third	Total
Longest	8 times	12 times	7 times	27
Medium	1 time	9 times	4 times	14
Shortest	2 times	none	4 times	6
Total	11	21	15	47

Table 3. A summary of the number of times that each of the three contingencies were presented as the first, second, and third components of the multiple schedules in Phases I and III, and the relative mean IRT that each had for its session

schedule, since long pauses under FI were rare. Perhaps very small FR and FI values could be presented prior to the actual study with progressive increases to help build up discriminations. In Tom's case, beginning with an FR-2 and moving later to an FR-4 occassioned desirable changes in his rate of response.

The accuracy data for the three boys are difficult to interpret. Generally, accuracy was high, but whereas Ed's accuracy was maintained for the entire study, Bill's declined noticeably toward the end of Phase I, and Tom's accuracy was disrupted during Phases II and III. It is not known exactly why these changes occurred with Bill and Tom. The disruption in both rate and accuracy during Phase III might have been the result of introducing available alternative responses such as the space maze and the target game. There was some direct play with these toys and this was particularly true of Tom.

The accuracy curves do not indicate differential effects as a function of the contingency. It was predicted that accuracy would be highest during FR with FI and Ext following in that order, but this was not the case. We would expect this because incorrect responses always produce delays of reinforcement under FR but not always with FI. Again, the difficulty of the material could be a factor in the study.

The data from the last six sessions of Phase I were analyzed in another way to detect possible differences in the patterns of responding during FR and FI, and the results of this analysis are shown in Table 4. It is clear that the characteristic scallop pattern found in animal studies using FI schedules are not indicated from these data. Nor do the FR patterns correspond to those found with animals. The

FIXED-RATIO
Response Following Reinforcement

		1	2	3	4
Ed Mean IRT		13.7"	12.9"	12.8"	13.3"
Bill Mean IRT		16.0"	15.8"	19.8"	16.5"
Tom Mean IRT		17.9"	12.3"	12.6"	11.5"
	Totals	47.6"	40.0"	45.2"	41.3"

FIXED-INTERVAL
Response Following Reinforcement

		1	2	3	4
Ed Mean IRT		15.2"	13.6"	12.5"	19.0"
Bill Mean IRT		20.3"	15.2"	16.5"	20.9"
Tom Mean IRT		22.2"	11.8"	16.3"	18.5"
	Totals	57.7"	40.6"	45.3"	58.4"

Table 4. Mean IRT's for the first, second, third, and fourth responses following the presentations of reinforcement under fixed-ratio and fixed-interval during the last six sessions of Experimental Phase I.

patterns that are represented here may be phases in the eventual development of the more characteristic patterns, or they could be due to some unique conditions of this experiment such as the reinforcement intrinsic to the program materials, the particular choice of FR and FI values, and the history provided by the Baseline. Following the study, the boys were interviewed informally to see if they could verbalize a discrimination of the contingencies. They said that they knew they could not get any points when the lights were off, but were not sure what the difference was between the two lights when they were on.

Generally, the results of this study suggest that extrinsic reinforcement increases the rate of responding on programmed mathematics instruction, and that with some children it may improve accuracy. The determination of appropriate schedules of reinforcement will require extensive additional research.

APPENDIX A

Sample Data Sheet

Subject_____
Date_____
Session_____

FR Value____
FI Value____

No.	IRT	No.	IRT	No.	IRT	No.	IRT	No.	IRT	No.	IRT
1	20.7			41	31.5			90	15.0		
2	33.2			42	13.4			91	25.0		
3	17.6			43	11.0			92X	22.0		
4	25.9			44X	9.5			93	50.0		
5	10.8			45	15.6			94X	15.0		
				46*	16.2			95	12.0		
				47	20.3			96*	10.0		
				48*	19.9			97	15.0		
				49	14.0			98X	16.3		
				50X	12.0						

Ext. FR FI

Sequence	IRT
1. Ext	___
2. FR	___
3. FI	___

Session mean IRT_____

X indicates presentation of point

* indicates incorrect response

Correct Responses
Total Responses _____

APPENDIX B

The boys purchased the following items with their points.

Item	Price
candy bars	5 points each
gum	5 points each
model airplanes	69 points each
baseball	100 points
Sweet Tarts candies	1 point each
cap gun	120 points
caps	10 points each
Jarts Game (bonus)	500 points

Total cost $17.58.

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