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INTERRUPTION: ITS EFFECT UPON PERFORMANCE IN A "TROUBLESHOOTING" SITUATION*

Institute of Educational Research, Indiana University

NICHOLAS A. FATTU AND E. VICTOR MECH[1]

A. THE PROBLEM

There is, no doubt, some agreement that the process of interrupting a task constitutes an introduction of new factors in the stimulus situation. It is surprising, therefore, that so little effort has been made to determine experimentally the effects of interruption upon performance in operationally defined situations. A basic problem has grown out of this lack of systematic information.

The periodic assessment of the proficiency level of personnel with regard to performance on a particular equipment-system poses a problem not only for the armed forces but for industry as well. For example, the assessment of "troubleshooting" proficiency entails obtaining an equipment-system that the person works with on-the-job, and, under standardized conditions inserting problems or malfunctions for the man to locate.

In many instances the simulated situation will, at best, only approximate the actual one that confronts the maintenance man or troubleshooter. The physical equipment, for example, may be identical in two instances. However, in one case its location might be some intricate part of an aircraft while on the other hand, for the purpose of testing a group of mechanics, its location might be a laboratory room or a mobile unit. Clearly, in the latter case the stimulus properties might not be highly related to the situation a mechanic is actually faced with on-the-job.

It is well known that limitations of such approximations constitute a basic problem for psychologists. If the rationale of a performance test is to determine the proficiency level of a troubleshooter under standardized conditions, how, then, is this best accomplished? Various procedures with regard to accomplishing this are open to observers or examiners, as follows:

Procedure I. The subject is interrupted in the preceding task as well as in the present task in order for the examiner to obtain predetermined information.

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Procedure II. The subject is permitted to complete the preceding task as well as the present task, but is "interrupted" by the examiner after each task for the purpose of obtaining information.

Procedure III. The subject is permitted to complete the preceding task as well as the present task, the examiner never attempting to obtain any verbal information from the subject, simply recording whether the malfunction is located and in what time limit.

Clearly, Procedures I and II provide the basic information that Procedure III does, and allow, also, the examiner to obtain extra data by virtue of questioning the subject as to knowledge possessed about the equipment.

It appears plausible to postulate that since a proficiency test would require repeated trials during which a considerable amount of learning could take place, performance might, in part, well be a function of the procedure used by the examiner to obtain information.

At present, however, the evidence is anything but conclusive with regard to whether interruption, from an operational point of view, produces cues that tend to engender performance in a problem situation.

These possible cues, coupled with the additional ones that examiners might provide during the course of asking questions, could temporarily make a mechanic appear more "proficient" than actually was the case. Clearly in a functional maintenance situation the troubleshooter does not, generally, have the benefit of these examiner cues.

That experimenters in the area of learning often are likely to underestimate their rôles in the situation is known well. The responsibility involved is embodied in Melton's (8) statement:

> Stimulus response and field theories frequently engage in the same types of investigations, with similar situations, but with such conditions imposed as to maximize the applicability of their own conceptual structure or minimize the applicability by the opponent's conceptual structure.

Brogden (5) points out, also, that the experimenter must play a large and frequently uncontrolled rôle.

Boguslavsky (4) describes a situation analogous to Procedures I and II that were referred to previously. His data showed that although the differences were not sufficiently significant to warrant the rejection of the null hypothesis, the trend was in favor of completed tasks to be recalled more often than the interrupted tasks. Hays (7) however, presents evidence that completed tasks are recalled more frequently when the interpolated task is complex and that interrupted tasks are more frequently recalled when they precede simple tasks. He adds that if the two types of tasks are combined in one experiment, results in either direction, or results showing no advantage for either condition, might be found.

The problem, then, is whether requiring a troubleshooter to synthesize and verbalize information under Procedures I or II produces differential results when compared with another group not receiving an opportunity to verbalize.

B. Method

1. *Apparatus*

The apparatus in Figure 1 is called a gear-train, consisting simply of a set of gears and shafts mounted on a piece of aluminum ½ inch thick, 24 inches in length, and 20 inches in width. The gear-trains were arranged to form two series and four parallel channels, which provided for crossed information chains. Two operating controls, *A* and *B*, provided the input necessary to obtain the desired motion. The motion was transferred through the gear-trains and as an end result closed a switch that caused a series

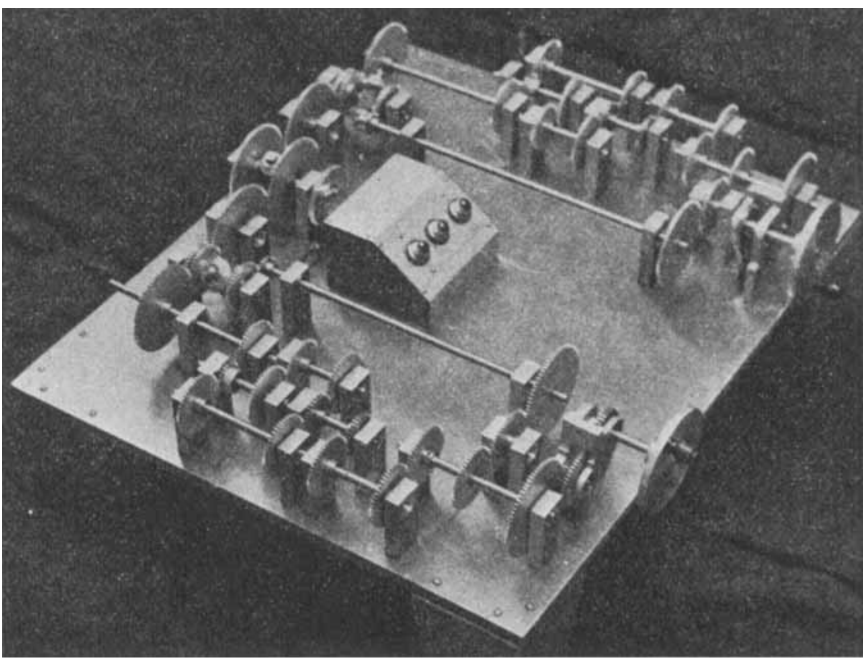

FIGURE 1
The Gear-Train Apparatus

of red lights to illuminate the control panel. The red lights would illuminate only if the equipment were working properly and Control *A* was turned 13 times and Control *B*, 12 times. When the appropriate number of turns was made and the expected end result (control panel lighting up) did not occur, this indicated to *S* that there was a "malfunction" in the gear-train.

2. *Malfunctions*

For the purposes of this experiment only three classes of "malfunctions" were utilized: (*a*) a gear not meshing, such as a distance between gears, (*b*) a slipping gear due to a set screw having been removed, (*c*) a damaged gear tooth. Each *S* received one malfunction from each class on the pre-test and one malfunction from each class on the post-test, making six malfunctions that each *S* was required to locate. *S*s were presented malfunctions in a random order, and, in addition, the location of each of six malfunctions on the gear-train was selected at random.

3. *Procedure*

The different conditions for the three groups are described in Table 1. However, certain training factors were common to all experimental groups.

*S*s were run individually, and immediately upon entering the laboratory for the first time, *E* gave *S* the Standard Operating Procedure (hereafter referred to as *SOP*) for the apparatus. The *SOP* simply consisted of turning the control handle *A*, 13 turns and control handle *B*, 12 turns, and if the red lights on the control panel did not light up, this indicated to *S* that something was wrong with the gear-train and the task was to "trouble-shoot" the equipment.

After the *SOP* orientation, *S* was given three malfunctions or problems to locate. Each problem was given singly, *S* being placed in an adjoining room while each new malfunction was being inserted by *E*.

After *S* had performed on the first three problems which were given to determine initial levels of ability, a tape recorded "basic knowledge" lecture lasting 10 minutes was given. Integrated with the lecture was a series of slides projected on a screen with a 35 mm. camera. The rationale of the lecture was to convey the basic nomenclature of the gear-train. Included were the concept of transfer of motion, function of gears, bearings, and shafts. *S*s received the lecture individually, which was played twice.

Up to this point, conditions were the same for all *S*s. They had all received the *SOP*, three initial problems, and a tape recorded basic knowledge lecture, played twice.

TABLE 1

SUMMARY OF EXPERIMENTAL PROCEDURES

Group	Pre-test	Training	Test conditions
I. Interrupted during troubleshooting.	All *S*s were given the Standard Operating Procedure and received three initial problems on the gear train.	All *S*s received a tape recorded basic knowledge lecture on transfer of motion, gears and shafts, and bearings.	Given three problems. Immediately after completing the *SOP* for each defect, *S* was required to indicate in which part of the equipment the defect was located.
II. Interrupted after defect was located.			Given three problems. After a decision was reached as to the location of the defect *S* was required to verbalize how the decision was reached in terms of information received from the equipment.
III. Control			Given three problems.

In the post-test, three malfunctions also were given to each *S* and the following procedure was used with the experimental groups:

Group I. As soon as the *S*s in this group had completed the *SOP* and the control panel did not illuminate, indicating to *S* that the apparatus was defective, *E* would interrupt with the following statement: "On the basis of the information you have received thus far from the apparatus, and without manipulating the controls for the moment, show me or tell me the area where you think the defect may be located."

Group II. When *S* had completed the *SOP* and searched for the malfunction and made a *decision* with regard to location of the malfunction, *E* would say: "Tell me how you decided that the defect is there. Try to tell me how you made this decision in terms of the checks you made and things noticed or information gotten from the equipment."

Group III was simply given three malfunctions to locate, and was not interrupted during the trouble-shooting process or after it.

*S*s were allowed no more than 15 minutes to locate each defect either on pre-test or test conditions. No knowledge of results was given to any *S*.

4. *Subjects*

The *S*s were 27 females enrolled in an educational psychology course in the School of Education at Indiana University. Three groups of nine *S*s each were used in the experiment. Assignment of the 27 *S*s to each of the three groups was done from a table of random numbers. Participation in the experiment was required in order to eliminate the bias often found by asking for volunteers.

C. Results and Discussion

Figure 2 shows the number of *S*s in the three groups that correctly located each malfunction under initial and test conditions. Clearly, there were several inversions for the groups on the pre-test malfunctions, while under test conditions performance appeared more stable with respect to maintaining rank position.

To test whether statistically significant gains had been made by any group it was decided to take the difference between frequency of defects correctly located on the initial and test conditions. Theoretically, this procedure would provide seven number possibilities ranging from +3 to —3, permitting the use of a simple analysis of variance.

Prior to applying the analysis of variance, Bartlett's χ^2 test (2) was utilized to test the homogeneity of variance of defects located. Since the χ^2 value

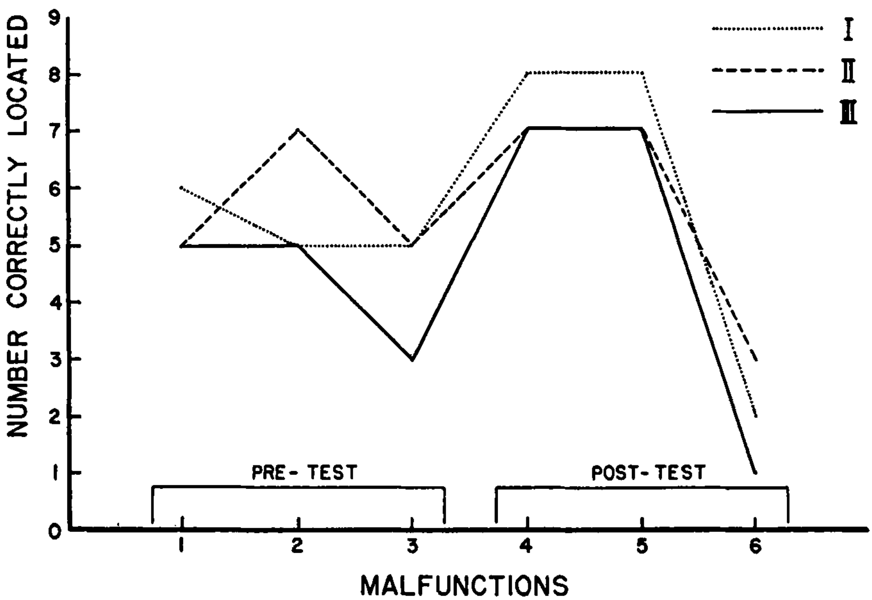

FIGURE 2
FREQUENCY OF CORRECTLY LOCATING EACH OF SIX MALFUNCTIONS FOR THREE GROUPS OF *S*s

of 2.15 did not reach the 5 per cent level ($df = 2$), the hypothesis of no differences among group variances could not be rejected.

The analysis of variance performed on the difference scores is presented in Table 2.

The obtained F value of 8.75 for 2 and 24 degrees of freedom falls far short of the value of 19.45 required for significance at the 5 per cent level.

TABLE 2
ANALYSIS OF VARIANCE OF DIFFERENCE SCORES

Source of variation	*df*	Mean square	*F*
Between groups	2	.148	8.75
Within groups	24	1.296	

Figure 3 shows the time in minutes required for the groups to reach a decision with respect to where the malfunction was located. Although the "interruptions" did not exert a differential effect, causing any one group to locate correctly more defects, it was deemed necessary to test for differences with regard to time taken to reach a decision as to the location of the defect.

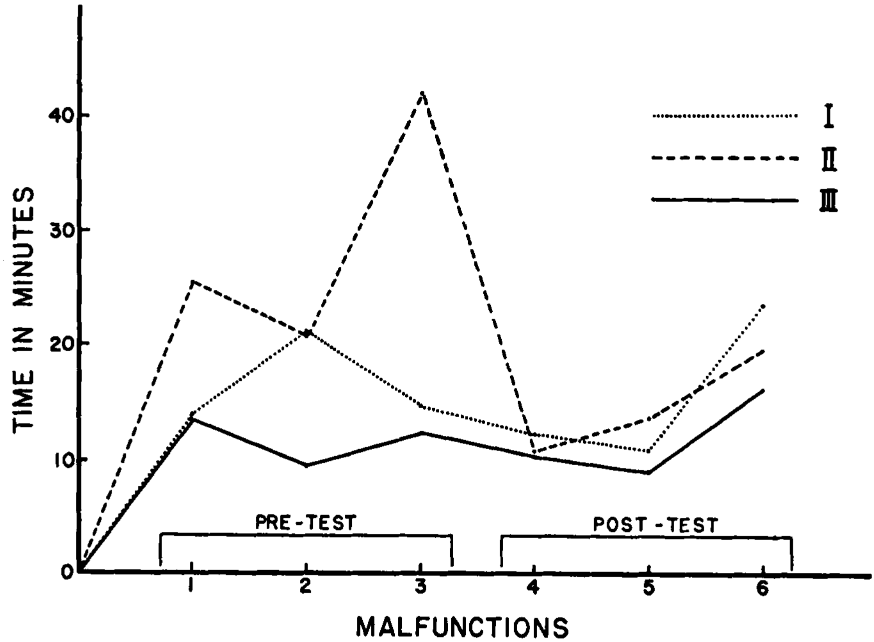

FIGURE 3
TIME REQUIRED FOR THREE GROUPS OF *S*s TO REACH A DECISION AS TO THE LOCATION OF EACH OF SIX MALFUNCTIONS

In order to reduce the heterogeneity of variance and correct somewhat for a skewed distribution, it was decided to apply a square root transformation to the time measures as recommended by Bartlett (1). An analysis of covariance, shown in Table 3, was carried out between the transformed pre-test and post-test total time measures.

The F of 0.00 is not significant, indicating that the means of the groups on the post-test time measures can be accounted for by differences in mean level of initial ability as measured in the pre-test trials. In effect, the experimental operation of interruptions, one group after the *SOP,* and another after they had completed one problem, and before they were given another, appears to produce no differential results in time taken to decide the location of a defect.

TABLE 3

ANALYSIS OF COVARIANCE OF THE $\sqrt{X}$ TRANSFORMED SCORES FOR TIME TO REACH A DECISION AS TO THE LOCATION OF SIX "MALFUNCTIONS"

Source of variation	Sum of squares of errors of estimate	*df*	Mean square	*F*
Total	13.1	23*		
Within groups	13.1	21*	.62	
Adjusted means	0.0	2	0.00	0.00

*Two degrees of freedom are lost since two missing time scores were estimated from the remaining data. A formula recommended by Cochran and Cox (6, p. 99) was employed to estimate the missing data.

Since the experiment described herein can be more correctly classed as one requiring problem-solving ability rather than one requiring recall of specific materials previously learned, direct comparisons with the data of others is not feasible.

However, certain general aspects of this experiment may be compared with other experiments dealing with the effects of interruption and completion on recall.

In a theoretical article Boguslavsky used a procedure in which the interruption of a task is simultaneous with the presentation of a new task, but the subject fails to respond to the new task immediately. This situation, he points out, is likely to occur when the experimenter gives oral instructions for a new task, at the same time that the original task was interrupted. Supposedly a change from visual to auditory stimulation would cause a change in postural set and receptor orientation.

In the present situation some *S*s were orally instructed to stop working on the gear-train after the *SOP* was completed and required to verbalize information gained up to that point, while another group was allowed to complete each problem before being required to verbalize the necessary information. Interestingly enough, also using oral instructions, Boguslavsky and Guthrie (3) found no statistically significant differences between two groups in recall, one of which was permitted to complete each task while the other was interrupted during each task.

The results obtained from the present experiment are similar to those reported by Boguslavsky and Guthrie. They found no significant differences in effects between subjects permitted to complete each problem and those who were interrupted while working on each problem. Similarly, for the operations employed in this experiment, no differences were apparent between the three groups for number of malfunctions solved or time to reach a decision.

The results, however, should be reviewed as provocative of further basic experimentation. Evaluating the trouble shooting proficiency level of a maintenance man often entails interruption and, consequently, the asking of questions while in the actual process of trouble shooting.

Although for the equipment, task, and procedure used in the experiment being reported, no differential effects were found, one should be cautious in assuming that these interruptions do not necessarily have effects.

There are several explanations with respect to the conditions necessary for interruption to have a differential effect. For example, the results obtained by Hays indicate that if simple and complex tasks are *combined* in one experiment, results in either direction might be found.

Admittedly, this was the case with the gear-train malfunctions. The task of locating the defect in which slippage was caused due to the removal of a set screw was clearly more complex than locating two gears separated, or a broken gear tooth.

In terms of the evidence presented here, it is to be concluded, then, that no advantage exists for "schedules" of interruption when problems or malfunctions of varying complexity are combined.

D. Summary

Twenty-seven female *S*s participated in an experiment on the effects of interruption in a trouble-shooting situation.

Certain training factors were common to the three groups. All *S*s received thorough indoctrination in the Standard Operating Procedure for a gear-train apparatus, after which each *S* was given three problems or defects to locate in the equipment. This procedure was used to obtain a pre-test measure of "trouble shooting" ability on the gear-train. After the initial measures each *S* received a 10-minute basic knowledge lecture that was played twice. The lecture discussed the nomenclature and functioning of the gear-train. Finally, under test conditions each *S* was given three gear-train malfunctions to locate.

In addition, however, one group was interrupted immediately upon completion of the *SOP* and required to verbalize where the defect was thought to be located. This group was also asked what information was obtained from the *SOP* that helped *S* to arrive at a decision. After *S* had given the required information the instructions were to continue searching for the defect until a definite decision could be reached. There was, however, a 15-minute time limit on each defect for all *S*s.

Another group was allowed to complete each task, and then, *S*s were required to verbalize how they had located the defect, what information was obtained from the equipment, and what checks were made. The third group was allowed to complete each task without being questioned by the experimenter.

No differential effects in troubleshooting performance were found that could be attributed to interruption or completion. These data suggest that if simple and complex tasks are combined, results showing no advantage for either condition will be found.

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Institute of Educational Research
Indiana University
Bloomington, Indiana