A METHOD FOR THE ANALYSIS AND CONTROL OF SPEECH RATE¹

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A multitude of possible response measures is available to the student of verbal behavior (Skinner, 1957). Perhaps the clearest illustrations of the control of verbal behavior are from the experimental scrutiny of response classes based on content (e.g., plural or singular nouns) and their maintaining stimuli (Greenspoon, 1951; Verplanck, 1955). More recently, stuttering has been brought under the control of response-contingency arrangements (Flanagan, Goldiamond, & Azrin, 1958, 1959). Although some attention has been paid to rate of verbal response (Kanfer, 1958a, 1958b), the functional relationship between rate of response and the schedule of reinforcement has not yet been studied.³

For nonvocal behavior, an impressive display of data is available on the dependency of the rate of response upon the schedule of reinforcement. The consistency of these data derives more from the particular schedule of reinforcement than from the kind of animal emitting the response or from the topography of the response. If verbal behavior is considered as another variant of topography, its control probably could be similarly accomplished with particular reinforcement schedules.

There is, of course, the problem of automation in the programming and recording of events relevant to rate of verbal responding. Intimately involved with this is the notion of a discrete or "phasic" verbal response. In other words, how should the flow of speech be divided into individual units? In the present research, a verbal-response class is defined in terms of its effect upon the environment, *i.e.*, upon an electronic manipulandum. Such a manipulandum has two properties which seem to be fruitful. First, it reliably defines the verbal response, just as the lever and associated switches define a bar-press response. Second, it provides suitable linkage between the Ss' speech and automatic recording and programming apparatus.

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³Since this article was submitted for publication, the control of vocal behavior by schedules of reinforcement has been reported by Lane (1960a, 1960b). A similar technique for the analysis of vocal behavior has been reported by Starkweather (1960).

METHOD

Subjects

The Ss were 14 undergraduate students at Indiana University and one psychiatric patient from the Veterans Administration Hospital, Indianapolis. The undergraduate Ss were volunteers who received class credit for participation. The patient was selected for the experiment because he demonstrated continuous verbal behavior at high rates in the presence or absence of a verbal community. He received 10-15 milligrams of Compazine three times a day throughout the study.

Apparatus

A high-impedance, stand-type microphone was used with the university students. In later experimental sessions, when the psychiatric S was run, a carbon throat microphone with a battery-transformer booster was substituted. This arrangement proved to be far more sensitive and reliable than the stand-type arrangement. Practically all nonvocal noise was eliminated with the throat microphone.

The signal from the microphone was then amplified by a standard audio amplifier and passed to a modified Heathkit electronic voice control (Model VX-1). This device, which is commonly used by radio amateurs, was constructed according to the instructions in the kit with the following exceptions. First, the "receiver" components of the kit were not used, because only "transmit" circuitry was relevant. Second, a 0.005-microfarad capacitor was substituted for the 0.1-microfarad capacitor in parallel with the time-delay control potentiometer to shorten the time between the cessation of a speech sound and reset of the circuit in preparation for the next speech sound. Third, the relay spring of the voice control was removed to increase sensitivity. From the normally closed contacts of this relay, the remaining circuitry followed standard operant arrangements.

To evaluate the limits of the voice-control device in terms of the physical events necessary to operate it, the following calibration procedure was used. A Grayson-Stadler electronic timer was set to recycle at a given rate and start a Hunter timer, which in turn timed a constant portion of each cycle. The operation of the Hunter timer passed a pulse from an audio oscillator directly to the voice-control device. By varying the recycling time of the Grayson-Stadler timer, the pulse rate could be varied to the voice control; and by changing the setting of the Hunter timer, different pulse durations and interpulse durations could be used for a given pulse rate. With this procedure, the shortest pulse and interpulse times necessary for reliable opera-

tion of the voice control could be determined at four arbitrary pulse-rate settings (2, 10, 15, and 20 pulses per second). A pulse or interpulse duration which was too short was rather easily detected when a counter monitoring the voice control either chattered or stopped altogether. A Berkeley electronic counter receiving 1000 cycles per second first timed a minimum pulse duration for 500 pulses and then a minimum interpulse duration for 500 pulses. The average minimum pulse time necessary to operate the voice control was 1.4 ± 0.5 milliseconds, while the average minimum interpulse time was 14.2 ± 5.2 milliseconds. (Average values are reported because no systematic differences occurred across pulse rates.) The average voice-control counter reading of the 500 pulses was 501, with 505 the most discrepant reading.

An additional test was run because the human *S* obviously would not provide pulses so cooperatively as the calibration apparatus. (A typical speech spectrogram clearly shows this.) For this check, we asked four *Ss* to read a 100-word passage at various rates, and then we plotted the voice-control counter readings against the speaking rates as shown in Fig. 1. Subject, read technical material, and, over a year later, the other *Ss* read a passage from a novel. Our expectation that sounds would tend to run together at higher rates seems to be borne out in view of the linear decrement in counts as a function of speaking rate.

Reinforcement was delivered by a modified vertical scoring panel taken from a pinball machine. A 1-cycle-per-second motor drove wipers across contacts to advance the number of points, blink the lights, and ring a bell. The number of points per reinforcement was determined by the length of time this motor was activated by a reset timer. The time used throughout the research reported here was 3 seconds.

The *Ss'* room and the programming and recording room were separated by a third room. Because of the length of cable necessary to connect these rooms, an audio amplifier was used to compensate for the in-

creased impedance. The gain of the amplifier was set within the range which allowed free operation of the voice-control device without chattering. In addition to the voice-control microphone, a separate microphone was connected to a tape recorder in the recording room.

Procedure

After the college students were seated in front of the scoring panel and had microphones positioned, they were instructed, "Earn as many points on the scoreboard as you can during the session." If *S* asked questions, these instructions were repeated. Furthermore, additional cues were provided by again adjusting the microphone, which was about 6 inches in front of *S's* face. Each college student was run on FR 30 for one session, lasting from 40 to 120 minutes. In most instances, extinction was introduced following a period of reinforcement. Points for the college students were not negotiable.

The psychiatric patient was told that he could earn points by talking, and that a poker chip would be given for a certain number of points. Also, each time he earned 10 chips, he would be taken to the hospital canteen (a privilege he was not granted in his ward). This *S* was run on a DRL schedule for a total of 34 sessions, varying from 30 to 150 minutes. The first 20 of these sessions were devoted to DRL values exceeding 5 seconds with no apparent success. During the next two sessions, the first vocalization after a pause of 3 seconds was reinforced. The value was then held at 2 seconds for 4 days; then it was increased to 2.5 seconds for 4 days; and, finally, it was changed back to 3 seconds for the final 4 days of the experiment.

RESULTS AND DISCUSSION

Fixed-ratio with Students

Figure 2 shows the complete performance of four *Ss* (Records A, B, C, and D) on FR 30 which are rather representative of the performance of all *Ss* on this schedule. Despite the short total time this contingency was in effect, some instances of fixed-ratio behavior are present. For example, pauses following reinforcement occur in Fig. 2C. Figures 2A and 2D are somewhat illustrative of extinction following fixed-ratio reinforcement, in that fairly long runs followed by pauses occur (as compared with Fig. 2B and 2C, where no more than rough grain is revealed). Deceleration during extinction appears in all the records except Fig. 2B, where a high over-all rate is shown throughout about 25 minutes of extinction. On some occasions, the reinforcement device failed to operate. The *S* received no stimulus which was correlated with these reinforcement failures.

All *Ss* start at fairly high rates from the beginning of the session, but the *Ss* in Fig. 2C and 2D shift to their highest rates toward the middle of the session following gradual deceleration. (See points *a* and *b*.) These

Fig. 1. Voice-control device count as a function of speaking rate.

Fig. 2A. Record A: Performance of S_1 on FR 30 followed by extinction.

Fig. 2B. Record B: Performance of S_2 on FR 30 followed by extinction.

Fig. 2D. Record D: Performance of S_1 on FR 30 followed by extinction.

Fig. 2C. Record C: Performance of S_3 on FR 30 followed by extinction.

Fig. 3A. Record A: Performance of a psychiatric patient on DRL 3 seconds before this DRL value was decreased.

Fig. 3B. Records B, C, D, and E: Performance of a psychiatric patient on DRL 3 seconds after the DRL value was restored to 3 seconds.

abrupt changes in rate accompanied changes to specific topics, which both *Ss* later reported to be instrumental in increasing the number of points ("adding by threes" and "psychological problems"). The fact that most *Ss* indicated that point increases were contingent upon *what* was said suggests that this technique may be used profitably to study superstitious behavior.

DRL with the Psychiatric Patient

Record A of Fig. 3 shows the performance under the 3-second pause contingency after 20 sessions on DRL values exceeding 5 seconds, but before the shorter intervals were introduced. Records B, C, D, and E of Fig. 3 show the performance after the shorter intervals were used. However, since this *S* was run with a throat microphone which was somewhat more sensitive than the stand-type microphone, these rates are not easily compared with the FR rates. (Similarly, rates obtained with rat levers of different force requirements are not directly comparable with each other.)

The rates clearly decline across these sessions, although they are considerably higher throughout than those typically demonstrated with nonvocal behavior under the DRL contingency. With the early DRL of 3 seconds shown in Curve A, only a few reinforcements occurred. Many more reinforcements were provided when the interval was decreased to 2 seconds. Later, when the interval was again increased to 3 seconds, the patient earned a considerable number of reinforcements (*cf.* Curve A versus Curves B-E).

Figure 4 presents ratios of the number of reinforced responses to the number of nonreinforced responses for the various DRL values. The number of responses per reinforcement was highest for the first 3-second pause session. When the length of the pause was decreased from 3 seconds to 2 seconds, the ratio decreased, as one would expect. As training progressed during the four sessions of each interval, the ratio declined (except on the second day of the 2-second interval). Therefore, the number of pauses meeting the DRL contingency was systematically increased.

The experiment with the psychiatric patient ended when he refused to participate any longer, explaining, "I don't have to talk like that anymore."

CONCLUSIONS AND SUMMARY

Rate of verbal emission was handled in a fashion similar to rate of nonvocal responding with the use of an electronic voice-control manipulandum. College students were run on a fixed-ratio schedule. A psychiatric patient with a high-operant verbal rate met an increas-

Fig. 4. The ratio of reinforced responses to nonreinforced responses for the psychiatric patient on four DRL values.

ing number of DRL contingencies and demonstrated a progressive reduction in his rate of verbal emission.

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