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HANDWRITING AS AN OPERANT[1]

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An apparatus was designed to monitor handwriting behavior. Two subjects were studied under various schedules of monetary reinforcement for handwriting. The different schedules engendered and maintained distinctive response patterns but the rates of sustained responding did not vary across schedules. The development of fixed-interval performance following continuous reinforcement resembled the same transition in lower animals. In one subject, availability of reading material interacted with the schedule to determine response pattern. It was suggested that handwriting may be a more appropriate response for the experimental analysis of human behavior than the more frequently used button-pushing or lever-pulling responses.

The results of most studies of human behavior under schedules of reinforcement suggest that some schedules, most notably the fixed-interval schedule (FI), do not readily produce in man the characteristic response patterns produced in other species (*e.g.,* Long, 1962, 1963; Orlando, 1961; Weiner, 1969). Several studies have demonstrated that additional variables interact with the schedules to determine the subject's performance. These additional variables may be adjusted to approximate in man the schedule-characteristic response patterns.

Some variables known to interact with schedule of reinforcement to determine the pattern of responding in man are: (1) the subject's history of schedule contact (Long, Hammack, May, and Campbell, 1958; Long, 1962, 1963; Weiner, 1964*b*, 1969*a*, 1969*b*, 1970*a*); (2) "response cost," *e.g.,* making potentially punishing events contingent upon responding (Azrin, 1958; Weiner, 1962, 1963, 1964*a*, 1964*c*; Davidson and Kirkwood, 1963; Scobie and Kaufman, 1969); (3) response "effort", *e.g.,* the minimum force required for the subject to operate the response manipulandum (Azrin, 1958; Miller, 1968; Schroeder, 1972); (4) instructions given to the subject (Kaufman, Baron, and Kopp, 1966; Lippman and Meyer, 1967; Baron, Kaufman, and Stauber, 1969; Weiner, 1970*b*) and, (5) concurrent tasks that the subject may, or must, perform (Laties and Weiss, 1962, 1963; Sanders, 1969; Frazier and Bitetto, 1969; Poppen, 1972).

A variable that has not been manipulated, and which may be important for schedule research with humans, is the nature of the required response. Most studies have used a response situation originally devised for animals, *e.g.,* button pushing, lever pulling. Perhaps better schedule control would result if a typically *human* response was used. The present study was designed to explore this possibility by using a response highly specific to humans: handwriting.

Handwriting is an appropriate response for experimental analysis. It is a "typical" human response that is emitted with some frequency by most literate members of the species. It occurs in units that may be defined behaviorally as operants or linguistically as words. In addition, handwriting produces its own record as a script or text that can be analyzed as to its content and as to its topographic features.

We report here an apparatus designed to monitor handwriting behavior. Some prelim-

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inary results of experiments manipulating schedules of reinforcement and availability of reading materials are also given.

METHOD

Apparatus

The writing console consisted of a rectangular (108 by 54 by 20 cm) plywood box that rested on a small table and sloped toward the subject at a 30-degree angle. The top surface of the box (the panel) was made of 2 mm aluminum. Attached to the panel were two push buttons, two jewel lamps, and a digital counter. Near the center of the panel was a rectangular aperture, the "writing slot". The writing slot was located 23 cm from the near edge of the top surface and was 93 cm above the floor. A back-projection screen made out of a square piece of sandblasted Plexiglas was placed behind and above the console. The slides were projected on the back of this screen and could be clearly seen by a subject sitting in front of the console.

Figure 1 shows the interior of the writing console. The main feature of the apparatus was the large "key" used to monitor the handwriting response. This device consisted of a 30 by 10 by 0.6 cm paddle of white translucent Plexiglas that was pivoted on a thin bronze tube. This tube was placed parallel to and 1.3 cm from one of the long edges of the paddle. The top flat surface of the paddle constituted the "writing surface", which was located 1 mm beneath the panel and parallel to it. The writing slot was located over the writing surface, parallel to and 7.5 cm from the edge of the paddle nearest the pivot. A microswitch placed under the paddle operated whenever a downward force of 0.39 N was exerted on the writing surface through the writing slot. A 1 mm vertical displacement of the writing surface, as measured at the edge of the paddle farthest from the pivot, was required for closure of the microswitch. The maximum vertical displacement of the farthest edge of the writing surface was 2 mm.

The writing paper consisted of rolls of 5.5-cm cash register paper. The roll of paper was placed on a free axle to the left of the paddle. The paper passed through a paper guide, which kept it in position over and barely touching the writing surface. On the other side of the paddle the paper passed through another paper guide and was attached to a wind-up reel. The speed of the wind-up reel was adjusted so that the paper moved at about 25 cm per second. The paper was stationary during writing.

The subjects' chamber was a small room divided by a folding screen. One side was occupied by the scheduling and recording equipment. The other side contained a chair, the writing console, and a table with a tape recorder and a slide projector. A view of the subjects' side of the chamber is presented in Figure 2.

The tape recorder and earphones provided white noise to mask the sound of the conventional electromechanical scheduling and recording equipment. The only illumination in the room other than that resulting from the slide projector was provided by a 25-W bulb in a standard, shaded, lamp placed on a shelf

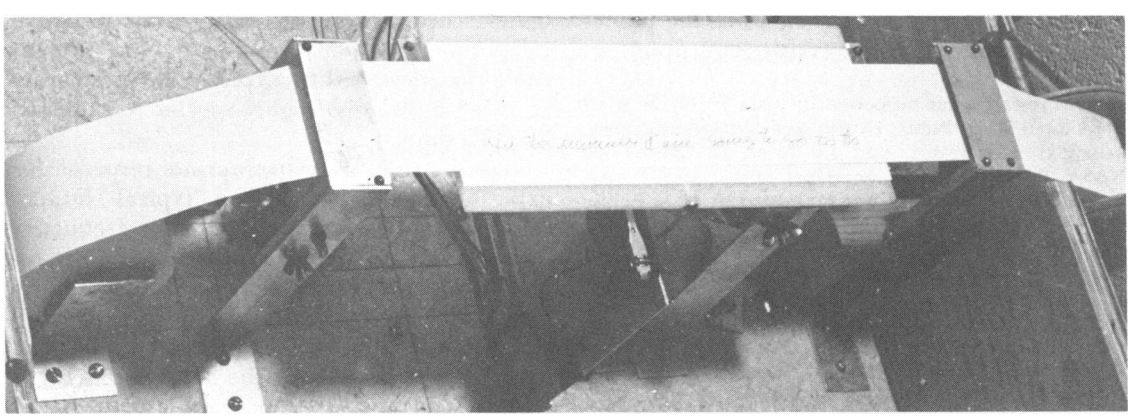

Fig. 1. View of the inside of the writing apparatus showing paper-feed mechanism and the device for monitoring the handwriting responses.

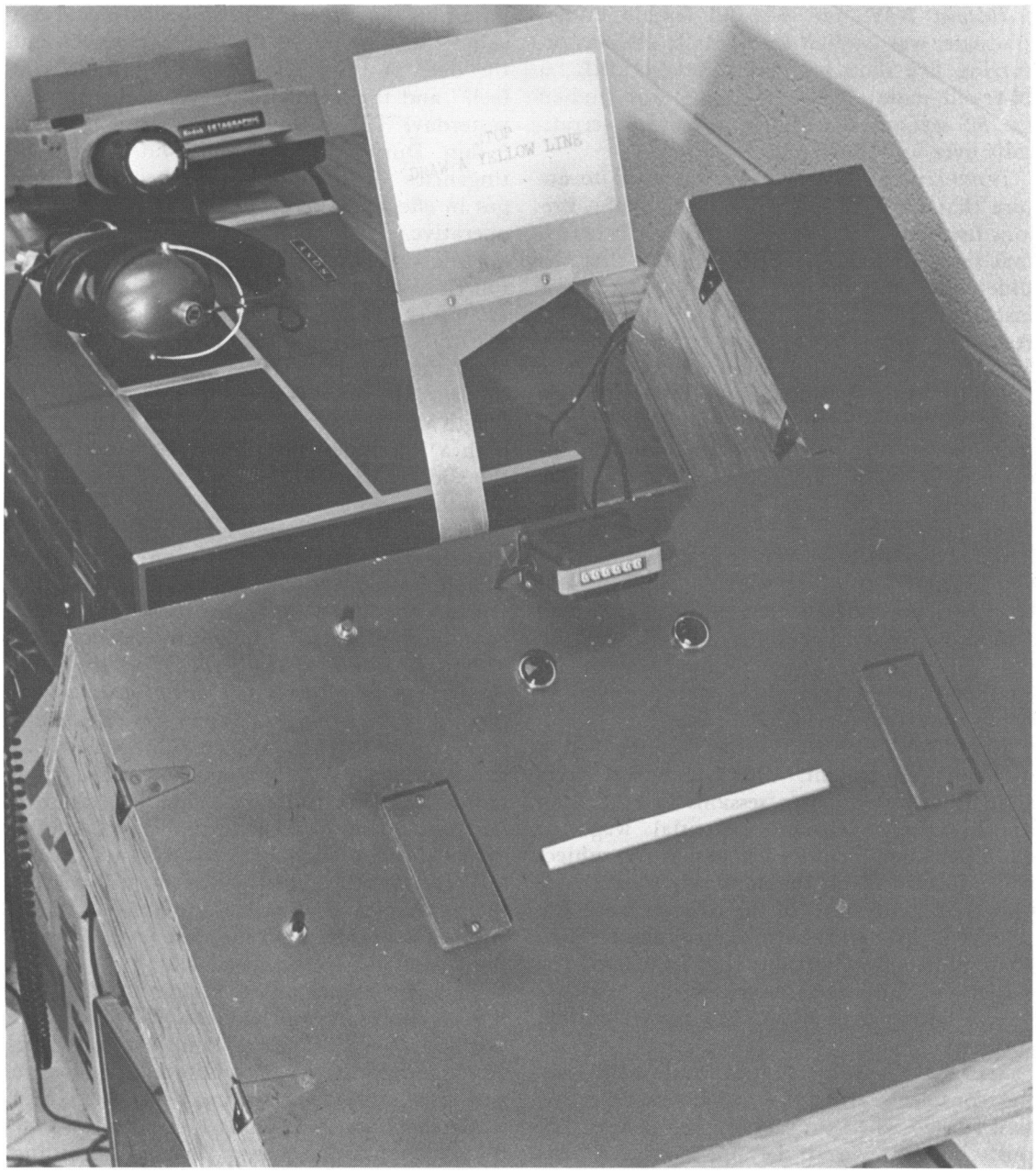

Fig. 2. View of the subject's half of the experimental chamber. Writing apparatus is shown in the foreground.

above the writing console. Subjects could be observed during the session by means of an Observ-o-scope door viewer (Baldwin Hardward Manufacturing Company) installed in the door of the chamber.

Subjects

The two subjects were hired through the Student Employment Office at the University of North Carolina. Participation in the experiment was represented as a work situation. The selected subjects expressed willingness to participate regularly for the duration of the experiments. Applicants were rejected if they had ever taken a psychology course in which schedules of reinforcement might have been emphasized, or if they reported being frequent users of drugs, including alcohol.

Subject B.W., an 18-yr-old female undergraduate, was studied for 61 daily sessions occurring five days per week. Subject D.L., a 24-yr-old male college graduate, was studied for 50 sessions distributed somewhat erratically over four-and-a-half months.

Instructions.[2] Instructions were used to ensure that each subject could operate the various features of the writing console efficiently, that some writing should occur, and that the slides and counter would be observed. The instructions did not provide any information regarding the relation between handwriting and the occurrence of reinforcement. It was specified in the instructions that subjects could write about any topic in whatever way they chose, but that doodling, random sequences of words, and/or excessive repetitiveness would be penalized by reducing the subject's pay. Subjects were also asked to use cursive handwriting. When reading material was initially introduced into the experimental chamber, the subjects were instructed to feel free to use these materials at any time while in the experimental room. Subjects were instructed not to take their watch, pens, or books into the experimental room.

Reinforcer. Counts on the counter had a monetary equivalent. This value was occasionally adjusted across sessions to ensure an approximately constant potential wage of $2.25 per hour. Before each session the subject was informed about the monetary equivalence of a count. Advances of the counter were emphasized by arranging concomitant slide changes (see next section) that instructed the subject to "Stop. Draw a yellow line." (with a yellow felt-tip marker on the exposed writing surface.)

Sessions. The subject sat in front of the writing console wearing the earphones. The session started when the subject first pressed the push button nearest the upper edge of the panel (the slide-change button). This illuminated the houselight and projected instructions on the screen requesting that the subject write down his name. After carrying out this instruction, the subject cleared the paper by pressing the second push button (the paper-clear button). Pressing again on the slide-change button caused a second slide to be projected on the screen. This slide instructed the subject to write down the session number and the date. A third slide asked "How do you feel?" and the fourth read "What did you do yesterday?" This fourth slide remained for 5 min. During the first four slides, the contingencies of monetary reinforcement were not in effect and recording equipment was inoperative.

Following the 5-min presentation of the fourth slide, a new slide, which read "Stop. Draw a yellow line." (the DYL slide), was automatically presented. The subject would then clear the paper by pressing the paper-clear button. He would draw a line across the length of the writing slot on the fresh paper with a felt-tipped pen. Then he would press the slide change button, and press the paper-clear button to obtain fresh paper. The next slide and all other slides during the session that the subject produced by pushing the slide-change button were colored either red or blue. During the initial sessions, these slides also contained suggested topics for writing, *e.g.*, "Vietnam war", "drugs", *etc.* The colors of these slides were correlated with specific schedules of reinforcement. When reinforcement occurred or when a limited-hold period was exceeded, a DYL slide was automatically presented. Pressing the slide-change button had no consequence except during DYL slides. When the houselights were turned off during a DYL slide the subject was permitted to leave the experimental chamber for 5 min. At the end of the session, both the slide projector and the houselight were turned off.

The jewel lamps (see Figure 2) signalled the occasions during which writing was and was not allowed. The red lamp was on whenever handwriting was not allowed, *i.e.*, before and after the session, during DYL slides, and while the paper was being cleared after a response on the paper-clear button. Recording equipment was not operative when the red light was on. The green light was on whenever the red light was off. Most sessions lasted between 120 and 180 min with the green light on approximately 100 to 140 min.

Response units. When the subject exerted a downward force of more than 0.39 N on the writing surface the microswitch beneath it was operated. By writing on the paper with a ball point pen the subject emitted a sequence of responses.

[2]Copies of the instructions can be obtained from the authors.

Response duration could vary widely. The briefest responses corresponded to punctuation, dots over "i" or "j", "t" crosses, or printing. Long duration responses corresponded to multilettered words written cursively. While response durations and interresponse times (IRT) are free to vary independently, the two measures may be positively correlated. It seems likely that time between words will be greater than the time between the end of a word and the punctuation. We defined two response units hereafter referred to as "all-responses" and "criterion-responses". "All-responses" as a class consisted of every closure of the microswitch without regard to duration of closure or duration of IRT. "Criterion responses" were defined by a 0.05-sec minimum IRT followed by a 0.5-sec minimum duration of closure followed by a minimally detectable IRT (paper-clearing time was not considered to be an IRT). Reinforcements were scheduled for the emission of criterion responses. Presumably, this increased the likelihood that reinforcements would be contingent upon the cursive writing of words four or more letters in length; however, the present experiments did not establish this effect.

Schedules of reinforcements.[3] The subjects were exposed to various schedules of reinforcements. The sequence of schedules varied for the two subjects but contained replications of a number of standard schedules. The schedules used for which data are reported were:

Fixed interval (FI *t*-min), in which reinforcement became available after a given time interval *t* (min) since the onset of the color slide correlated with the schedule. The first criterion response emitted after reinforcement had become available advanced the reinforcement counter and produced the change to a DYL slide. *Multiple fixed-ratio fixed-interval with limited-hold.* (*mult* FR *n* FI *t* LH *t″*) in which the two component schedules alternated in simple fahsion. The FI *t* LH *t″* component was similar to the FI schedule except that reinforcement was available only for a specified time period *t″* sec. If a criterion response was not emitted during this time, then when the period elapsed, the DYL slide was presented but the counter did not advance. Under the FR component schedule, the emission of the n^{th} criterion response since the onset of the correlated color slide resulted in reinforcement. Each component schedule was correlated with slides of a distinctive color.

Detailed specification of the schedule parameter values will be indicated at appropriate places in the Results section.

Reading material availability (RMA). Reading materials, *e.g.*, books, newspapers, magazines, could be introduced into the subjects' chamber at the beginning of a session or during one of the 5-min break periods. Materials made available at the beginning of a session could be removed at a break period. When made available, sufficient material was provided to allow the possibility of continuous reading for the entire session. Reading was not required.

RESULTS

Cumulative records of the occurrence of all responses and criterion responses were obtained during each session. Reinforcements are indicated by slash marks. Time meters and counters accumulated post-reinforcement pause (PRP) time, all-responses, criterion-responses, reinforcements, and paper-clear responses for each session. The recording equipment was inoperative during the reinforcement cycle and during paper clearing.

The cumulative records displayed in Figure 3 were produced by B.W. on her forty-second session. The schedule was *mult* FR 15 FI 5-min LH 10-sec and reading material was available in the experimental chamber. Comparing the all-responses record with the criterion-responses record indicates that approximately one-third of all-responses meet the duration requirements necessary to qualify as criterion-responses. No obvious interaction takes place between component schedule of reinforcement and response definition. Throughout the session, performance during the ratio was characterized by minimal duration PRPs followed by stable responding. Most interval components were characterized by long-duration PRPs followed by abrupt changes to a high rate. The terminal rate in the interval com-

[3]Tables with the details of the procedure for each subject can be obtained from the authors.

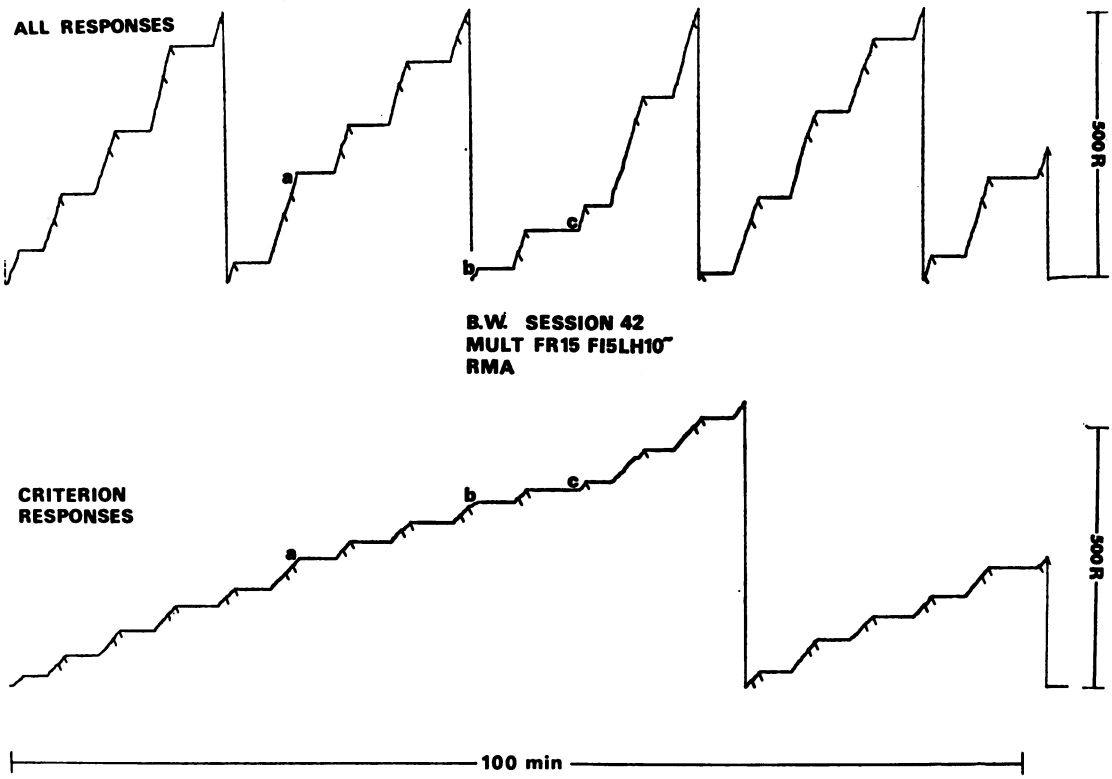

Fig. 3. Cumulative records of all-responses and criterion-responses emitted by Subject B.W. in her forty-second session. The schedule in effect was *mult* FR 15 FI 5-min LH 10-sec and reading material was available in the experimental chamber.

ponents was the same as the rate in the ratio components. Post-reinforcement responding in interval components occurred occasionally, as indicated at *a* and *b* on both records. At *c* the PRP exceeded the limited-hold contingency and reinforcement was missed. The PRP was appreciably shorter during the next interval.

Summary statistics describing the performance of each subject during the last five sessions on these multiple schedules are presented in Table I. These data indicate that the mean PRP in the interval components was much longer than in the ratio components. The mean PRP of D.L. under interval components was twice as long as the mean PRP of B.W. Mean PRPs under both components were quite variable across sessions. Mean overall response rates were similar in the two subjects but were higher in the ratio than in the interval components. Mean response rate during interval components was extremely variable across sessions. All differences in response rates, however, reflect differences in

Table 1

Summary Statistics for Each Subject During the Last Five Sessions Under *Mult* FR FI LH

Subject	Component of Multiple Schedules	PRP (sec)		Rate (Resp/sec)		Crit-Resp/ All-Resp		Words/ Crit-Resp	
		Mean	Range	Mean	Range	Mean	Range	Mean	Range
B.W.	FR 15	5.82	0.89	0.824	0.095	0.348	0.024	1.314	0.067
	FI 5-min LH 10-sec	111.88	70.23	0.387	0.175	0.338	0.023	1.321	0.052
D.L.	FR 30	6.18	1.61	0.801	0.111	0.430	0.040	1.224	0.141
	FI 5-min LH 10-sec	225.71	59.72	0.234	0.139	0.441	0.041	1.236	0.176

PRPs, rather than differences in rates of sustained responding.

Less than half of the responses made by either subject met the criterion-response requirements. This is indicated in Table 1 by the ratio of criterion-responses to all-responses, which was less than 0.5 for both subjects. This ratio was different for the two subjects but it was very similar between schedules and was stable across sessions.

The number of words written by the subjects, obtained by counting words in the handwritten script, was greater than the number of criterion responses emitted in writing the words. This is apparent from the ratio of words to criterion responses, which is greater than 1.0 for both subjects. This ratio was similar for both subjects and very similar between schedules. For Subject B.W., this measure was highly stable across sessions.

The various schedules of reinforcement maintained characteristic patterns of responding in each subject. Figure 4 displays typical cumulative records showing the performance of D.L. under *mult* FR 30 FI 5-min LH 10-sec and the performance of B.W. under *mult* FR 15 FI 5-min LH 10-sec. No reading material was available to the subjects during their sessions. In these schedules, the components alternated in a simple fashion and the subjects earned 15¢ per count. Subject D.L.'s performance in the interval components was clearly different from his performance in the ratio components. Post-reinforcement pauses exceeding 3 min in duration were common in interval components. Occasionally, as at *a*, *b*, and *c* the PRPs approached 5-min durations. No acceleratory patterns (scallops) were evident, however, and the terminal rates in the interval components were the same as the rates in the ratio components. The limited-hold contingency led to no loss of reinforcement in the sessions shown. B.W. sustained a high rate during most of the session. Where PRPs occurred (*a*,*b*,*c*) they were located in interval components and durations were no longer than 1 min. The pauses indicated at *a* and at *c* were not immediately post-reinforcement but were preceded by short runs following reinforcement. For B.W., as for D.L., rates of responding in the interval and ratio components were comparable and no scallops were observed.

Figure 5 shows the development of the handwriting performance of D.L. on FI 1-min following a history of reinforcement on continuous reinforcement. During this session and during the prior session on CRF, the sub-

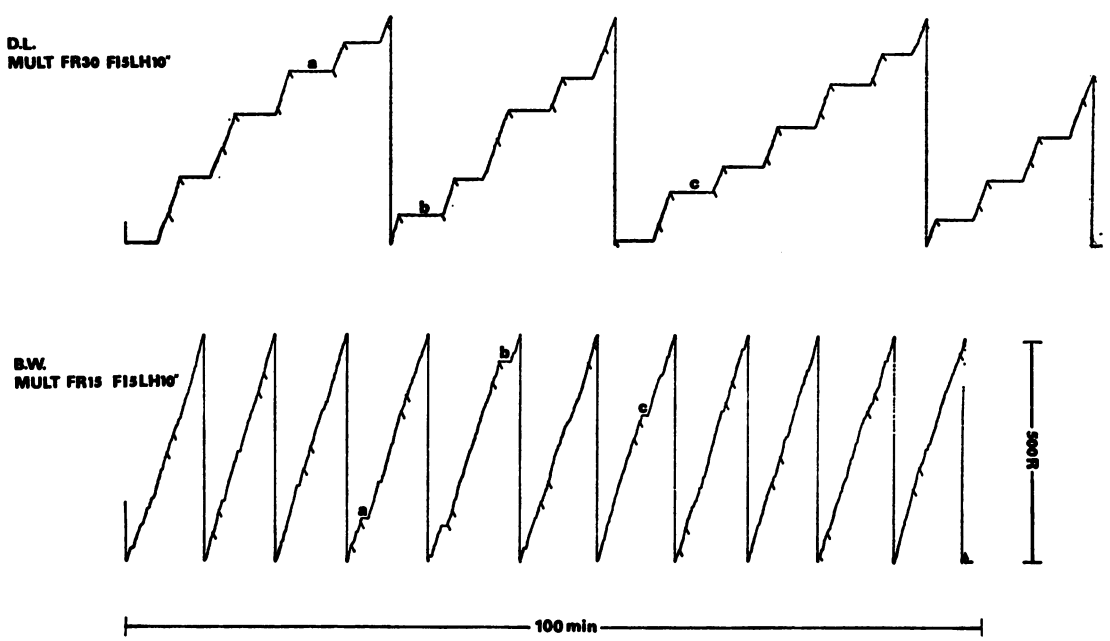

Fig. 4. Cumulative records showing representative performances of Subject D.L. under *mult* FR 30 FI 5-min LH 10-sec and Subject B.W. under *mult* FR 15 FI 5-min LH 10-sec with no reading material available in the experimental room.

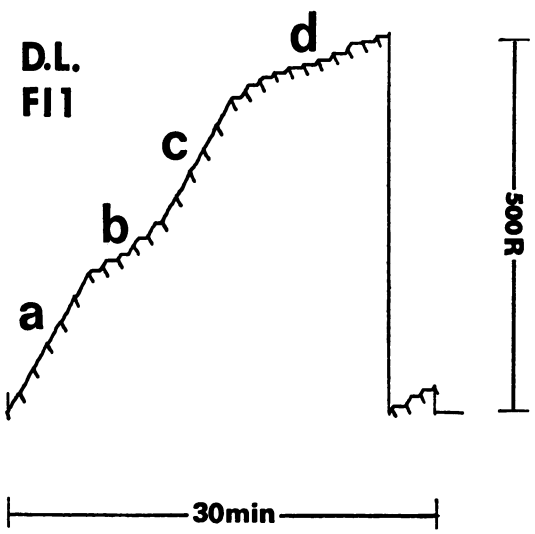

Fig. 5. Cumulative record showing the transition from CRF to FI 1-min for Subject D.L.

ject earned 20¢ per count. The subject's performance under FI 1-min was characterized by an initial period of constant responding (*a*) followed by several intervals during which the response pattern consisted of post-reinforcement responding followed by pauses (*b*). During the next few intervals the subject responded continuously (*c*), but pauses, including some PRPs, occurred during each of the remaining intervals of the session (*d*).

Figure 6 illustrates the effect of reading material availability (RMA) on the *mult* FR 15 FI 5-min LH 10-sec performance of B.W. There were two 5-min breaks scheduled for the session, as indicated by the arrows. Reading material was introduced at the first break and removed at the second. Before its introduction, brief PRPs began to occur in each interval component. With RMA, the PRPs during the intervals became much longer and more regular. Upon its removal, the durations of PRPs decreased to values similar to those occurring before it was introduced. Performance on FR 15 components was unaffected. The cumulative records shown in Figure 3 illustrate the characteristic performance of B.W. with RMA throughout the session. Long PRPs occurred consistently in the interval components. RMA had no detectable effect on the interval performance of D.L., which was characterized by long duration PRPs (see Figure 4) without RMA.

The subjects were occasionally observed during the session through the door viewer. When reading material was not available, neither subject was observed to do anything consistently while pausing from handwriting. With RMA, however, both subjects typically engaged in reading during PRPs.

In these experiments, handwriting always produced a legible, cursively written text. Sample verbatim texts excerpted from each subject's writings are reproduced with the correlated schedule component indicated by (FI) or (FR) for each change in component. Distinctive features of the performances *e.g.*, pauses from handwriting (Pause), and reinforcements (RFT) are also indicated at appropriate points in the texts.

Subject B.W.

Schedule: mult FR 15 FI 5-min LH 10-sec (for the correlated cumulative record refer to

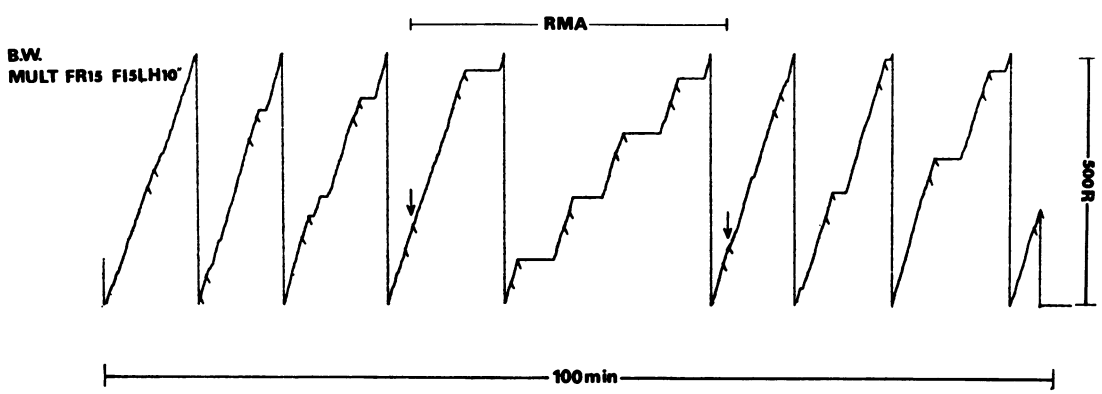

Fig. 6. Cumulative record showing the effect of having reading material available (RMA) in the experimental room on the performance of Subject B.W. under *mult* FR 15 FI 5-min LH 10-sec. The first arrow indicates the introduction of reading material into the experimental room and the second arrow indicates removal of the reading material from the room.

Figure 3 and begin at the FR 15 component preceding *a*. This text ends with the FR 15 reinforcement following *c*).

FR: Lewis is really being nice this semester; he seems a lot more concerned about what I want. I really am (RFT)
FI: talking just about the last few days I guess. Probably, I'm the one who's changed attitudes. (Pause) I guess we won't do much Saturday. I really need to catch up with everything. Maybe we can go out Friday night. (RFT)
FR: That'll be a good way to break between week-end and week. It wouldn't be a bad idea at all. I really can't decide (RFT)
FI: (Pause) I have 2 quizzes tomorrow so I'll really have to study tonight. I'm kind of glad I got that sleep last night; I'm a lot more rested now. I haven't been really sleepy (RFT)
FR: Maybe I can keep awake tonight. I really do need to study. Probably be my luck to have a pop quiz in Music tomorrow. (RFT)
FI: (Pause) I like that new song by the Carpenters. It really is good. There's something about her voice. Lewis says that her voice is (RFT)
FR: somewhat masculine. So I made a few inferences. Since the girl singers I know are kind of boyish looking (RFT)
FI: then maybe it's their low hormones which affect secondary sex development—also affect the voice. (Pause) That's a layman's prophecy, I guess. An educated guess. We saw (RFT)
FR: a movie in Ed. today about a typical eighth grader. It was pretty good. Our Ed. class is divided (RFT)
FI: (Pause; exceeded LH-missed RFT)
FR: I missed that one. I didn't keep my mind on time perception. I couldn't remember when the time should be (RFT)

Subject D.L.

Schedule: mult FR 30 FI 5-min LH 10-sec (for the correlated cumulative record refer to Figure 4 and begin at FI LH component designated *a*. This text ends with the FR 30 reinforcement following *b*).

FI: (Pause) I really (RFT)
FR: must be strange about this, but I feel as if I haven't done something that I'm supposed to do if I don't finish what I have begun to read. It's really strange I know, but I'm just a person who likes to see what is supposed to (RFT)
FI: (Pause) There is really something very weird about walking around feeling as if there was something that you intended to do, but you haven't done it. I feel as if I always need to get finished with one thing at a time, before I start to do anything else that I had (RFT)
FR: Planned. I know that it's really kind of a heckling experience because I'm continually on myself to get things done, and I really want to more or less pace myself to get the maximum (RFT)
FI: (Pause) I am trying to get my wife and I going (RFT)
FR: on sort of an exercise schedule, so that she'll be able to pull together some of the muscles and skin that were stretched out when she was pregnant. I never realized how delicate that whole (RFT)

The texts are typical in several respects. First, the discontinuities in content, particularly for B.W., are correlated with pauses from handwriting. Where no PRPs are observed in an FI component the text indicates a continuation of the content begun in the previous FR component. Second, the content produced by both subjects concerns significant aspects of their daily lives. Occasionally, subjects referred to the immediate situation. For example, B.W. refers to the reinforcement missed as a result of the limited hold contingency.

DISCUSSION

The results illustrate that various schedules of reinforcement control typical response patterns in human subjects emitting handwriting. Furthermore, schedule-appropriate responding was apparently also controlled by correlated visual simuli. Occasionally, Subject B.W. emitted short runs of responses early in the fixed intervals following reinforcement on the ratio components. These short runs of responses corresponded to the completion of sentences initiated during the ratio components. Thus, for this subject, sources of control other than the correlated visual discriminative

stimuli existed. These responses cannot be accounted for by textual stimuli produced by the subject's prior handwriting because the text was removed from view by the procedures arranged with reinforcement.

The patterns of responding of Subject D.L. during transition from CRF to FI 1-min were similar to the patterns of responding of pigeons during the transition from CRF to FI schedules (Ferster and Skinner, 1957, pp. 135-142). This transition performance in humans has not previously been reported.

In one subject, the schedule of reinforcement was shown to interact significantly with the availability of reading material. Whereas reading material had little or no effect on the performance of B.W. under FR schedule control, it had immediate and large effects on her performance maintained by the interval schedules, producing significant increases in the duration of post-reinforcement pauses. Laties and Weiss (1963) obtained results different from ours when they required their subjects to perform a subtraction task while button pushing under fixed-interval schedules. Generally, they observed reductions in PRP durations and some changes in the rates of sustained responding. The differences between their results and ours may be due to differences in the concurrent tasks. Whereas Laties and Weiss required their subjects to engage in the subtraction task continuously as they button pressed, the present subjects were not required to engage in reading but were free to do so. The introduction of the reading materials into the experimental chamber provided the opportunity for an activity that must have had an extensive reinforcement history, namely, reading. Reading effectively competed with handwriting at times when handwriting was poorly maintained by the monetary reinforcements, that is, early in the fixed-interval components. This interpretation is consistent with that provided by Poppen (1972) to account for his results obtained with humans button pushing under various concurrent schedules.

The results contained one disappointing characteristic. While various schedules of reinforcement controlled distinctive patterns of responding, the rates of sustained responding were essentially identical for all schedules. A casual visual examination of the handwriting records did not reveal schedule-correlated differences in the subjects' penmanship. The ratios of criterion responses to all responses, and of words to criterion responses, did not change with the schedules (see Table 1), which further indicates the constancy of topographical features of the subjects' handwriting. Several factors may be involved. Cursive handwriting in college students has had a long and varied history of reinforcement in the "real world". It is reasonable that a modal rate exists for the performance, which is determined by a host of historic and current "real world" contingencies of reinforcement. We would not expect to alter these mechanisms appreciably within our experimental situation. An additional factor may have been that the criterion response, designed to reinforce cursive writing of words four or more letters in length, effectively distinguished topographical differentiations that would lead to distinctive rates of responding. This factor is subject to experimental manipulation. A third factor involved linguistic constraints. Writing involves sequential dependencies more or less specified by the structure of the language. Since we observed no instances of random production of graphemes in more than 200 hr of writing, whatever constraints exist were obviously operating during the present experiments.

Generally, however, the results obtained are encouraging. In addition to the data reported here, we have obtained some which suggest that schedule controlled handwriting may be a useful tool for assessing drug effects in humans. Furthermore, a cursory reading of the more than 300,000 words of text written by the subjects suggests that expressions of mood and effect and descriptions of personal situations occurred with considerable frequency. A content analysis of these texts might be interesting. Handwriting may prove to be a more appropriate response for the experimental analysis of behavior than other responses commonly used with human subjects, such as lever pulling or button pushing. However, other variables not systematically manipulated in this study such as the instructions, the sequence of exposure to the various schedules, and the characteristics of the reinforcing event, may have contributed to the observed results. Additional experimentation will be necessary to determine the relative importance of these variables.

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