SUPPLEMENTARY KNOWLEDGE OF RESULTS¹

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Children learned to respond differentially to four tones when correct responses were indicated by re-sounding the tone and flashing a signal lamp (simple knowledge of results). Correct responses were then made to advance a display counter. With this procedure, rate of response increased, but accuracy decreased. Mild punishment—points subtracted from the count—was then arranged for incorrect responses. Accuracy returned to or above its previous level. Response rate tended to remain above its initial level. These results indicate that when supplementary reinforcers are employed, precise contingencies must be arranged to ensure desired behavior.

Reinforcement in programmed instruction typically consists of displaying the correct answer after a response to the material. The use of other events to supplement this type of reinforcer (Skinner, 1954) has not been generally adopted. The experimental basis for using only some form of simple knowledge of results would seem to stem from several studies which did not find additional consequences to change the rate of human learning (McGeoch and Irion, 1952, p. 246). These experiments considered only the percentage of correct trials, or some similar derivative of performance, as the measure of learning. But, particularly in applied situations, other aspects of "learning" would also seem important.

For example, Staats, Staats, Schutz, and Wolf (1962) found that some reinforcer in addition to simple knowledge of results was essential to maintain participation of young children in a learning task. Without supplemental reinforcement, the children quickly asked to terminate the experiment. Sizable numbers of subjects in programmed instruction fail to complete the procedures (*e.g.*, Cartier, 1963; Snelbecker, Sherman, Rothstein, and Cramer, 1963). A possible explanation is that reinforcement was insufficient to maintain participation. This may also explain re-

ports of boredom, failing motivation *etc.* among captive subjects.

Another important effect of reinforcement may be to determine the rate of response. Programmed instruction material is designed to enable the subject to respond correctly after appropriate precursory behavior. The rate at which he works can thus be considered a rate of learning. In a fixed period of time, the faster student will master a larger portion of the subject matter.

The present experiment studied the effect of supplementary reinforcers on rate of response at a discrimination task. The situation did not involve learning *per se* inasmuch as the discrimination was brought to an asymptotic level before the experimental variable was introduced. The procedure is similar to a programmed learning situation and permits the effect of the variable to be assessed with respect to changes in individual performance. Variance due to individual differences in response rate and experience is thereby minimized.

METHOD

Subjects

Five 7-year old children were used.

Apparatus

An electrically operated reed organ presented the notes *f'*, *g'*, *a'*, *b'*. They were on a tempered scale and corresponded to the frequencies: *f'*-350cps, *g'*-392cps, *a'*-440, *b'*-494.

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The differences between them are all musical whole steps, approximately equidistant (difference limens in this range are approximately 2 to 3 cps, Liklider, 1951). Depressing the keys activated an electrical switch. The four appropriate keys were marked. An add-subtract counter was located on the console, above the keyboard. Automatic control equipment was in a separate room.

Procedure

The child was seated before the keyboard. A 0.6 sec tone was presented every 4.5 sec until a correct response (depression of the key corresponding to the tone) occurred. Incorrect responses (depression of any other key) were recorded, but had no effect and could be followed immediately by a correct response. Correct responses re-sounded the tone and flashed a signal lamp. The next new tone was presented 0.6 sec later.

During the first session, each of the four tones was introduced singly, several times in succession. Then, two tones would alternate, later three tones, until finally all four tones were used. In all subsequent sessions the four tones were presented randomly. Sessions lasted 10 min and were run five days a week.

Response rates stabilized in three to six sessions. The experimental variable was then introduced. Each correct response advanced the display counter. This procedure was in effect for a minimum of six sessions. In the next procedure, correct responses continued to advance the counter, but incorrect responses subtracted from the total.

At the first session, the assistant chatted with the child for a few moments and then gave the following instructions:

"You will come up to play a game every day for 10 min. You will be

playing the same game every day so that you and I can see how much better you do it each time you play. You are going to play with the four keys that are lit. When the game starts, the machine will play a sound. When the sound stops playing, you are to find which key makes that sound. When you press that key down, the same sound will be played again and the red light will come on. If you push the wrong key nothing will happen and the machine will wait for you to find the right one. See how many times you can make the red light go on on your first press. I will start the machine and leave the room. I will be back in when you are all finished."

The counter and the subtraction procedure were introduced without comment. When the assistant returned at the end of each of these sessions, she and the child plotted the total score on a graph. (A new graph was started when the subtraction procedure was introduced.) She commented favorably when the score was higher than in the previous session.

RESULTS

Table 1 summarizes the final three to five stable sessions of each condition. It presents the mean total responses and the mean percent correct of initial responses to each stimulus. The major effect of the counter was to increase the number of responses. But there was also a tendency to perform less precisely, *i.e.*, a decrease in percent correct. High point accumulations could result from quick responses without careful attention to the stimuli. The subtraction procedure penalized hasty, impre-

Table 1
Means and Average Deviations of Stable Performance

Subject	Initial		Counter		Errors Subtract	
	Tot. Resp.	Perc. Corr.	Tot. Resp.	Perc. Corr.	Tot. Resp.	Perc. Corr.
RB	147 ± 2	95 ± 4	301 ± 9	80 ± 2	243 ± 5	94 ± 2
LW	135 ± 29	68 ± 6	250 ± 10	58 ± 4	204 ± 14	66 ± 4
GP	183 ± 6	67 ± 3	290 ± 18	57 ± 4	211 ± 5	77 ± 2
EF	241 ± 14	45 ± 5	275 ± 44	41 ± 9	199 ± 28	62 ± 6
SH	165 ± 9	92 ± 2	212 ± 4	92 ± 2	231 ± 10	92 ± 1

cise performance. Under it, the total number of responses decreased somewhat but the percent correct increased to its previous level or above. The only deviation from this pattern was shown by subject SH, for whom the counter did not decrease accuracy. Figure 1 shows the course in which the changes develop. Typically, only a few sessions were required for the measures to reach stable values.

Figure 2 shows the distribution of responses to each of the tones for one subject. The ordinate shows the percent of initial responses to all presentations of each stimulus made on the keys shown by the abscissa. Responses were concentrated on the appropriate key under all conditions. Erroneous responses were concentrated on adjacent keys, and occurred less frequently on keys farther away. These distributions describe typical stimulus generalization functions. The addition of the counter procedure reduced the percent correct responses, and elevated the tails of the distributions. The subtraction procedure increased the percent correct responses and lowered the tails of the distributions. Random responding, which would have led to equal responding on all keys, did not occur. Nor is there evidence

Fig. 1. Session-to-session changes in total responses and percent correct of initial responses to the stimuli for one subject. Lines represent means of each condition.

Fig. 2. Distribution of responses to each stimulus under the three conditions for one subject. Each graph shows the results for all presentations of a particular tone. The ordinate indicates the percent of responses that occurred on the response key indicated on the abscissa.

of systematic searching, *e.g.*, starting with a particular key and trying each adjacent key in succession. This would have elevated a particular tail of the distribution.

Table 2 shows the rate of initial correct responses under the initial conditions of knowledge of results and the final conditions of adding points for correct responses and subtracting points for incorrect responses. The rate of these responses increased overall as a result of supplementary reinforcement.

DISCUSSION

Adding supplementary reinforcement to simple knowledge of results increased the rate at which the children worked; but unless this reinforcement was specifically related to correct performance by having errors subtract, the precision of performance tended to decrease. When correct responses advanced the counter and errors subtracted, performance tended to be changed from that resulting from

Table 2

Median rate of initial correct response per minute during stable sessions.

Subject	RB	LW	GP	EF	SH
Initial	13.0	6.0	8.3	4.4	13.8
Counter + Subtract	20.5	7.8	11.5	4.6	19.1

simple knowledge of results. The changes were not uniform. For subjects RB, LW, and SH, the rate of response was facilitated, without change in the percent correct. For subjects GP and EF the percent correct increased, but in one case (EF) the rate of response decreased. The effect of the reinforcement procedures would seem to interact with other aspects of the performance. However, in all cases there was a net gain in rate of initially correct responses.

Several experiments found that penalizing undesired responses reduces them. Experiments with pigeons (Zimmerman and Ferster, 1963) have found that punishing incorrect responses by a time-out from positive reinforcement improved matching to sample performance. Weiner (1962, 1963, 1964a, 1964b) has shown that the rate of a free operant response reinforced by counter points can be drastically reduced when the subtraction of points is made contingent upon these responses. Weiner's experiments suggest that point subtraction has its greatest effect on responses least essential to positive reinforcement. The procedure may thus be of great value in applied situations.

The effectiveness of mild punishment in these experiments also contrasts with earlier findings, suggesting that punishment of errors does little to facilitate learning (McGeoch and Irion, 1952, pp. 260-265). Much of the dispute that arose from these experiments (Postman, 1947; Stone, 1950) may relate to the aspects of performance which are changed by punishment, and the other variables which maintain the performance. If the counter plus subtraction is compared only with the initial knowledge of results performance, the effect on per-

cent correct is small and inconsistent. The effect of punishment in this experiment was most apparent when the counter alone and counter plus subtraction are compared.

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