*A COMPARISON OF THE EFFECTS OF FIXED AND
VARIABLE RATIO SCHEDULES OF REINFORCEMENT ON
THE BEHAVIOR OF DEAF CHILDREN*

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The performance of all five students in an adjustment class for deaf children was compared under fixed and variable ratio schedules of reinforcement. During the fixed ratio (FR) condition, students earned checks if they were attentive and did not engage in disruptive behavior. These checks could be exchanged for the opportunity to draw a prize from a grab bag. During the variable ratio (VR) condition, they earned a draw from the grab bag according to a variable ratio schedule with a mean ratio equal to the value of the preceding FR schedule. During the VR condition, students visually attended more and engaged in disruptive behavior less often than during the FR condition. The number of math problems completed per minute was also higher during the VR condition although no specific consequences were applied to math performance.

DESCRIPTORS: variable ratio, fixed ratio, token reinforcement, classroom behavior, deaf children

Although numerous applied studies have demonstrated that behavior can be altered successfully by continuous reinforcement (Barton, 1970; McReynolds, 1969; Whitman, Zakaras, & Chardos, 1971) and various types of fixed ratio (FR) schedules of reinforcement (Birnbrauer, Wolf, Kidder, & Tague, 1965; Bushell, Wrobel, & Michaelis, 1968; Christophersen, Arnold, Hill, & Quilitch, 1972; Johnston & Johnston, 1972; Koegel & Rincover, 1977; Lahey & Drabman, 1974; Lovitt & Esveldt, 1970; Miller & Schneider, 1970; O'Leary, Becker, Evans, & Saudargas, 1969; Phillips, 1968; Stephens, Pear, Wray, & Jackson, 1975; Wolf, Giles, & Hall, 1968; Zimmerman, Zimmerman, & Russell, 1969), less research has been concerned with the use of variable ratio (VR) schedules (Clark & Sherman, 1975; Guess & Baer, 1973). Furthermore, no studies have directly compared the relative

efficacy of fixed ratio and variable ratio schedules in applied settings.

Studies that have compared the effectiveness of different schedules have either compared continuous reinforcement with fixed ratio reinforcement (Koegel & Rincover, 1977; Stephens et al., 1975), or fixed with variable time schedules of reinforcement (McLaughlin & Malaby, 1972; Saudargas, Madsen, & Scott, 1977). For example, Stephens et al. (1975) demonstrated that fixed ratio schedules of reinforcement produced better learning rates in retarded children than did continuous reinforcement.

These studies, the data obtained from animal studies (Ferster & Skinner, 1957), and the results of one human analogue study (Orlando & Bijou, 1960) comparing performance on FR and VR schedules suggest that VR schedules might produce more consistent performance than FR schedules in applied settings. However, the findings of at least one human analogue study (Weiner, 1966) indicated no difference in response rate or pattern on these two types of schedules.

Therefore, in the absence of sufficient applied data on the relative efficacy of FR and VR

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schedules, it is impossible to conclude that the common practice of employing FR schedules in applied work is an optimum one. Hence, the purpose of the present study is to compare the efficacy of these two schedules with children in an applied setting.

METHOD

Subjects and Setting

Three boys and two girls in a special public school adjustment class for deaf students served as subjects in this experiment. Three of the children were placed in the class because of behavior problems; the remaining two lacked sufficient speech and language skills to be integrated into regular classrooms. The severity of their hearing losses varied from moderate-severe to profound. A summary of each child's background is presented in Table 1.

The children all had their own desks which faced the front of the classroom. The teacher used a wireless FM transmitter, and the students monitored her voice with Phonic-Ear group aid receivers which could either function as normal hearing aids or receive the teacher's FM transmissions directly, thus attenuating background noise. A switch on each unit enabled the students to select the appropriate operational mode. A cassette tape recorder was located at the rear of the classroom to deliver prompts to the teacher.

General Procedure

All measures were obtained during a 40-min period each day. During the first 30 min of this period, the teacher conducted a language lesson while seated at the front of the class with the students seated in a semicircle around her. During this lesson the teacher had the students respond verbally to both structured and open questions. During the final 10 min of the period, the teacher gave the students written assignments based on the formal lesson; they worked on these at their desks for the remaining 10 min of the period. In some sessions, the teacher gave the students simple math problems which served as a probe measure on work volume.

Measures

Observers attended class several days prior to the beginning of the experiment in order to allow the children to adapt to their presence. Throughout the experiment, the observers watched each student in the same sequence from left to right for 10 sec every minute, resting for the last 10-sec period in each minute. Recording continued throughout the entire period. Only the behaviors of the particular student being observed during any 10-sec interval were recorded by the observers.

Attentive behavior. Attentive behavior was scored during the first 30 min of the period whenever a student was observed to be seated and visually attending to either the teacher's

Table 1
Information on the Age, Extent of Hearing Loss, and Type of Problems for Each Student

<i>Student</i>	<i>Age</i>	<i>Extent of Hearing Loss</i>	<i>Types of Problems</i>
Brian	6	Moderate-severe	Lacked sufficient speech skills.
Wanda	8	Moderate-severe	Severe behavior problems at home and in school.
Rhonda	9	Progressive-profound	Labeled learning disabled and lacked sufficient language skills.
Jamie	8	Moderate-severe	Severe behavior problems at home and in school.
Trevor	8	Profound	Behavior problem in school and lacked sufficient communication skills.

lips or hands (the teacher spoke and signed simultaneously) or those of a student who was speaking in turn. This behavior was essential for these children because they were being taught to lip read. Hence, if students were not looking at the speaker, they generally could not discriminate what was said. Looking away from the speaker was considered to be off task. A whole-interval sampling procedure was employed for this behavior such that children had to be oriented toward the speaker during the entire 10-sec interval to be scored as attentive.

During the last 10 min of the period, when the students worked at their seats, they were scored as attentive whenever they were sitting in their seats with their pencils in hand, either writing or looking at the material they had written. If they were engaged in a math task, appropriate manipulation of counters was also scored as attentive.

A second independent observer also recorded attentive behavior for the entire 40-min period during most days of the experiment (a minimum of 2 sessions during each condition). Both observers began recording at a designated signal and stopped at the end of the period. The percentage of interobserver agreement on the occurrence of attentive behavior was calculated by dividing the number of times the observers agreed on its occurrence by the number of times they agreed or disagreed on its occurrence. Similarly, interobserver agreement on the nonoccurrence of attentive behavior was calculated by dividing the number of times both observers agreed on its nonoccurrence by the number of times they agreed or disagreed on its nonoccurrence. The mean percentage agreement on the occurrence of attentive behavior was 94% and ranged from 83 to 98%. The mean percentage agreement on the nonoccurrence of attentive behavior was 80% and ranged from 64 to 86%.

Disruptive behavior. Disruptive behavior consisted of any of the following: talking out of turn, making noises, wandering around the room, playing with or throwing instructional materials, fighting, tantrum behavior, and re-

fusals to comply with the teacher's requests. A partial interval sampling procedure was used for measuring this behavior such that a child was scored as disruptive whenever any of these behaviors was observed during the 10-sec observation interval.

The second independent observer also recorded disruptive behavior. Agreement on the occurrence of disruptive behavior averaged 76% and ranged from 67 to 84%. Agreement on the nonoccurrence of disruptive behavior averaged 92% and ranged from 88 to 97%.

Other measures. The observers recorded reinforcement by circling the appropriate interval on the recording sheet during the minute that the reinforcer was delivered. Similarly, each instance of teacher praise was also recorded throughout the experiment. Interobserver agreement on the occurrence of reinforcement was 100%, and interobserver agreement on teacher praise averaged 98% with a range of 96% to 100%. Teacher praise rate throughout the experiment averaged .13 praises/min with a range of 0 to .23 praises/min. Teacher praise rate was stable throughout the experiment. Thus it is highly unlikely that this variable could have influenced the results.

Finally, beginning with the first FR condition, the teacher was asked to keep and score all seatwork completed during the last 10 min of each session. The teacher was also instructed to mark how much work was completed at the end of the 40-min period. All seatwork was later recorded by another independent observer. Interscorer agreement was always 100% on assignment correction.

Experimental Design

A reversal design was employed in this experiment. After stable baseline performance was obtained, reinforcement was introduced on a fixed ratio (FR) 8 schedule of reinforcement. After behavior stabilized, the schedule was changed to a variable ratio (VR) 8. Next the FR 8 schedule was reintroduced followed by a

return to the baseline condition. Finally, an FR 12 schedule of reinforcement was introduced followed by a VR 12 condition. The introduction of the FR 12 and VR 12 conditions served as a systematic replication of the FR 8 and VR 8 comparison.

Baseline 1. During this condition, no formal contingencies were applied, and the teacher was instructed to manage the class in her usual manner.

Fixed ratio 6. During this condition, a chart containing each of the children's names was introduced. The chart was a 20 by 70 cm sheet of white bristle board with each of the children's names printed on it. Under each name were eight boxes. The chart was covered in clear acetate so that the boxes could be checked with a grease-based crayon and the checks erased later. The children were told that a noise (a loud, low frequency buzzer that was audible to 4 of the 5 students) would sound every 5 min, and if they had been paying attention to the teacher or a peer who was speaking in turn and were not disruptive during the past 5 min, they would be awarded a check on the chart. The teacher then explained which behaviors constituted attending and which constituted disruption.

They were further instructed that whenever any of them obtained 8 checks, the student would have a chance to reach in a grab bag and take a prize. The prizes in the grab bag were inexpensive toys (valued approximately 6¢ each) which were bought in bulk from a local novelty distributor.

The teacher wore a wrist strap that contained each of the children's first initials printed eight times in rows (one row for each time the buzzer sounded), and she was instructed to circle any student's initial whenever she observed that the student was not attentive or engaging in disruptive behavior during the interval. A high-pitched tone which was inaudible to the students was sounded every minute in order to remind the teacher to take note of student behavior. However, the teacher was free to circle a student's

initial any time she observed a student to be either inattentive or disruptive. Students were not told when their initials were circled. Only those students whose names were not circled when the buzzer sounded were awarded a check. Students who had earned a check received praise, while those who had not were briefly told why they had not. Checks could be accumulated over sessions; however, students had to draw a prize whenever they earned eight checks.

Whenever students earned prizes they were instructed to put them on the teacher's desk until their lunch period. Because the buzzer only sounded 8 times per session, it was not possible to earn more than one prize per session during this condition. Basically this is a fixed ratio 8 schedule with the chart serving as added counter (Ferster & Skinner, 1957). Furthermore, each response had to satisfy two independent conditions. First, the student had to engage in 5 consecutive min of attentive behavior, measured from the time checks were last awarded. Second, the student was required not to engage in any disruptive behavior during that period (DRO 5 min).

Variable ratio 8. During this condition, the chart was removed and the children were instructed that they would have a chance to draw a winning block from a brown paper bag rather than get a check if they did not have a circle when the buzzer sounded. The paper bag contained one blue block (winning block) and seven brown blocks, so that the probability of drawing a blue block and earning a prize was one in eight. After each draw, the block was replaced in the bag so that the probability of drawing a blue block remained constant throughout this condition. This condition was similar in all other respects to the previous condition. Because the schedule was a VR 8 during this condition, it was possible for students to earn more than one prize per session; however, the overall reinforcement rate was the same as that during the FR 8 condition. Again the teacher defined a response as the student engaging in appropriate attentive behavior for the entire

Fig. 1. The mean percentage of intervals with attentive and disruptive behavior during each daily session across all conditions. The broken vertical lines represent the introduction of the various conditions. The open data points are the data obtained by the second observer.

5-min interval between cues without a single disruptive response.

Fixed ratio 8. This condition was identical to the first FR 8 condition.

Baseline 2. This condition was identical to the first baseline condition.

Fixed ratio 12. This condition was identical to the FR 8 condition with the exception that the chart was modified so that each name was followed by 12 boxes, and the student had to earn 12 checks to win a prize.

Variable ratio 12. This condition was identical to the VR 8 condition with the exception that the brown bag contained 1 blue block and 11 brown blocks.

RESULTS

The class' (overall) mean percentages of attentive and disruptive behavior during all experimental conditions are presented in Figure 1. The level of attentive behavior increased and the level of disruptive behavior decreased following the introduction of the first fixed ratio 8 (FR 8) condition. However, the change to the variable ratio 8 (VR 8) condition led to a further improvement in both attentive and disruptive behavior to nearly perfect levels of performance. The change back to the FR 8 condition led to a decline in attentive and an increase in disruptive behavior, although performance during this condition did not appear to be as poor as during the first FR 8 condition. The return to baseline led to a further deterioration in performance, which improved

somewhat following the introduction of the FR 12 condition. Finally the introduction of the VR 12 condition produced further improvement in both behaviors.

The open data points in Figure 1 represent the results obtained by the second observer. These data points confirm that the judgments of both observers were in close accord.

Because students were attentive nearly 100% of the time and were rarely disruptive, reinforcement rate was optimal when the VR schedules were in effect. For example, during the VR 8 condition, students earned reinforcers every 8 intervals on the average. During the two FR conditions, reinforcement rate was lower, with students earning reinforcers approximately every 11 intervals during the FR 8 condition and every 16 intervals during the FR 12 conditions.

The performance of each of the students is presented in Figure 2. These data show that each of the individual behavior patterns was similar to that of the group results, even though the initial performances varied over a wide range.

Academic performance was compared for those sessions in which the students were seated at their desks and working on similar math assignments. There were two such sessions during the FR 8, during the VR 8, and during the Baseline 2 conditions. The teacher did not assign mathematics during any of the remaining conditions. The results indicated that mean problem solving rate was highest during the VR 8 sessions (2.26 problems/min), lowest during the second baseline session (.71 problems/min),

Table 2

The individual and mean number of math problems completed per minute during each condition.

<i>Student</i>	<i>Fixed Ratio 8</i>	<i>Variable Ratio 8</i>	<i>Baseline 2</i>
Brian	1.57/min	2.82/min	.12/min
Wanda	1.65/min	3.18/min	1.19/min
Rhonda	1.65/min	2.94/min	1.19/min
Jamie	.79/min	1.25/min	.65/min
Trevor	1.09/min	1.13/min	.42/min
Mean Rate	1.35/min	2.26/min	.71/min

Fig. 2. The percentage of intervals with attentive and disruptive behavior for each student during each session across all conditions. The broken vertical lines represent the introduction of the various conditions; breaks in the data lines represent individual absences.

and intermediate during the FR 8 sessions (1.35 problems/min). The mean problem solving rate in problems worked per minute is presented in Table 2. Individual trends were consistent without exception. Each child performed best during the VR 8 condition, poorest during the second baseline condition, and at an intermediate level during the FR 8 condition. The data also indicated that accuracy remained constant across these three conditions, averaging approximately 82%.

A comparison of the rate and accuracy on days when the students had to write sentences showed no systematic changes over the course of the study. However, these data are difficult to interpret because writing assignment content varied from session to session.

The time to administer each program was calculated from the scoring sheets. The results showed that it took approximately 25 sec to record the checks on the board or to draw a block for each student who had earned a point.

DISCUSSION

The results of this experiment demonstrated that both the FR and VR contingencies improved attentive and disruptive behavior. The results also showed that the VR contingencies generated better performance than their FR counterparts for each of the individual children. Further these results were obtained for both ratio values employed in this study.

Although data were not collected systematically on academic productivity throughout the entire experiment, the data from equivalent math assignments also indicate better performance on the VR schedules than on the FR schedules. Further, the teacher and both observers noted that appropriate student verbalizations during the group language instruction paralleled the results obtained with the other measures. These results were particularly pronounced for two of the subjects who almost never engaged in appropriate spontaneous verbalizations during the baseline condition. Un-

fortunately, these impressions cannot be verified because no systematic measurement of these behaviors was obtained during the experiment.

The more consistent performance on the VR schedules than on the FR schedules is in accord with both infrahuman (Ferster & Skinner, 1957) and human analog (Orlando & Bijou, 1960) study results. Further, the failure of the behavior to return completely to the original FR 8 levels following the transition from VR 8 to FR 8 is consistent with Orlando and Bijou's (1960) finding that transitions from FR to VR produced more marked changes than transitions from VR to FR.

Although individual children worked on independent schedules in the present experiment, the presence of concurrently performing peers may have influenced the results. For example, both observers occasionally noted instances during the FR conditions in which one student appeared to induce disruptive behavior in a second student who was close to obtaining a reinforcer. This phenomenon may have further contributed to the differences between behavior observed during the FR and VR conditions.

The teacher preferred the VR over the FR condition because it was easier to use and produced a larger effect. However, one possible limitation of VR schedules in large classroom situations might be the logistics involved in reinforcing student behavior on a VR schedule. Teachers could likely overcome this problem by employing various alternatives, such as numbering all students' worksheets and selecting winning numbers from a table of random numbers. Each student having completed a winning worksheet at the end of the day would receive a prize or a privilege.

In many cases token economies are FR schedules with an added counter where the number of token bears a simple quantitative relationship to a single backup reinforcer (Bushell et al., 1968; Johnston & Johnston, 1972; Lahey & Drabman, 1974; Marholin & Steinman, 1977). The findings of this experiment demonstrate that a variable ratio schedule can be more ef-

fective than fixed ratio schedule in a simple token economy.

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