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The purpose of this study was to determine whether or not performance on a complex perceptual-motor task (available on the Star Discrimeter) is differentially affected by the previous learning of verbal responses which are differentially concordant with the required motor responses.

McAllister (3) had previously investigated the effects of three varieties of relevant verbal pretraining on the subsequent performance of the Star Discrimeter task. A subject (S), in practicing on the Star, learns to associate directional movements of a wobble-stick with different colors. Six colors of light appear on the stimulus panel, one at a time, in random sequence. In response to each color, S learns to move the wobble-stick into one of the six slots (channels) which radiate from a common center in the top plate of the response unit. Moving the stick into the correct slot turns off the color and brings up a new one.

About half of McAllister's subjects (Ss) were pretrained for the motor task by means of paired-associates learning in which the Discrimeter colors were the stimuli and even-numbered hours on the face of a clock—2 o'clock, 4 o'clock, etc.—were the response words. Before beginning on the motor task, these Ss were told that the six slots in the response unit could be conceptualized as pointing toward the even-numbered hours on a clock, with its face up and with 12 o'clock straight ahead. The results clearly indicated that relevant verbal pretraining in terms of the clock analogue facilitates subsequent performance on the Discrimeter.

The present study used the clock analogue as the basis for paired-associates verbal pretraining but provided for varying the degree of concordance between the correct responses of the verbal task and those of the motor task. In addition to four experimental groups whose verbal pretraining was of different degrees of appropriateness for the motor task, there was a control group which learned to associate irrelevant adjectives with the stimulus lights. The experimental design is summarized in Table 1.

Experimental Method

Apparatus

As indicated in Figure 1, the response unit of the Star Discrimeter consists of six slots, spaced 60 degrees apart, which radiate from a

Table 1
Experimental Design

Group	*N*	Verbal Responses	Degree of Concordance*
1	20	Clock hours	6
2	20	Clock hours	4
3	20	Clock hours	2
4	20	Clock hours	0
5	20	Adjectives	–

*Number of verbal responses concordant with motor responses.

central opening in a horizontal steel plate. Out of this opening protrudes a wobble-stick, which can be moved into any one of the six slots. The stimulus panel contains a circular piece of opal glass onto which six colors can be projected from inside the unit. The sequence of colors is controlled by a 50-point stepping switch.

For a particular task, each color is connected with one of the response slots. S moves the stick into the appropriate slot for each color. Pushing the stick all the way into the correct slot closes a microswitch, which simultaneously activates the stepping switch and the correct response counter. Entering any of the other five slots closes first a shallow and then a deep error microswitch; and each of these microswitches activates its corresponding counter. The Star situation is a free-responding one in that a color will remain on the stimulus panel until S goes all the way into the correct slot, turning off the stimulus color and bringing up a new one.

The verbal paired-associates pretraining utilized the stimulus panel of the Discrimeter. The stimuli were the colors, which appeared in

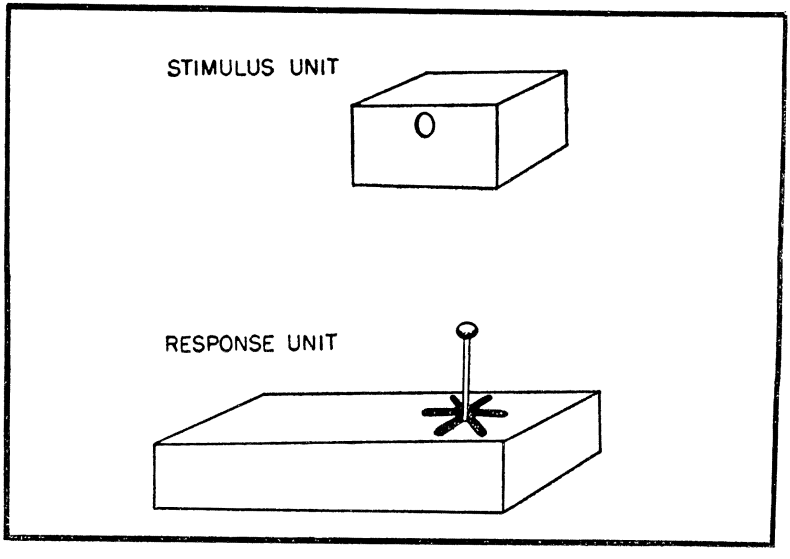

Figure 1. Schematic drawing of the Iowa Star Discrimeter.

the circle; the responses were flashed beneath this circle by means of a LaBelle 33 automatic slide projector, which was mounted adjacent to the response unit. This unit was covered during pretraining. During verbal learning a color appeared on the stimulus panel for a period of four seconds. During the first half of this period, S was to anticipate the verbal response (clock hour or adjective) associated with the color. Then the color and response appeared together for two seconds; during this time S read the correct response aloud, if the attempt at anticipation had been incorrect. The stepping switch of the Star and the slide projector were operated synchronously with five decade interval timers.

Subjects

The subjects were 117 women, all of whom were students in elementary psychology classes and all of whom correctly read cards 1-9 and 12-13 of the Ishihara color-discrimination test. Of the total, 17 were discarded: 12 because of apparatus breakdown or experimental error; four because of Ss' failure to follow motor task instructions; one because of failure to meet the pretraining criterion. Except in the case of Ss run to replace those discarded, assignments to groups were made with the aid of a table of random numbers.

Procedure

For verbal pretraining, the Ss were seated in a high chair facing the stimulus panel. The instructions were identical for all groups. Each S was presented with each of the six light-word pairs 24 times, making a total of 144 presentations. E recorded the responses in three categories: correct anticipation, incorrect anticipation, and failure to respond during the anticipation interval. A 90-second rest occurred midway through the verbal learning.

Upon completion of verbal pretraining, Ss were given a three-minute rest during which E arranged the apparatus for the motor task. The motor task instructions were the same for all groups except that the analogy between the clock and the response slots was not mentioned to group 5, the control group. The four experimental groups were told either that all, some, or none of the verbal responses they had learned to the colors would help them in performing the motor task.

All Ss were given 30 trials on the Star. The trials were each 20 seconds in length and were separated by 10-sec. rests. After the 15th trial, a one-min. rest was given.

Results

Verbal Learning

The verbal learning performances of the five groups of Ss were practically identical. All Ss learned the six pairings within 100 pre-

sentations of them; the remaining 44 (or more) presentations provided an overlearning of the color-adjective or color-clock hour combinations.

Motor Task: Correct Responses

Figure 2 shows a plot of the means of number or correct responses for the five groups on the 30 motor task trials. Over the first half of the trials, the curve for Group 1 (the group for which all of the verbal responses were concordant with the motor responses) is far above the curves for the other groups. The superiority of the performance of Group 1 over that of Group 5 confirms McAllister's findings (3). Up to trial 10, the order of the curves for the four experimental groups is the same as the degree of concordance. Group 5 began at a level between Groups 2 and 3, but beyond trial 4 performed about the same as Group 4. The performance of Group 3 fell between the performances of Groups 2 and 4 on most of the trials, while Group 2 eventually equalled the level of Group 1.

A trend analysis, Lindquist's Type I design (2), over trials 5-14[1] indicated that the hypotheses of no group differences and of no trials by groups interaction may be rejected at the .1% level of significance. The analysis is summarized in Table 2. (For group differences $F = \frac{825.028}{113.571} = 7.26$, with 4 and 95 degrees of freedom; for trials by groups interaction, $F = \frac{6.763}{2.568} = 2.63$ with 36 and 855 degrees freedom). Of the simple effects between groups, only those involving Group 1 proved significant. These effects were evaluated by the following t test:

$$t = \frac{M_1 - M_2}{\sqrt{ms_{\text{error (b)}} \left(\frac{1}{n_t n_1} + \frac{1}{n_t n_2}\right)}}$$

where n_t is the number of trials and n_1 and n_2 are the numbers of subjects in the comparison groups. The number of degrees of freedom is $(n_1 + n_2 - 2)$. Applied to groups 1 and 2, the result is

$$t = \frac{13.31 - 10.38}{\sqrt{113.57 \left(\frac{1}{200} + \frac{1}{200}\right)}} = \frac{2.93}{1.0657} = 2.75,$$

[1] It had been decided to carry out a trend analysis over ten consecutive trials in the first half of motor practice. Trials 1-4 were excluded from the analysis because the assumption of homogeneity of variance with respect to them was unwarranted.

Table 2
Summary of Trend Analysis of Correct Responses Over Trials 5-14

Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	F	p
Between Subjects	14,089.344	99			
Between Groups	3,300.114	4	825.028	7.26	.001
Error (between)	10,789.230	95	113.571		
Within Subjects	3,770.400	900			
Between Trials	1,330.064	9	147.784	57.54	.001
Trials × Groups interaction	243.466	36	6.763	2.63	.001
Error (within)	2,196.294	855	2,568		

Grand means for the five groups over trials 5-14

1	2	3	4	5
13.31	10.38	9.64	8.45	8.30

which for 38 df is significant at the .01 level. The grand means for trials 5-14 are given in Table 2.

Motor Task: Errors

A plot of the means of number of errors for the five groups on the 30 Discrimeter trials is presented in Figure 3. Group 1, with the fewest errors on the initial trials, was far superior in performance to the other groups. Further, the performance of Group 2 is now clearly differentiated from the performances of Groups 3, 4, and 5. The error curve for Group 2, considered along with this group's correct responses curve in Figure 2, demonstrates that performance was facilitated when four of the verbal responses were concordant with

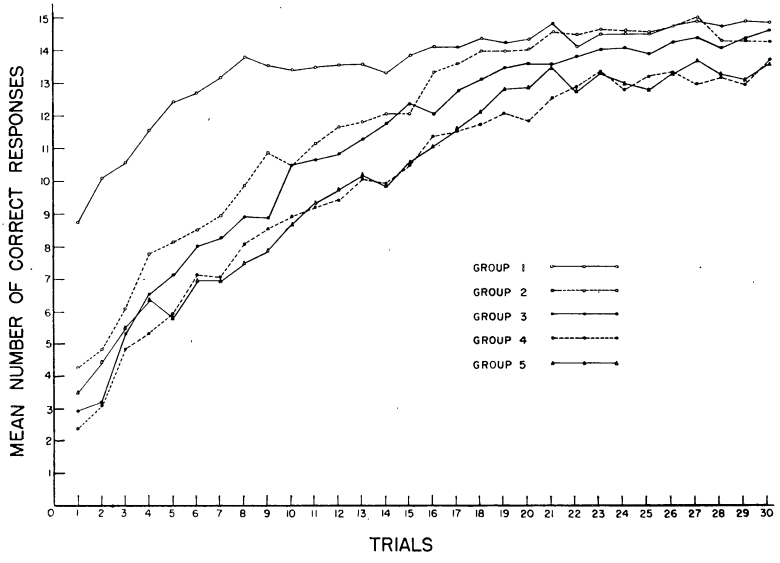

Figure 2. Plat of the means of correct responses over trials.

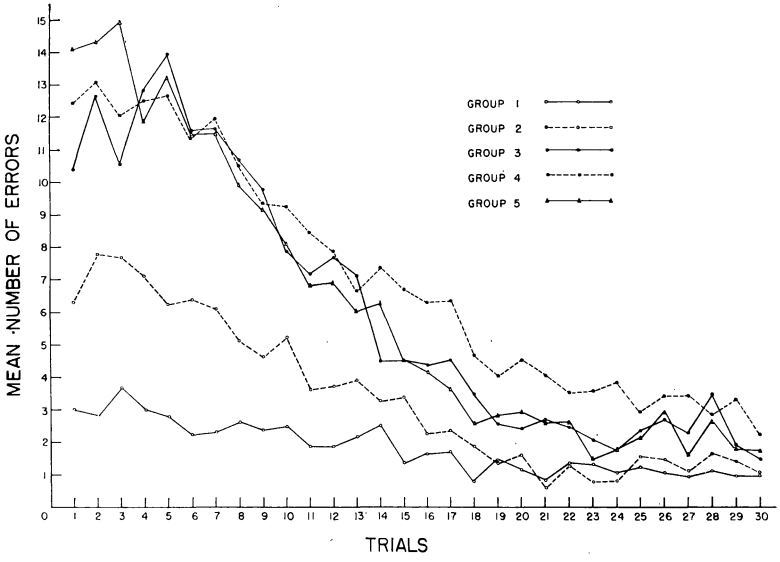

Figure 3. Plat of the means of number of errors over trials.

the motor responses. After trial 18, the curves for Groups 1 and 2 overlap and lie consistently below those of the other groups. The control group (Group 5) started by making more errors than the other groups but from trial 6 on settled to about the same error level as Group 3. Of some interest is the fact that the curve for Group 4, the group for which all of the verbal responses were incompatible with the required motor responses, lies consistently above the other four curves between trials 14 and 27. This tendency to make a greater number of errors suggests the presence of negative transfer.

The differences between the means of errors made by the five groups were evaluated by applying the Mann-Whitney U test to the data for selected trials. The U test was employed, instead of either the F or t test, because the separate distributions of scores were markedly skewed and/or differed significantly in variance. The distribution of scores for Group 1 on trial 6 fell significantly below the distributions of scores on the same trial for the other four groups, and the distribution for Group 2 fell significantly below the distributions of Groups 3, 4 and 5. Trial 6 was selected, because the performance differences on this trial were considered typical of those in the initial part of motor practice. Table 3 gives values of U, with corresponding probabilities, for comparison of the distributions of scores on trials 6, 10 and 16. Trial 10 was chosen as displaying representative differences among the group means after the larger differences had disappeared. Trial 16 was selected as showing representative differences among the group means after Group 4 showed a greater number

Table 3
Results of Mann-Whitney U Tests for Data at Selected Points in the Error Curve

Trial 6 Comparison	U	p	Trial 10 Comparison	U	p	Trial 16 Comparison	U	p
1 vs. 2	104.5	.005	1 vs. 2	116	.02	1 vs. 2	174	>.10
2 vs. 3	135.5	.05	1 vs. 3	79	.001	1 vs. 3	148	.10
2 vs. 4	129	.04	2 vs. 3	158.5	>.10	1 vs. 4	91.5	.005
2 vs. 5	96	.005	2 vs. 4	135	.10	2 vs. 4	107.5	.01
			2 vs. 5	153	>.10	4 vs. 5	147.5	.10

of errors than the others and before the early differences had disappeared altogether.

On trial 10, the performance of Group 1 was still superior to the performances of the other groups but the differences between Group 2 and Groups 3, 4 and 5 were beginning to lack statistical significance. On trial 16, Groups 1 and 2 both made significantly fewer errors than did Group 4, but the differences among Groups 1, 2, 3 and 5 were no longer statistically dependable.

Discussion

The results clearly indicated that the learning of relevant verbal responses of different degrees of concordance with required motor responses differentially affected the performance of the motor task. The facilitative effects were unmistakable when six and four of the verbal responses were compatible with the motor responses. The findings relating to six compatible responses are in complete agreement with those reported by McAllister.

A point that deserves special mention is that the present experiment differs characteristically from most previous studies of transfer in that the expected transfer is from verbal responses to motor responses. Transfer of training in human performance has been studied previously with one general type of response being used in both the original (OL) and transfer learning (TL) phases. Ss first learn to make one set of verbal responses to the stimuli and then another set of verbal responses to the same stimuli, or they first respond with one set of movements and then with another set of movements. It will be of interest to compare the results of the present investigation with those of previous studies which have followed the more usual pattern.

A representative study using motor responses in both the OL and TL phases is reported by Duncan (1), whose Ss were given practice on the Northwestern version of the Star Discrimeter. He investigated the proactive effects of practice on OL tasks which varied in their similarity to the TL task. For one of his three groups, two light-slot pairings were changed in obtaining the transfer task; for a

second group, four pairings were changed; and for a third, all six were changed. His control level was the average performance of all Ss in all groups on the initial task. All groups performed the second task at a level above that of the control, the group with the least change doing best and the one with complete change doing poorest. The superiority of the three experimental groups over the control level persisted over 60 trials, while the differences among the three groups persisted over 30 trials.

Except for the type of responses learned in the OL phase, groups 2, 3 and 4 of the present study practiced under the same conditions as the three groups in Duncan's study. With respect to number of correct responses the results are similar except that the differences between groups obtained by Duncan were statistically significant. With respect to the error count groups 3 and 4 of the present study overlapped for some of the trials, while the corresponding groups in Duncan's study performed at clearly different levels throughout. Duncan does not report a statistical analysis of his error data.

An important difference in the results of the two studies is that Duncan's control curve was relatively lower than the curve for the control group in this study. The probable reason for this difference is that Duncan used the performance of his Ss on the initial task as the control. In contrast, Group 5 had as much experience with the stimuli as the experimental groups and also the same learning experience. Duncan himself points out that, because of his failure to control for learning to learn, he was unable to tell how much of the facilitation was due to transfer.

A recent example of study using verbal responses in both the OL and TL phases is reported by Porter and Duncan (4). Using verbal paired associates learning, they investigated the negative effects arising when the transfer list has the same stimulus and response words as the original list, but in which the words have been re-paired. They use the symbol A-B, A-C for the situation in which the same stimuli are used in both the OL and TL phases and entirely new responses are introduced for the TL phase. The symbol A-B, A-B_R is applied to the situation in which the same words are used throughout, but the stimulus-response pairs are re-paired for the TL phase. Their finding was that interference effects are significantly greater for the groups learning the A-B, A-B_R lists.

The groups in the present study comparable to those in the Porter and Duncan experiment are 4 and 5. These are the complete reversal and control groups, which may be called the A-B, A-C and A-B, A-B_R groups, respectively. After the first few trials, the error data for Groups 4 and 5 tend to agree with the Porter and Duncan results. The correct responses count, however, shows no difference

between Groups 4 and 5. The fact that the differences are not as pronounced as in the Porter and Duncan study might be explained by the failure of the experimenter to tell Group 5 of the analogy between the response slots and the even-numbered hours on the face of a clock. It has been empirically demonstrated—Price and Lewis (5) for example—that response availability, having a name for a response, greatly facilitates learning. Group 5 may well have been at a disadvantage with respect to the other groups in that possibility of a clock analogue was not pointed out to them.

Summary

Five groups of 20 Ss each learned verbal responses to six colors of light as a pretraining task for practice on a perceptual-motor task, provided by the Star Discrimeter. One group, the control, learned irrelevant responses to the motor stimuli, while four experimental groups learned responses which were relevant but which varied in degree of concordance with the motor responses. The results indicate that, in comparison with the control group, when more than two of the verbal responses are incompatible with the motor responses the net transfer effect is zero. When two or fewer of the verbal responses are incompatible, facilitation results.

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