Subject strategies and interference in a discrete motor task

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Three groups of Ss were trained to use different cues in learning a simple motor task. All Ss then made three series of test movements, each series including an original movement, an interpolated movement, and recall and relearning of the original movement. The degree to which different kinds of interpolated movements interfered with relearning was dependent on the cues used by S in learning the movement. Group differences in response to the training trials and in retention were also discussed.

Extending the laws of verbal learning to the acquisition of motor skills has proved to be a difficult and perhaps fruitless task. When classical verbal interference paradigms are applied to motor tasks, relearning and long-term memory seem to be only slightly affected by interference (Lewis, McAllister, & Adams, 1951; McAllister & Lewis, 1951; Lewis, Smith, & McAllister, 1952; Barch, 1953; Barch & Lewis, 1954; Lewis & Miles, 1956). Short-term memory for motor tasks (STMM) is also remarkably unaffected by interpolated tasks (Posner, 1966; Posner & Konick, 1966).

Because little is known about what cues are attended to and stored in the process of motor learning, it is difficult to specify the similarity of various motor movements. If similarity of tasks is an important variable in motor interference, as it is in verbal interference (Osgood, 1949), then the failure of interpolated tasks to produce interference in motor learning might be due to the particular interpolated tasks that have been used. As long as there is no rational basis on which to specify the similarity or dissimilarity of two tasks, it is difficult to know whether or not those tasks should be expected to interfere with each other.

The purpose of this research was to analyze the cues actually used by Ss in learning a simple line-drawing task, to specify movements for which these cues were similar or dissimilar, and, finally, to study the interference generated by interpolated tasks that were either similar or dissimilar to the original learning tasks.

Questionnaires from pilot studies indicated that some Ss learned to reproduce the line-drawing movements by learning the *position* of their hands at the end of the movement. These Ss often referred to the angle formed by the arm and body at the end of the movement, or to the "feel" of their hands as being the cues they tried to recall in duplicating the movement.

Other Ss learned the *distance* moved. They reported counting rhythmically while moving at a constant rate of speed, judging the distance by the number of counts required to complete the movement. A few Ss reported using both position and distance cues in learning this simple motor task.

In the present study, Ss were trained to use either distance or position cues in learning a series of movements of various lengths and positions. All Ss were then given a series of tests in which they practiced one movement (OL), then practiced an interpolated movement (IL), and, finally, recalled and relearned the original movement (RL). The interpolated movements differed from the original movements in *either* distance (length) or position. It was predicted that Ss trained to use distance cues would make larger errors in recall and relearning when the interpolated movement was of a different length than the original movement and that the position learners would make larger errors when the interpolated movement had a different final position from that of the original movement. These predictions can be expressed as an interaction between the type of IL task and the type of strategy used by the Ss.

APPARATUS

The apparatus was a modification of that used by Montague & Hillix (1968). A meter stick was mounted 2 in. above a table; attached to the meter stick was a free-moving slide with a knob for S to grasp. When S was asked to learn a specific movement, stops were placed on the stick to restrict the length and position of the movement. Stops were removed when S was asked to recall a movement. All Ss were blindfolded.

PROCEDURE

Three groups of Ss were instructed and trained to use different strategies in learning a series of 31 movements. After this pretraining, all Ss were given

the same three test series, to determine whether the different strategies caused different tasks to be interfering for the three groups.

Both the instructions and the method of determining errors on the three pretraining trials were different for the three strategy groups. Specifically, Ss in the position strategy group were instructed to duplicate the final position of the stop in recalling the movements in the pretraining series, and their errors were reported as a function of how closely they duplicated that position. The distance group was instructed to duplicate the length of the movements in the pretraining series, and their errors were reported as a function of how closely they duplicated the lengths of those movements. The control group was simply instructed to duplicate the movement and was scored accordingly. The movements for each group were selected in such a way that the position and distance groups could minimize their errors only by using the cues that they were instructed to use, while the control group could minimize errors by using either distance or position cues. All Ss received verbal knowledge of results (KR) after each recall trial, and the intertrial interval was 10 sec. There was also a 10-sec interval between each pretraining movement and the test for recall of that movement. When the 31 pretraining trials had been completed, all Ss had a 5-min rest period, during which the test instructions were read. These instructions were the same for all Ss and were neutral with regard to the cues that were to be used in learning the movements.

All Ss completed the same three series of test movements. Each test series consisted of three practice trials and recall tests on an original movement (OL) with verbal KR after each trial, three practice trials and recall tests on an interpolated movement (IL) with verbal KR after each trial, a single test of recall for the OL movement with no verbal KR, three relearning trials and recall tests (RL) without verbal KR, and two relearning trials and recall tests with verbal KR. The data obtained for each S were: (1) a single recall score on each of the three test series, (2) three scores for recall of the OL movement during relearning without KR on each of the three test series, (3) two scores for recall of the OL movement during relearning with KR on each of the three test series. The three test series were distinguished by their IL tasks. On one test series, the position of the IL movement was the same as the OL movement, but the lengths of the two movements were different. On another test series, the distance moved in IL

Fig. 1. Mean absolute errors for three strategy groups on the pretraining trials.

and OL was the same, but the positions of the two movements were different. In the third test series, the IL task was a 2-min rest period. Each trial within a series was followed by a 10-sec interval, and each test series was followed by a 2-min rest period.

When all test series had been completed, Ss were asked to complete a questionnaire concerning their methods of learning the movements and their theories concerning the purpose of the experiment. A blind procedure was used to classify the Ss on the basis of their reported strategies after all Ss had been tested. The questionnaires were later matched by number to the data sheets so that the data could be organized according to the strategies that they were instructed to use.

EXPERIMENTAL DESIGN

The design of the experiment may be summarized as a three-factor ANOVA, with two between-Ss variables and one within-Ss variable. Twenty-four Ss were assigned randomly to each of the three strategy groups—position strategy, distance strategy, and control strategy. The

other between-Ss variable was the order in which the three test series were presented. Three different orders were used, with each order assigned randomly to one-third of the Ss in each strategy group. The within-Ss variable was the type of test series, with all three test series presented to all Ss.

SUBJECTS

The Ss were 72 undergraduates at the University of Illinois. Although all Ss had served in other experiments, none had participated in any other experiments involving the learning of motor responses.

RESULTS

Pretraining Trials

Because movements of various lengths and positions were used in the pretraining series, it was not possible to compare error scores on all 31 trials. However, Trials 1, 11, 21, and 31 involved identical movements and offer some information about the effects of practice. A repeated measures ANOVA on the error scores of the three strategy groups revealed a significant effect of strategy [$F(2,69) = 7.5, p < .01$]. The position group

made larger errors than did the other strategy groups, as shown in Fig. 1.

The effect of trials was not significant, indicating that practice produced no observable change in accuracy. Only the position learners showed significant improvement from the first trial to the last [$t(22) = 2.7, p < .01$].

Assigned Strategies

ANOVAs with strategy and order of test series as between-Ss factors and type of test series as the within-Ss factor were performed on the error scores for recall, relearning without verbal KR, and relearning with KR. These analyses revealed no significant main effects or interactions in the data for recall and relearning with verbal KR.

However, the predicted interaction between strategy and type of test series was significant in the data for relearning without verbal KR, with $F(4,126) = 2.7, p < .05$. The mean absolute error scores for relearning without KR are shown in Table 1 and reveal the source of the interaction: the position learners made smaller errors when the position of the IL movement was the same as the OL movement, but the lengths of the two movements were different; the distance group made larger errors on the same series. When the lengths of the two movements were identical and the positions were varied, the distance learners made smaller errors than did the position learners. The main effect of strategy was also significant [$F(2,63) = 3.5, p < .05$], indicating that the three strategy groups performed at different levels of accuracy. The distance group performed least accurately and the control group performed most accurately.

Reported Strategies

Because all Ss were asked to describe their strategies on the questionnaires, it was possible to reorganize the data according to the strategies that the Ss reported that they had used, including 22 Ss that had been assigned to the position strategy group, 4 Ss that had been assigned to the distance strategy group, and 7 Ss that had been assigned to the control group. The 28 Ss categorized as distance learners

Table 1
Mean Absolute Errors on Relearning Without KR for the Assigned and Reported Strategy Groups on Three Types of Test Series

Test Series	Assigned Strategies			Reported Strategies			
	Position	Distance	Control	All Ss		Control Ss	
				Position	Distance	Position	Distance
Position Varied	10.9 ± 1.32	9.4 ± .80	8.4 ± 1.04	10.2 ± 1.02	9.6 ± .76	9.2 ± .91	8.8 ± .48
Distance Varied	9.6 ± 1.06	12.7 ± 1.20	9.6 ± .70	9.2 ± .92	12.3 ± 1.00	8.6 ± .41	10.6 ± .58
Rest	8.6 ± .70	11.7 ± .96	8.1 ± .88	9.4 ± .87	10.3 ± 1.13	7.5 ± .45	9.7 ± .68

Note—Means and standard errors of means are presented in millimeters.

included 18 Ss from the distance strategy group, 1 S from the position group, and 9 Ss from the control group. The remaining 11 Ss were unclassified, either because they reported using both strategies or because their descriptions were too vague to permit assignment to either category.

Because this reorganization of the data involved placing the Ss in new groups after the experiment had been completed, the original statistical design was no longer appropriate. However, it was possible to test for the predicted interaction with a simple correlational technique. Using the mean absolute errors for relearning without KR (see Table 1), a point biserial correlation between reported strategy and performance on the test series in which position was held constant and distance was varied yields $r_{pt\ bis} = -.274$, indicating that the position learners made smaller errors on this test series than did the distance learners. To demonstrate that the predicted interaction between strategy and type of test series is present, it is only necessary to show that the association between strategy and performance on the test series where position was varied is different from the association between strategy and performance on the test series already described. In fact, the correlation between strategy and performance on the test series in which position was varied was $r_{pt\ bis} = +.058$, which falls outside the .95 confidence interval for the first correlation, where $-.410 \leq \rho \leq .136$, with $N = 61$. A similar pattern of means may be seen in the data for control Ss who reported using either a position strategy or a distance strategy (Table 1), although the small number of Ss precludes a powerful test of the predicted interaction.

As in the data for assigned strategies, the predicted interaction was not found in the recall scores or in the scores on relearning with KR when these scores were reorganized according to reported strategies.

DISCUSSION

Pretraining Trials

The results of the pretraining trials were unexpected, in that only the position learners showed improvement over trials. This result poses problems for the interpretation of the results of the three test series because the pretraining trials were intended to teach the Ss how to apply their assigned strategies and to bring the Ss to asymptotic levels of accuracy. The lack of improvement during the pretraining trials suggests that training

was not effective in achieving these goals.

Scores on Recall and Relearning

Support for the hypothesis that the strategy used by S determines what type of task will be interfering was found in the data for relearning without KR but not in the data for recall or relearning with KR. The significant effect of strategies in the data for relearning without verbal KR is of no importance to the hypothesis, but the significant interaction between strategy and type of test series suggests that Ss using different strategies respond differently on series of trials with different kinds of interpolated tasks. The failure to find this effect in the data for relearning with verbal KR confirms the result of an earlier pilot study in which interference effects disappeared when verbal KR was given.

As predicted, the control Ss made similar scores on all three test series but their errors were somewhat smaller overall than the errors for the other groups, rather than being intermediate. It should be noted, however, that the controls also performed more accurately on the pretraining trials. The series in which IL was a 2-min rest period was not an ideal control, because the Ss varied considerably in the time they spent on each trial. Thus, the rest period was longer than the other IL tasks for some Ss and shorter than the other IL tasks for other Ss. The most interesting feature of the data for this series, in which rest was substituted for the interpolated task, is that the rest period seemed to have very different effects on the two strategy groups; the position learners performed far more accurately than did the distance learners, following the rest period, suggesting a difference in the retention of the two types of cues.

It is not surprising that the data organized by reported strategies produced a pattern of means very similar to the means of the assigned strategy data, since only 5 of the 48 Ss trained to use a specific strategy reported using a strategy other than the one to which they were assigned. Although it is always dangerous to base conclusions on very small samples, it is interesting that the control Ss, who had not been trained to use any specific strategy, showed a pattern of means that was consistent with those obtained from the assigned strategy groups.

As a whole, the results offer some support for the hypothesis that interference in motor learning is not

only a function of the nature of the interfering task, but is also a function of the strategy that Ss adopt in learning the task. This view is compatible with closed loop theories of learning, such as that stated by Adams & Bray (1970), in which responses are compared to certain standards for the assessment of errors and possible alteration of the response on the basis of perceived error. It might be assumed that the different strategy groups developed different reference standards for the assessment of their errors, and that this difference in reference standards accounts for the differences in the groups' responses to the various interpolated tasks in the absence of verbal KR. Within this framework, the addition of an external reference standard (verbal KR) might be expected to minimize any differences in responses between the two groups.

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