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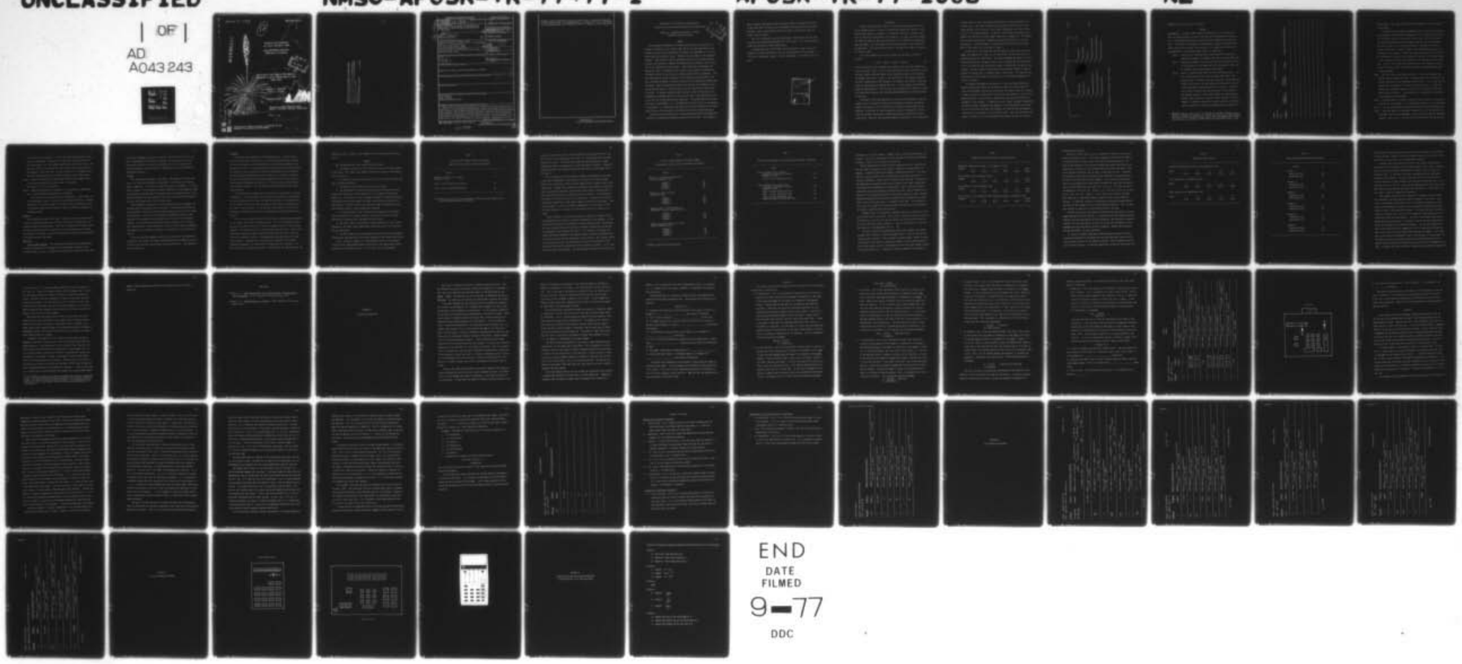

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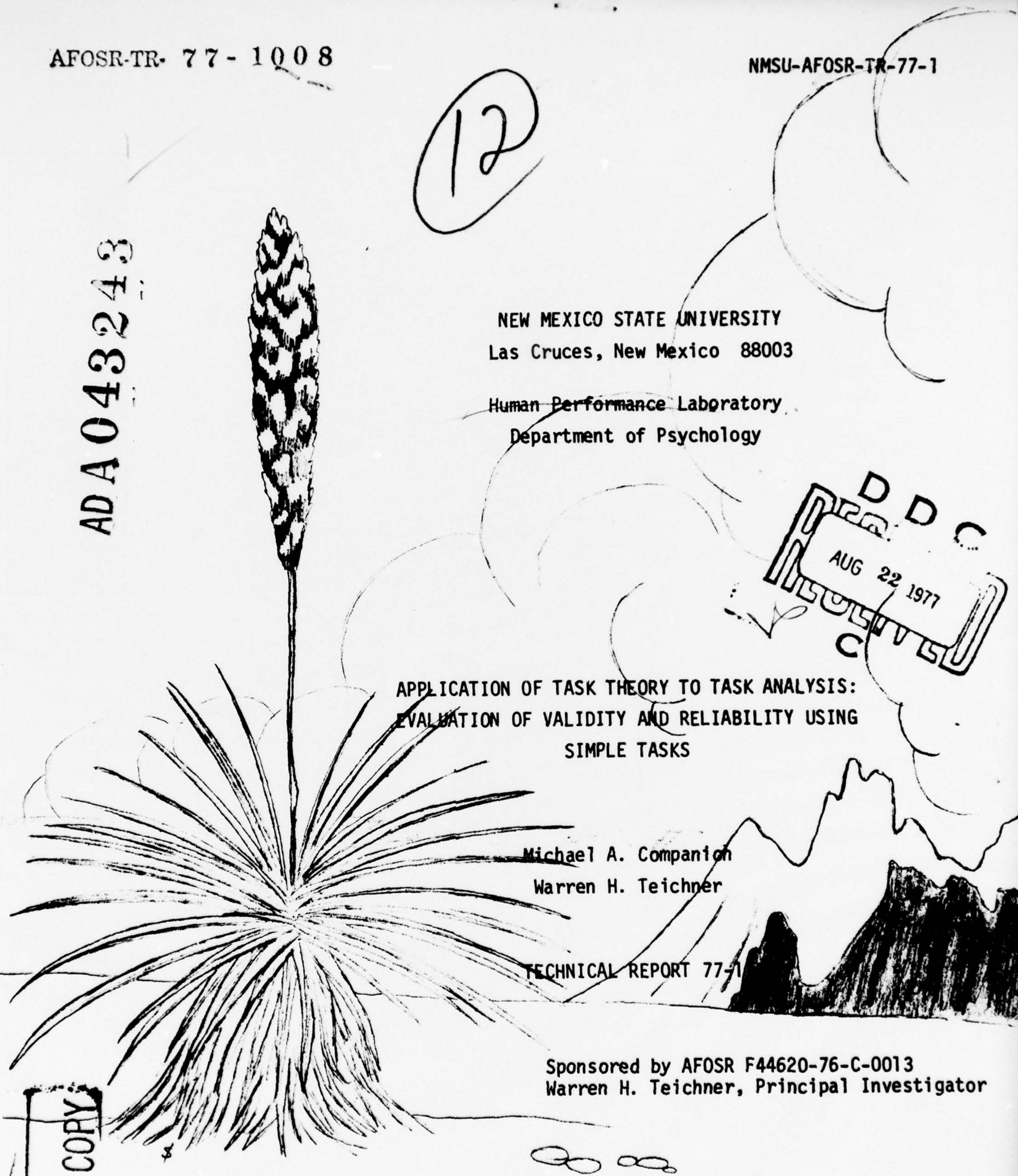

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APPLICATION OF TASK THEORY TO TASK ANALYSIS: EVALUATION OF VALIDITY AND RELIABILITY USING SIMPLE TASKS

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The research to date has provided a first evaluation of the validity and reliability of a task analysis performed with respect to Teichner's theoretical task taxonomy, and an instructional procedure for training individuals to perform the analysis. Specifically, problems performed on desk and pocket calculators were developed to represent selected theoretical tasks. It is concluded that operational task descriptions or task analysis can be translated correctly into the tasks of the theory by minimally trained observers. Reliability was high

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410 343

enough to allow a substantial level of validity and to extend the evaluation to more complex tasks. The establishment of a formal first set of procedures for training personnel was established, which are subject to later improvement.

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Application of Task Theory to Task Analysis:
Evaluation of Validity and Reliability Using Simple Tasks

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Summary

An experiment was conducted to evaluate the validity and reliability of Teichner's theoretical task concepts when applied to simple operational tasks. Problems performed on desk and pocket calculators were developed so as to represent selected theoretical tasks. Subjects were instructed in the theoretical concepts, then provided a partial operational analysis of the task problems, and were then required to complete the operational task analysis, and to transform it to a theoretical task analysis. Using the built-in operational and theoretical steps as references, the validity of the subject's procedures was evaluated in terms of how closely his analyses agreed with the references. The mean percentage of correct responses for the theoretical analyses was 81 percent; the mean percentage of correct responses for the operational analyses was 88 percent. When the theoretical analysis was adjusted to accomodate errors in the operational analysis, the percentage of correct theoretical responses was 88 percent. It appears, therefore, that with very little training people can comprehend the concepts and be at least as proficient in the theoretical analysis as they are in describing actual operations. Considering that and the general level of performance, it is concluded that the practicality of the approach is supported, i.e., operational task descriptions or task analyses can be translated correctly into the tasks of the theory by minimally trained observers.

Estimates of the reliability of the procedures, both within and between the 10 subjects, provided only moderate correlation coefficients. This suggests a

need to improve some aspect of the training in order to increase reliability. On the other hand, reliability was high enough to allow the level of validity observed. Thus, it would appear that an increase in reliability should increase validity further.

All in all the results are very encouraging. They support the idea that the theory can be applied meaningfully to "real" tasks. It is now important to extend the evaluation to more complex tasks.

A second objective of this effort was to establish a formal set of procedures for training personnel in the use of the theoretical task concepts. A first set of procedures, subject to later improvement, is provided in this report.

Introduction

Teichner (1974) proposed a theory of tasks which postulated that a task can be conceptualized as a series of translations between the input of a stimulus and the output of a response. A translation represents a change in the form or code of the information in the stimulus. This paper outlines a method for using the theory to describe actual tasks, and it describes a study based upon the method. Only the aspects of the theory pertinent to the method will be summarized. For a detailed discussion of the theory the reader is directed to Teichner (1974).

In its most complex form a task, according to the theory, can be expressed:

$$P = f_1(a) + f_2(S\text{-}S) + f_3(S\text{-}R) + f_4(R\text{-}ex) \qquad (1)$$

In this expression $f_1(a)$ represents the stimulus acquisition and encoding portion of the task, $f_2(S\text{-}S)$ is one or more translations of the information in the original stimulus where the output of the translation serves as the stimulus for another translation, $f_3(S\text{-}R)$ is the translation of the stimulus code into the code corresponding to the response to be executed, and $f_4(R\text{-}ex)$ is the execution of the response to complete the task. P is any measure of performance. Since the description of a task can only vary according to the types of S-S and S-R translations required, the following method concentrates on these portions of the task.

The general distinction between an S-S and an S-R translation is that the output of an S-S translation serves as the stimulus for another translation, whereas the output of an S-R translation is the code for the response to be executed. Within each of these two general classes of translations, distinctions can be made concerning the input-output mapping relationship for each translation. There are three possible mapping relationships: (1) conservation-an equal number of input and output alternatives or a one-to-one mapping, 2) classification - more input alternatives than output alternatives or a many-to-few mapping, and 3) creation - more output alternatives than input alternatives or a few-to-many mapping. In addition a distinction can be made as to whether the translation involves symbol reduction or compression. The combination of these characteristics produces twelve distinct types of S-S and S-R translations. The twelve types of translations and their relation to other parts of the theory are illustrated in Figure 1.

In describing a task using the Teichner theory of tasks there can be any number and combination of types of S-S translations, but only one of the six possible types of S-R translations. The key to employing the theory is to consider each translation separately rather than as combinations of translations. In this way there are only twelve basic types of translations that must be considered. The basic number of translations can be further reduced to seven by considering compression as a separate type of translation. This approach, distinguishing only seven types of translations, will be adopted throughout the rest of this paper.

The present experiment was designed as a first step toward determining whether inexperienced people can be trained to apply the Teichner theory of tasks with reasonable validity and reliability, and without extensive training. In order to achieve a high level of face validity and hopefully a high level of generalizability, it was desired to conduct the study using real tasks or assignments on real systems. To achieve this goal, simple arithmetic computations on pocket and desk calculators were employed. The basic approach to the question of the validity with which the concepts can be applied was approached by "building in" task concepts in the calculator tasks. Thus, the validity of any subject's analysis of a task was defined as the degree to which his analysis

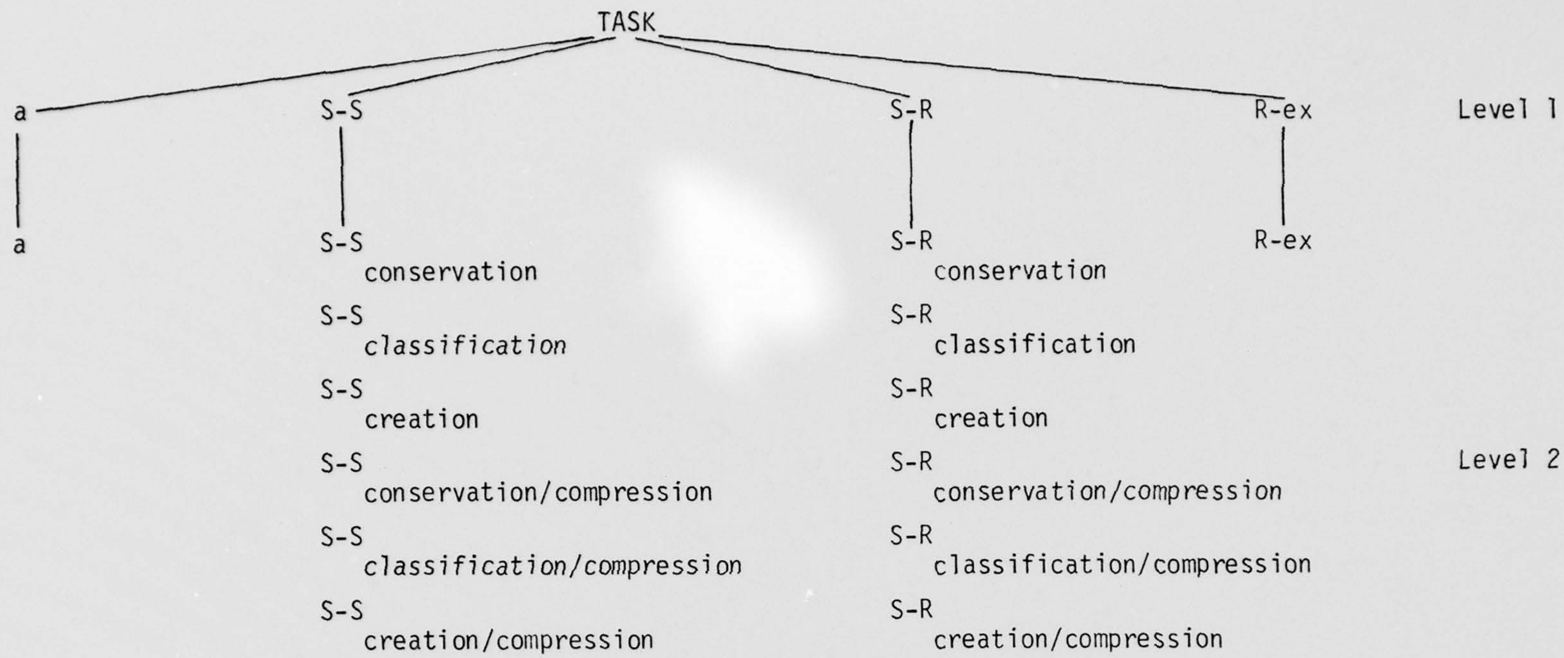

Figure 1. Components of the Teichner theory of tasks.

produced the originally built-in concepts.

Methods

Task Analysis. In order to move toward standardization in the analysis of tasks, we present below an outline of the steps we have employed for that purpose. This method provide both an operational and theoretical task description.[1] The outline is provided as an experimenter's guide; different instructional material was provided to the subjects. An inexperienced analyst with no opportunity to ask questions would do well to study both.

Step 1. Acquire a basic understanding of the concepts and terms which comprise the theory. See comment with Step 9 for more about this.

Step 2. Formulate an example or two for each type of translation to clarify the concepts of the theory and to provide yourself with a set of reference translations which you understand.

Step 3. Devise a standard answer sheet for use in describing tasks. Figure 2 illustrates the basic form of answer sheet used in the present study. The sheet should have spaces for listing what the system for the task is and any additional description of the situation which might affect the analysis of the task. It should have a space to record the state of practice of the subject if the detailed aspects of the Teichner theory are to be employed. Finally, there should be a space to specify the task to be performed. It should be noted that in most cases what is labelled a task on this sheet is really an assignment which is made up of

1 The basic analytic steps were first developed by Benjamin Fairbank and applied in a theoretical analysis of a complex task used by the Human Engineering Division, USAF, Wright-Patterson AFB in their experimental DAIS system. This analysis was presented in AFOSR F44620-76-C-0013 Annual Report, 1976.

System:

Practice:

Task:

Additional Description:

Response	Number of Alternatives	Response Information	Stimulus	Nature of Translation Required

Figure 2. Suggested layout for analysis sheet.

several steps. The steps in this case are equivalent to a task in terms of the theory.

In addition to this heading information, which outlines the situation to be analyzed, there should be allowance for five columns (two are optional) in which to carry out the analysis of the task. The first column is to record the responses needed to complete each task in the assignment. The second column is for listing the number of alternatives for the response to each task. The third column is for tabulating the amount of information in the response. (These two columns only need to be included if an informational analysis fo the situation is desired.) The fourth column is for listing the stimulus which indicates that the next task may be begun. (This is not usually the stimulus for the first translation of the task.) The final column is used for the actual description of the tasks in the assignment.

Step 4. The first step in the actual analysis is to list the responses that must be made to complete each task. Reference should still be made to the original statement of the assignment during analysis. This column only indicates what the output of the final translation (S-R) is. It does not provide any information concerning the form of the stimulus at the beginning of the translations. That information is contained only in the original statement of the assignment.

Step 5. List the number of response alternatives and the amount of information contained in the response, if an informational analysis is to be performed.

Step 6. List the stimulus which indicates that the next translation may begin.

Step 7. Under the nature of translation required, first list the function for each step or task in the assignment. (Each line on the analysis sheet represents a step or task.) The function for each task will be the stimulus for the first S-S translation. At this point the starting point for the series of translations, the function of that step, and the end point of the translations, i.e., the response identified in Step 4, are known. The only task in which the function will not be the initial stimulus for the translations is the first task. In this situation it is a command to perform the assignment which is the initial stimulus for the translations.

Step 8. Identify the operational transformations which occur between the initial stimulus and the final response code. For example, enter digit ⟶ 5 ⟶ 5 position.

Step 9. Identify the theoretical translation (S-S conservation, compression, etc.) associated with each operational translation.

The success of the last eight steps is dependent, to some extent, upon the adequacy of Step 1. The type of instructional materials, including exercises, of the type employed in the present study (see Appendix A for instructional materials) may provide a simple and effective procedure for completing Step 1.

Subjects

Ten subjects were used in the study. They were a senior psychology major, a full-time psychology laboratory assistant, a professor of psychology, and 7 graduate student psychology majors. The level of exposure to the theory before the study varied from no prior experience to classroom exposure to the terms and concepts of the theory. None of the subjects had had any actual experience in the application of the theory.

Materials

Instructional material. The instructional materials were constructed to provide the subject with an introduction to the concepts and terms of the Teichner theory of tasks. The material was presented in several sections, each of which was followed by a series of exercises or questions to test the subject's understanding of the material covered. The final portion of the instructions consisted of a step by step analysis of a task in terms of the theory followed by a practice problem. (See Appendix A for the complete instructional materials.)

Problems

Five problems were employed in the study. (See Appendix B for the problems.) All were simple arithmetic computations. The problems varied along several dimensions: 1) the form in which the task was presented, i.e., whether words or symbols, 2) the amount of response information, 3) the number and types of translations required, both in the operational and theoretical form, 4) whether the calculator for the problem was physically available for the subject to carry out the problem, and 5) the calculator used.

Three different calculators, the Texas-Instrument SR-51a, Commodore 1161, and Radio Shack EC-220, were used in the study. Three problems involved the Texas Instrument calculator, while one problem involved each of the two remaining calculators. Only the Texas Instrument and Commodore calculators were available for the subject to work on during the analysis of the associated problems. For the problem using the Radio Shack calculator only a diagrammatic representation of the keyboard was available for the subject's reference. (See Appendix C for pictures or drawings of the keyboards of the three calculators.)

On each of the four problems in which the calculator for the problem was available to the subject, the subject worked through three problems on the calculator of the same form and requiring the same translations. (See Appendix D for the exercises.)

Procedure

Each subject participated for five consecutive days. The first three days constituted the training period. On the first day the subject received the instruction manual, and was instructed to work through the material over the next three days. If any questions were encountered that the subject could not resolve, he was instructed to contact the experimenter for clarification. On the fourth day the subject was given a chance to ask questions concerning the practice problem that he had worked through during the training session. He then worked through two test problems. On the final day he worked through three more test problems. The five problems were counterbalanced for order across subjects.

On each problem the subject was provided with an answer sheet of the form in Appendix B. The answer sheet told the subject what calculator the problem was being performed on, the task or problem to be worked, the responses necessary to complete the problem, and the stimulus that signaled the beginning of each step in the assignment. It was the task of the subject to fill in the operational and theoretical forms of the translations required to perform the analysis.

The first test problem with each of the available calculators was presented to the subject along with a directed solution. That is, each keyboard action was given; the subject had only to follow the keyboard actions in the directed sequence. The subject carried out such directed activities twice. He was then given three successive problems (exercises) which were the same in kind, but different in numerical content. No computational steps were given with these three problems. Following this, he returned his attention to the original problem and analyzed it for operational and theoretical task structure. For that one of the five problems for which a calculator was not made available, the subject was given a diagram of the keyboard and carried out only the task analysis.

Results

The following measures were used to analyze the data:

1. the subject's rating on a scale from one to ten of his understanding of the theory. Only those seven subjects having prior exposure to the theory were asked to this.

2. the mean time to perform the three exercises on the four problems that had a calculator available.

3. the number of correct exercises on each test problem.

4. for the theoretical form of the translations, each translation proposed by the subject was scored against our set of standard analyses (See Appendix B). On each step of the assignment the number of consecutive correct translations and the total number of correct translations were compiled for each problem. From this analysis the cumulative number of consecutively correct and total correct on each problem were tabulated.

5. for the operational form, the translations proposed by the subject were scored against our standard analyses, and the total number of correct operational translations were tabulated for each problem.

6. the total number of consecutively correct theoretical, total correct theoretical, and total correct operational translations across all five problems was determined.

7. the total number of correct theoretical translations for each problem assuming that the operational translations proposed by the subject were correct.

Table 1 presents a summary of a correlational analysis of the subjects' ratings of their understanding before instruction of the theory against their performance in analyzing the tasks. On all three types of performance,

Table 1

Pearson Product Moment Correlations Between
Subject's Rating and Test Problem Performance[1]

Source	r
Cumulative consecutive % correct theoretical form	.47
Total % correct theoretical analysis	.62
Total % correct operational analysis	.54

[1]N=7 because only those with prior exposure to the theory were asked to rate their understanding before instruction.

cumulative consecutive correct and total correct on the theoretical form, and total correct on the operational form, there is a low-moderate positive correlation with rating. This implies that those who rated themselves as understanding the theory performed better in the experimental situation. Though all three correlations are moderately high none were significant presumably due to the small N.

Table 2 summarizes the correlational analyses of performance on the exercises against performance in the theoretical analysis of the test problems. None of the correlations, either for mean response time or number correct, were significant. However, those response time measures that showed any correlation with test problem performance indicated that those subjects that were able to work the exercises faster, did better on the test problems. The correlations for number of correct exercises is less consistent. In some cases a positive correlation existed and in some cases a negative correlation was present. From these analyses it is not clear whether understanding of the system, in this case the calculator, is necessary to the correct analysis of a task in the system.

Table 3 presents a correlational analysis of subject performance on the test problems with the amount of response information in the problems. As can be seen these analyses were performed in several different ways. The analysis was first performed using the data from all subjects against the two measures of performance on the theoretical analysis. The second set of analyses concerned the mean performance of the subjects against cumulative consecutive and total percent correct on the theoretical form of analysis, total percent correct on the operational form, and total percent correct on the theoretical form given that the subject's operational form be accepted as correct. In all cases the correlations were negative. The more response information, the poorer was

Table 2

Pearson Product Moment Correlations Between

Performance on Exercises and Test Problem Performance[1]

Source	r
Mean RT vs. Cumulative Consecutive % Correct Theoretical Form	
Problem 1	.01
Problem 2	.43
Problem 4	.04
Problem 5	-.33
Mean RT vs. Total % Correct Theoretical Form	
Problem 1	.26
Problem 2	-.40
Problem 4	-.53
Problem 5	.02
Number Correct in Exercise Data vs. Cumulative % Correct Theoretical Form	
Problem 1	.11
Problem 2	.65
Problem 4	-.09
Problem 5	-.28
Number of Correct Exercise vs. Total % Correct Theoretical Form	
Problem 1	.28
Problem 2	.60
Problem 4	.12
Problem 5	-.54

[1]Problem 3 did not have any exercises

Table 3

Pearson Product Moment Correlations Against Response Information

Source	r
Across Problems and all subjects	
cumulative consecutive % correct theoretical form	-.60
total % correct theoretical form	-.42
Across Problems for subject means	
cumulative consecutive % correct theoretical form	-.60
total % correct theoretical form	-.42
total % correct operational form	-.43
total % correct theoretical form accepting subject's operational form	-.32

performance on the test problems. However, none of the coefficients were significant. The lack of significance in this and other correlation coefficients obtained is likely to be a result of the small N.

Table 4 summarizes the percent correct computations for all problems and the four types of analyses of the subject's theoretical and operational responses. As would be expected the percent consecutively correct is less than the total percent correct, with the difference a relatively consistent 17% across the problems. Overall about 12 percent errors were made in identifying the operational translations with about 7 percent of the correct operational translations being theoretically misidentified. That is, when the subjects' operational forms were accepted as 100 percent correct, they misidentified 12 percent of the associated theoretical translations, whereas on those correctly identified operational translations the subjects only misidentified the theoretical form of the translation in 7 percent of the cases. The difference is small, but still suggests the possibility that the necessity for the theoretical analysis aided the operational analysis.

Friedman's test for nonidentical treatment effects was carried out on the data on which Table 4 was based. The cumulative consecutive percent correct on the theoretical form and total percent correct for the operational analysis were both significant among problems ($p < .05$) as was the test for total percent correct on the theoretical form ($p < .01$).

The order in which the problems were given to the subjects was counterbalanced across subjects so that each problem occurred twice in each of the possible order positions. Table 5 presents the mean percent correct for each order position for cumulative consecutive percent correct on the theoretical form, total percent correct on the theoretical form, and total percent correct on the operational form. Inspection of the data suggests little change in

Table 4

Summary of Validity Statistics (percent correct)

Cumulative consecutive correct (%) on theoretical form						
Problem	1	2	3	4	5	total
	52.91	70.00	71.54	62.66	65.63	64.54
Total correct (%) on theoretical form						
Problem	1	2	3	4	5	total
	70.83	87.22	85.38	81.50	83.12	81.61
Total correct (%) on operational form						
Problem	1	2	3	4	5	total
	77.92	88.33	90.31	90.50	91.25	88.06
Total correct (%) on theoretical form accepting subject's operational form						
Problem	1	2	3	4	5	total
	85.72	92.68	90.31	85.36	86.85	88.18

performance with practice.

The data of Table 5 were initially subjected to Friedman's test for non-identical treatment effects. The results suggested no significant difference in performance across order on any of the three performance measures. Because the performance on the different problems had already been found to be significantly different, it was suspected that there might have been an interaction between the problems and the order in which they ocurred. Therefore, the problem and order data were combined and reanalyzed as two-way analyses of variance of rank performance within subjects. These analyses showed performance on the problems to be significantly different for cumulative consecutive correct on the theoretical form, ($F(4, 25) = 5.107$, $\underline{p} < .01$, total correct on the theoretical form, $F(4, 25) = 5.928$, $\underline{p} < .01$, and total correct on the operational form, F(4, 250 = 4.468, $\underline{p} < .05$, as the earlier analyses indicated. Again there was no significant effect of order for any of the performance measures. In addition, there was no significant interaction between problems and order of the problems for any of the performance measures. Thus, the analyses provided no indication of any practice effect in the data.

The next two analyses were aimed at determining the consistency of the responses between and within subjects. To evaluate consistency between subjects, Cochran tests were performed on both the theoretical and operational responses. Cochran's test was used because it took into account the correctness of the response for every translation across all problems. Neither the theoretical nor the operational test was significant.

As a test of internal consistency, Kuder-Richardson reliability coefficients were computed for the theoretical and operational data from each problem separately, and for all the problems combined. Table 6 summarizes the results of these analyses. As would be expected the reliability coefficients for

Table 5

Summary of Order Effects

Cumulative consecutive correct (%) on theoretical form

Order	1	2	3	4	5
	58.72	63.29	68.51	67.34	62.71

Total correct (%) on theoretical form

Order	1	2	3	4	5
	76.58	85.47	83.71	82.53	79.26

Total correct (%) on operational form

Order	1	2	3	4	5
	83.48	91.05	89.04	91.63	85.05

Table 6

Kuder-Richardson Reliability Coefficients

Source	r
Overall	
Theoretical form	.90
Operational form	.79
Problem 1	
Theoretical form	.63
Operational form	.60
Problem 2	
Theoretical form	.81
Operational form	.51
Problem 3	
Theoretical form	.51
Operational form	.65
Problem 4	
Theoretical form	.74
Operational form	.51
Problem 5	
Theoretical form	.62
Operational form	.14

the individual problems were smaller due to the smaller number of translations or items involved. However, across the problems they were fairly high, .90 for the theoretical form and .79 for the operational analysis.

To evaluate the inter-subject reliability, the subjects were ranked by each kind of error separately for each problem except the first one. The mean rank of each subject was then determined for Problems 2 and 3 and then for Problems 4 and 5. A rank order correlation (Spearman) was then obtained between these two "halves" of the data based upon the two sets of mean ranks. For the consecutive correct responses, the correlation coefficient was .76; for the total correct it was .86. These are only moderately high values which suggests that the inter-subject consistency was acceptable as a first effort, but that there is room for considerable improvement.

Three subjects had had no prior theoretical knowledge; four had minimal prior knowledge, and three had had extensive exposure to the theory. Based upon this breakdown a Kruskal-Wallis test for nonidentical population distributions was performed on the mean ranks for cumulative consecutive and total percent correct in the theoretical analyses. The results were not significant. It may be concluded, then, that the prior exposure of these subjects did not appreciably affect their performance. The levels of performance observed depended upon the training given. The types of errors that were made tended to be fairly consistent across and within subjects. The two most common errors were 1) the identification of compression as an S-S conservation translation, and 2) the inclusion of extra translations that were not needed. This second type of error may be attributable in part to the design of the experiment. On the answer sheet that the subject used he was already provided with the responses that were necessary to complete the task as well as a statement of the task. It appears that after the initial reading of the problem the subject did not refer back to it. Instead the subject referred to the end responses in each step. As a result the subjects probably did not remember that a translation had been eliminated as a result of the form in which the problem was stated. Therefore, they had a tendency to reinsert a translation that had already been provided. This type of error is not as likely in a real life situation since the analyst will not be given the responses. He will have to identify them from the statement of the task and he will tend to be more conscious of the form of the task statement.

Other than these two major types of errors, most of the errors represented careless errors on the part of the subject, and in some cases the reversal of the labels of two types of translations within a problem. This latter type of error tended to appear in one problem, and then to disappear in subsequent problems. With more extensive practice in the theory this type of error should become less frequent.

In general, the subjects in this study were able to apply the theory effectively and with a relatively high level of consistency both within and between subjects. Since the amount of prior exposure to the theory did not significantly affect performance on the problems, it would appear that the instructional materials were fairly effective in conveying the concepts and terminology of the theory.[1] However, improvements in the training method which will increase reliability are needed. Otherwise, this first attempt to evaluate the reliability and validity of Teichner's (1974) task taxonomy suggests considerable promise for the method as "practical". There is now a need for a second study using more complex task systems and a large enough subject

[1]In one instance an aspect of the theory was modified to make the instructions easier. The modification dealt with the assumption of a perfect correlation between the response code and response execution. For the purpose of task description this is justifiable, since the task was being analyzed as if no errors occur.

sample to permit meaningful evaluation of the significance of correlation statistics.

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APPENDIX A

Instructional Materials

This study is designed to evaluate a method for describing tasks. With the following explanation and several examples the method will be explained to you. We are not expecting you to become experts in the application of the method. However, we would like you to try your best to understand and use the technique. The tasks you will evaluate all involve desk or pocket calculators.

It has been proposed that the processes which fall between the reception of a stimulus and the emission of a response can be thought of as one or more translations of the information in the stimulus. For our purposes information is the number of different possible alternatives in the input or output. There are two types of translations that could take place, stimulus-stimulus (S-S) translations and stimulus-response (S-R) translations. An S-S translation takes a stimulus and transforms it into some other form of stimulus code. For example, when you meet a friend you translate the image of his face to his name. You have taken a stimulus, the physical representation of the face, and translated it into another stimulus, the name of the person. Another example of an S-S translation would be reading. In this situation you are taking printed words and translating them to their meaning. If you are at a party and someone calls your name you will look around to find them. This is an example of an S-R translation, since you have translated from thestimulus of your name to the response of turning your head. In essence, anything you do will involve an S-R translation and in most cases one or more S-S translations will occur before it in order to obtain the stimulus code needed to cause the right response.

There are two other features which can be used to describe the processes occurring between the initial stimulus and the response you make. One feature is the relation between the amount of information in the input and output of the translation. In some cases the number of different possible outputs or the amount of information in the output is less than the amount of information, number of alternatives, in the input. This relationship is called classification. This is the same as the problem of sorting all the mail coming into Las Cruces by Zip Code. There are many pieces of mail but only two Zip Codes. Each piece of mail has 88001 or 88003 as its Zip Code. In this example the number of output items (mail grouped by the Zip Code) is less than the number of input items (individual pieces of mail).

The second possible relationship between the amount of information, number of alternatives, in the input and output is that they contain an equal amount of information. This is called conservation because the total amount of information does not change during the translation. An example of this relationship would be sorting ten Social Security Cards by Social Security number. Since each Social Security number is different, the ten cards must be sorted into ten piles with one card in each pile. The number of input items (Social Security Cards) is the same as the number of output items (number of piles), i.e., the amount of information has not been changed.

The third possible relationship is that there is more information, more alternatives, in the output than in the input. This relationship is called creation, since you are adding or creating information during the translation. An example of this relationship is your reaction if a child runs out in front of you, but you make several responses or outputs; a) take your foot off the gas, b) put on the brakes, and c) turn the steering wheel. You can see that there are more output items than there are input items, so we can say that information has been created.

The second feature that we can use to make our descriptions more accurate is whether the translation involves what is called compression. Compression indicates that the number of symbols used to represent the information is reduced. This is essentially the same as abbreviating a word. For example, L.C. is a compression of Las Cruces, and NMSU is a compression of New Mexico State University.

Before continuing it is necessary to make sure that you understand the concepts that have been presented so far. Please answer the following set of questions.

Question Set 1

1) Tabulating the states won by Ford and Carter in this year's election is an example of a ______________________________ input-output relationship.

2) Your initials represent a ______________________________ of your name.

3) If someone asks you for a recipe to bake a cake and you list out the ingredients and procedures, you have a ______________________________input-output relationship.

4) The translation of the word five to the symbol 5 is an example of a ______________________________ translation.

5) If on a touch-tone telephone you wanted to enter the number two, it would take a ______________________________ translation to go from 2 to pressing the 2 button.

6) The common compression of United Nations is ______________________________.

7) Dialing the seven digits of a telephone number is an example of a ______________________________ input-output relationship.

The answers and explanations of the answers to these questions appear at the end of this manual. If you missed any of the questions please reread the first section. If you still do not understand the answer to the question or any of the basic concepts please contact me. When you feel you understand this section proceed to the next section.

Section 2

If we combine the concepts discussed in the first section, we can formulate twelve types of translations.

1. S-S conservation - This is the translation from one form of a stimulus to another form of the stimulus with the amount of information in the input to the translation equal to the amount of information in the output. Example: Imagine that you have been told to subtract two numbers on a calculator. Before you can enter the subtraction operation, you must translate from the verbal command subtract to the symbol -, since this is how the subtract operation appears on the calculator. Because there is only one input item, subtract, that can lead to the output item, -, there is no change in the amount of information during the translation, i.e., information is conserved. Any time there is a one to one relationship between the number of possibilities in the input and the number of possibilities in the output, information will be conserved. This S-S conservation translation would be diagrammed

   Subtract ⇨ - ,
   S-S conservation

2. S-S classification - This is the translation from one form of a stimulus to another form of the stimulus with the amount of information in the input to the translation greater than the amount of information in the output. Example: If you are told to enter a digit into a calculator, there are ten digits that you could enter. You must translate from the stimulus of enter a digit to a particular digit. This requires translating from 10 possible input items to 1 output item. In this case the amount of information is reduced, going from many items to few, during the translation, so this is an example of an S-S classification and would be diagrammed

Enter digit ⇨ 5.
S-S classification

3. S-S creation - This is the translation from one form of a stimulus to another form of the stimulus with the amount of information in the <u>input</u> to the translation <u>less than</u> the amount of information in the <u>output</u>. Example: When you are using a calculator, the first thing you should do is clear the registers. If the calculator you are using combines the clear and clear entry functions on one key, as many calculators do, you must translate from the input of clear to clear/clear entry, i.e., the object of the S-S translations is to get the stimulus into the form needed to make the response, which in this case is the form of the stimulus as it is represented on the calculator key. The translation from clear to clear entry requires the addition of information during the translation. This translation is, therefore, an S-S creation, and it would be diagrammed

Clear ⇨ Clear/Clear Entry.
S-S creation

4. S-R conservation - This is the translation from the final form of the stimulus to the response with the amount of information in the <u>input</u> to the translation <u>equal</u> to the amount of information in the <u>output</u>. Example: If in a calculator problem, the final form of the stimulus is + (the form of the operation add as it appears on the key of the calculator), it must be translated to the response of moving your finger to the position of the + key on the calculator. Since there is only one + key on the calculator, there is a one-to-one relationship between the final form of the stimulus and the response. Because the number of inputs to the translation are equal to the number of possible outputs, this is an example of an S-R conservation translation. This translation would be diagrammed

\+ ⇨ + position.
S-R conservation

5. S-R classification - This is the translation from the final form of the stimulus to the response with the amount of information in the input to the translation is greater than the amount of information in the output. Example: If the calculator you are using combines the + and = operations on one key, one type of S-R translation that you might have to make is from the final stimulus form of +, for addition, to the $\overset{+}{=}$ position on the calculator (this would only occur later in practice, since initially you would probably have an S-S translation to $\overset{+}{=}$ from + and then an S-R conservation translation from $\overset{+}{=}$ to $\overset{+}{=}$ position). Since this key is used for both the add and equal operation, two inputs to the translation result in the same output. This translation is, therefore, an S-R classification translation, and it would be diagrammed

+ ⇨ $\overset{+}{=}$ position.
S-R classification

6. S-R creation - This is the translation from the final form of the stimulus to the response with the amount of information in the input of the translation less than the amount of information in the output. Example: If you are at a stage in practice where you deal with double digit numbers as single units, the translation of the final stimulus code of 13 to the position of the 1 key and the position of the 3 key is an S-R creation translation. This is an S-R creation because one stimulus, 13, produces two reaponses: pushing the 1 key and the 3 key. This translation would be diagrammed

13 ⇨ 1 position and 3 position
S-R creation

The final six types of translations are produced by the addition of compression to each of the first six types of translations. In order to keep the method of describing tasks simple, consider the compression operation as a separate, unique translation. In this way you only have to deal with seven types of translations.

7. Compression - This is the reduction in the number of symbols used to represent a stimulus. This is essentially the same as abbreviating. The calculator offers several examples of this operation, since it is impossible to spell out the entire name of a function on a key. Example: In the process of clearing a calculator you must compress from the stimulus code clear to C, since that is how the operation appears on the calculator. This compression is diagrammed

   Clear ⟹ C.
   compression

   It can be seen that this is simply an abbreviation of the input to the translation. If the calculator you are using has trigonometric functions and you want to take the tangent of some angle, you must compress from tangent to Tan because that is the way the function appears on the calculator. NOTE: The translation from ADD to + is <u>not</u> an example of compression. It is an S-S conservation because it involves a change in the form of the code for the operation and not simply an abbreviation.

Question Set 2

1) In using a telephone you must enter several digits. The translation from the stimulus of "enter digit" to a particulat digit (enter digit ⟹ 2) is an example of a ______________________________ translation.

2) Once you have chosen a digit to enter into the phone you need to push the corresponding button. This is an example of an _________________________ translation.

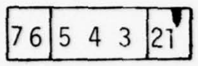
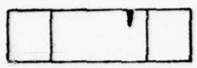
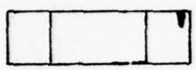
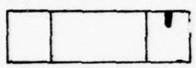
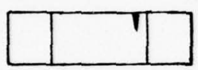
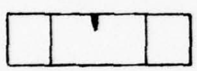
3) True or False: The translation from Divide to ÷ is an example of compression. _______________

TABLE 1

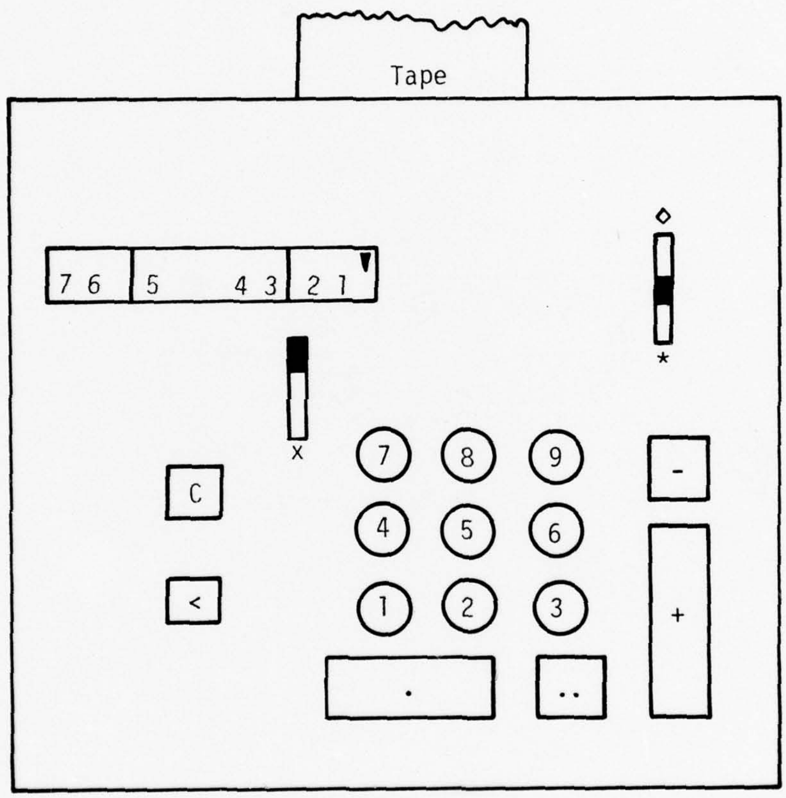
EXAMPLE

System: Olivetti Calculator

Task: add 4 and 13.6

Response	Stimulus	Nature of Translations Required
*	command	command ⟶ clear register ⟶ * ⟶ * position S-S class. S-S class. S-R conser.
4	*	enter number ⟶ 4 ⟶ 4 position S-S class. S-R conser.
..		shift decimal ⟶ shift decimal 2 positions ⟶ .. ⟶ .. position S-S creation S-S conser. S-R conser.
+		enter function ⟶ add ⟶ + ⟶ + position S-S class. S-R conser. S-R conser.
1	4.00	enter number ⟶ 1 ⟶ 1 position S-S class. S-R conser.
3		enter number ⟶ 3 ⟶ 3 position S-S class. S-R conser.
6		enter number ⟶ 6 ⟶ 6 position S-S class. S-R conser.
.		shift decimal ⟶ shift decimal 1 position ⟶ . ⟶ . position S-S creation S-S conser. S-R conser.
+		enter function ⟶ add ⟶ + ⟶ + position S-S class. S-S conser. S-R conser.
*	13.60	total ⟶ * ⟶ * position S-S class. S-R conser.

Olivetti



4) The translation from Divide to ÷ (divide ⇨ ÷) is an example of an ______________ *translation.*

The answers and explanations of the answers to these questions are at the end of the manual. If you missed any of the questions, reread this section. If you still do not understand the answer to the question or any of the concepts, please contact me. When you feel you understand this section proceed to the next section.

Section 3

In this section we will work through a problem step by step so that you will be able to see how the terms discussed in the preceding section can be used to describe tasks. When you are given a task to describe, you will use a table similar to that on the next page. It will have three columns: responses, stimuli, and tha nature of the translation required. You will always be given a statement telling you what system the task is being performed on, the level of practice, the task, the response required to perform each step of the problem, and the stimuli which indicate the beginning of each steyp. You will be required to fill in the translations required for each step of the task.

The sample problem is illustrated in Table 1 on the next page. The problem is a simple addition task being performed on an Olivetti calculator, which is diagrammed in the figure following Table 1. (TEAR THE TABLE AND FIGURE OUT, SO THAT IT WILL BE EASIER TO FOLLOW THE DISCUSSION OF THE PROBLEM.) The problem states that the person using the calculator is early in practice, which means you should assume he is using the calculator for the first time and every appropriate translation will be present. The task to be performed is to add 4 and 13.6.

The procedure that you should follow is first decide what the function of each step is, because in most cases this will give you the starting point (stimulus) for the translations in each step. Since you are given the response that must be made for each step to be completed, you also know what the final result of the translations in each step will be. The second part of the procedure is to outline the translations that are necessary to go from the starting point to the end point of the step.

Upon receiving the command to add the two numbers together the first thing that must be done is to clear the registers on the calculator, so this is the function of the first step. Because this is the first step in performing the problem, it is necessary to start with the translation from the command to add 4 and 13.6 to the operation of clear register. Since all commands require this one output we are translating from many possible input stimuli to one output stimulus, this first translation is an S-S classification. The next translation that is required is from the stimulus of clear register to the stimulus *, since this is the form of the stimulus on the calculator. Again this translation is an S-S classification translation. It is an S-S translation because * is another form of the stimulus not a response. It is a classification translation because on this calculator the same response is required to give the total, so the same output is required for two inputs, i.e., there are more items in the input than in the output. The final translation in this step is from the final stimulus * to the response of pushing the button labelled *. Because the output is a physical response, the translation is an S-R translation. It is an S-R conservation translation because there is only one response for the stimulus, i.e., there is a one-to-one correspondence between the stimulus and the key for that stimulus on the calculator. (Follow the discussion on the sample.)

Once the calculator is cleared, indicated by a * on the tape output, the function of the second step is to enter a number. You must first translate from the stimulus of enter number to a specific number. This is an S-S classification translation because the output is another form of the input and you are translating from 10 possible input items to 1 output item. The next translation in this step is to go from the number 4 to pushing the key for that number. Since the output is a physical response, this is an S-R translation. It is an S-R conservation translation because each number corresponds to only one key providing for a one-to-one relationship or equal amount of information in the input and output of the translation.

This particular calculator has a fixed two digit decimal point, so the function of the next step is to shift the 4 to the left of the decimal point. The first translation in this step is from shift the decimal point to shift the decimal point 2 positions. This is a S-S creation task. It is an S-S translation because the output is another form of the input, and it is a creation task because you must add the number of spaces the decimal point must be moved to the information in the input. The next translation is from shift decimal 2 spaces to .. because this is the symbol for performing this operation. This is an S-S conservation translation. It is an S-S translation becuase the output is another form of the input, not the physical response. It is a conservation translation because the only output which will produce the desired response is .., i.e., a one-to-one relation between the input and output (equal information). The final translation in the step is the S-R conservation translation from the final form of the stimulus, .., to the response of pushing the button marked ... It is a conservation translation because there is a one-to-one relation between input and output.

The function of the next step is to enter the operation to be performed. The first translation is from enter operation to add, since add is the operation specified in the task. This is an S-S classification translation because the output is another form of the input and there are four possible input items or operations (add, subtract, divide, and multiply) and only one specific output operation, i.e., a reduction of information during the translation. The next translation is to go from add to +, since that is how the operation is specified on the calculator. This is an S-S conservation task. It is an S-S translation because the output of the translation is another form of the input, and it is a conservation translation because there is a one-to-one relation between the input and output. The final translation in this step is from the symbol + to pressing the + key. This is an S-R conservation translation, since the output is a physical response and there is only one possible response or output item for the input item.

The next three steps are identical to the second step since their function is also to enter a digit. Because they are identical the translations will not be repeated, but you should look back at the explanations given for step two.

The eighth step is similar to the third step, since its function is to shift the decimal between the 3 and the 6. The actual number of spaces that the decimal point must be shifted does not affect the translations that are required for this step. As in step two, the first translation is an S-S creation because you are adding information about the number of spaces that the decimal must be shifted. The second translation is an S-S conservation because there is one and only one stimulus which will produce the desired operation (one-to-one relation between input and output). Finally, the third translation is an S-R conservation translation from the final stimulus . to the . key. It is an S-R translation because the output is a physical response, and it is a conservation translation because there is a one-to-one correspondence between the final form of the stimulus and the response required to perform it.

On this particular calculator another add operation is required before the numbers can be totaled, so the function of the next step is to enter another add operation. The translations in this step are identical to those discussed for step four. The first translation is an S-S classification translation where the specific operation is identified. This is followed by an S-S conservation translation which translates the name of the operation, add, to the symbol used to identify it on the calculator, +. Finally, an S-R conservation translation is made with the key corresponding to the add operation being pushed.

The function of the final step is to total the two numbers. This requires going from the stimulus total to *, which is the symbol for total on the calculator. This is an S-S classification translation. It is an S-S translation because the output is another form of the input, and it is a classification translation because, as mentioned earlier, the * symbol also stands for clear register, so there are two possible input items to the translation and only one output. The second translation requires the translation from * to the position of the * key on the calculator. Because the output is a physical response this is an S-R translation. It is an S-R conservation translation because only one response corresponds to the input (i.e., a one-to-one relationship between the stimulus and response).

This example illustrates how the terms introduced earlier can be used to describe a task. This particular task and calculator were used as an example because they involve many of the different types of translations. Hopefully this example will make some fo the translations and the method in which they are used a little more clear. This calculator is more complicated than the ones that will be used for the rest of the study.

In order for you to become more familiar with the procedure for describing tasks Work the practice problem following. Remember that you should first try to identify the function of each step in the problem (enter number, clear register, etc.). Second, you should write down the translations required (enter digit ⇨ 3 ...). Finally, you should try to identify what type of translation (S-S creation, etc.) each translation represents.

Remember: The types of translation you will be trying to identify are

1. S-S conservation
2. S-S classification
3. S-S creation
4. S-R conservation
5. S-R classification
6. S-R creation
7. compression (an example of how this would be used is

Las Cruces ⇨ L.C.
compression

You may refer back to earlier sections in this paper while you work through the practice problem.

A table showing the proper way that this problem should be diagrammed is at the end of the manual. If you missed a large number of the translations, reread the earlier sections of the paper. I will answer questions on this problem at the beginning of the first experimental session or you may contact me earlier.

PRACTICE PROBLEM

System: Radio Shack EC-220 calculator

Task: add 89 and 56

Practice: Early

Response	Stimulus	Nature of translations required
C/CE	command	
8	all zeros	
9	8	
+	89	
5	89	
6	5	
=	56	

Answers To Problems

Problem Set at the End of Section 1

1. classification - this situation involves classification because you are taking 50 states and dividing them into two groups, i.e., there are fewer output items than there are input items.
2. compression - your initials are simply the abbreviation of your name and compression is an abbreviation process.
3. creation - in this situation there is only one input item, the request for a recipe, but there are many output items since you list out each ingredient separately. Therefore information is being created.
4. S-S - this is an S-S translation because you are translating from one form of the stimulus, five, to another form, 5.
5. S-R - this is an S-R translation because you are translating from a stimulus, 2, to the response of pressing a button.
6. UN - this is the compression of United Nations because this is the manner in which it is abbreviated.
7. conservation - this is an example of conservation because there are seven digits in the number and you must make seven separate dialing responses. It is a one-to-one relationship between the digits and the dialing responses, so information is conserved.

Problem Set at the End of Section 2

1. S-S classification - this is an S-S translation because it involves the translation from the stimulus of enter any digit ot the stimulus of a particular digit. It is classification because there are ten inputs to the translation, the ten possible digits, and only one output item, the particular digit you chose.

Problem Set at the End of Section 2 (Continued)

2. S-R conservation - this is an S-R translation because the output is a physical response. It is an example of conservation because each digit corresponds exactly to a separate button.

3. False - this translation involves a change in the form of the input not an abbreviation of the input.

4. S-S conservation - this is an S-S translation because it involves a change in the form of the stimulus to another form. It is conservation because there is a one-to-one correspondence between the input and the output.

Practice Problem

System: Radio Shack EC-220 calculator

Task: add 89 and 56

Response	Stimulus	Nature of translations required
C/CE	command	command → (S-S Class.) clear → (S-S Creat.) clear/clear entry → (Comp.) C/CE → (S-R Consr.) C/CE position
8	all zeros	enter number → (S-S Class.) 8 → (S-R Consr.) 8 position
9	8	enter number → (S-S Class.) 9 → (S-R Consr.) 9 position
+	89	enter function → (S-S Class.) add → (S-S Consr.) + → (S-R Consr.) + position
5	89	enter number → (S-S Class.) 5 → (S-R Consr.) 5 position
6	5	enter number → (S-S Class.) 6 → (S-R Consr.) 6 position
=	56	total → (S-S Class.) equal → (S-S Consr.) = → (S-R Consr.) = position

APPENDIX B

Test Problems and Answers

System: Commodore Calculator

Task: subtract 4 from 7, then divide by 2

Practice: Early

Response	Stimulus	Nature of translations required
CLR REG ONLY & CLR DISP ONLY	command	Command → Clear → Clear Reg. & Display → Clear Register Only & Clear Display Only → CLR REG ONLY & CLR DISP ONLY → CLR REG Position ONLY CLR DISP Position ONLY S-S Class S-S Creat. S-S Consr. Comp. S-R Creat.
7	all zeros	Enter # → 7 → 7 position S-S Class. S-R Consr.
ADD =	7	Enter operation → add → ADD = → ADD position = S-S Class. S-S Creat. S-R Consr.
$	&	Enter # → 4 → 4 position S-S Class. S-R Consr.
SUBT =	4	Enter operation → subtract → subtract = → SUBT = → SUBT = position S-S Class. S-S Creat. Comp. S-R Consr.
Entr ÷	3	Enter operation → divide → Enter ÷ → Enter ÷ position S-S Class. S-S Creat. S-R Consr.
2	3	Enter # → 2 → 2 position S-S Class. S-R Consr.
ADD =	2	Total → = → ADD = → ADD = position S-S Class S-S Creat. S-R Consr.

$H_R = 22.306$

24 Total Translations

System: SR-51A calculator

Task: compute log 3 ÷ 5

Practice: Early

Response	Stimulus	Nature of translations required
C	command	command $\xrightarrow{\text{S-S Class.}}$ clear $\xrightarrow{\text{Comp.}}$ c $\xrightarrow{\text{S-R Consr.}}$ c position
3	all zeros	enter # $\xrightarrow{\text{S-S Class.}}$ 3 $\xrightarrow{\text{S-R Consr.}}$ 3 position
2nd	3	shift keyboard $\xrightarrow{\text{S-S Class.}}$ 2nd $\xrightarrow{\text{S-R Consr.}}$ 2nd position
log	3	enter operation $\xrightarrow{\text{S-S Class.}}$ log $\xrightarrow{\text{S-R Consr.}}$ log position
÷	.47712	enter operation $\xrightarrow{\text{S-S Class.}}$ ÷ $\xrightarrow{\text{S-R Consr.}}$ ÷ position
5	.47712	enter # $\xrightarrow{\text{S-S Class.}}$ 5 $\xrightarrow{\text{S-R Consr.}}$ 5 position
$\sqrt{x}$	5	enter operation $\xrightarrow{\text{S-S Class.}}$ $\sqrt{\ }$ $\xrightarrow{\text{S-S Consr.}}$ $\sqrt{x}$ $\xrightarrow{\text{S-R Consr.}}$ $\sqrt{x}$ position
=	2.2360679	Total $\xrightarrow{\text{S-S Class.}}$ = $\xrightarrow{\text{S-R Consr.}}$ = position

$H_R = 21.932$

18 Total Translations

System: Radio Shack EC-220 calculator

Practice: Early

Task: add 2 and 3

Response	Stimuli	Nature of translations required
C/CE	command	command —(S-S Class.)→ clear —(S-S Creat.)→ clear entry/clear —(Comp.)→ CE/c —(S-R Consr.)→ CE/c position
2	all zeros	enter # —(S-S Class.)→ 2 —(S-R Consr.)→ 2 position
+	2	enter operation —(S-S Class.)→ add —(S-S Consr.)→ + —(S-R Consr.)→ + position
3	2	enter # —(S-S Class.)→ 3 —(S-R Consr.)→ 3 position
=	3	Total —(S-S Class.)→ = —(S-R Consr.)→ = position

$H_R = 12.288$

13 Total Translations

System: Sr-51A calculator

Task: Compute $\frac{\sinh 4}{\ln 3}$

Practice: Early

Response	Stimulus	Nature of translations required
C	command	command ⟶ (S-S Class.) clear ⟶ (Comp.) c ⟶ (S-R Consr.) c position
4	all zeros	enter # ⟶ (S-S Class.) 4 —— (S-R Consr.) 4 position
2nd	4	shift keyboard ⟶ (S-S Class.) 2nd ⟶ (S-R Consr.) 2nd position
sinh	4	enter function ⟶ (S-S Class.) sinh ⟶ (S-R Consr.) sinh position
÷	27.2899	enter operation ⟶ (S-S Class.) —— ⟶ (S-S Creat.) divide ⟶ (S-S Consr.) ÷ ⟶ (S-R Consr.) ÷ position
ln x	3	enter operation ⟶ (S-S Class.) ln ⟶ (S-S Consr.) ln x ⟶ (S-R Consr.) ln x position
=	1.09861	equal ⟶ (S-S Class.) = ⟶ (S-R Consr.) = position

$H_R = 21.932$

20 Total Translations

System: SR-51A calculator

Task: compute the natural log of the cube root of 7

Practice: Early

Response	Stimulus	Nature of translations required
C	command	command $\xrightarrow[\text{S-S Class.}]{}$ clear $\xrightarrow[\text{Comp.}]{}$ c $\xrightarrow[\text{S-R Consr.}]{}$ c position
3	all zeros	enter # $\xrightarrow[\text{S-S Class.}]{}$ 3 $\xrightarrow[\text{S-R Consr.}]{}$ 3 position
$\sqrt[x]{y}$	3	enter operation $\xrightarrow[\text{S-S Class.}]{}$ $\sqrt{\ }$ $\xrightarrow[\text{S-S Creat.}]{}$ $\sqrt[x]{y}$ $\xrightarrow[\text{S-R Consr.}]{}$ $\sqrt[x]{y}$ position
7	3	enter # $\xrightarrow[\text{S-S Class.}]{}$ 7 $\xrightarrow[\text{S-R Consr.}]{}$ 7 position
=	7	subtotal $\xrightarrow[\text{S-S Class.}]{}$ equal $\xrightarrow[\text{S-S Consr.}]{}$ = $\xrightarrow[\text{S-R Consr.}]{}$ = position
ln x	1.1699308	enter function $\xrightarrow[\text{S-S Class.}]{}$ natural log $\xrightarrow[\text{S-S Consr.}]{}$ ln x $\xrightarrow[\text{S-R Consr.}]{}$ ln x position

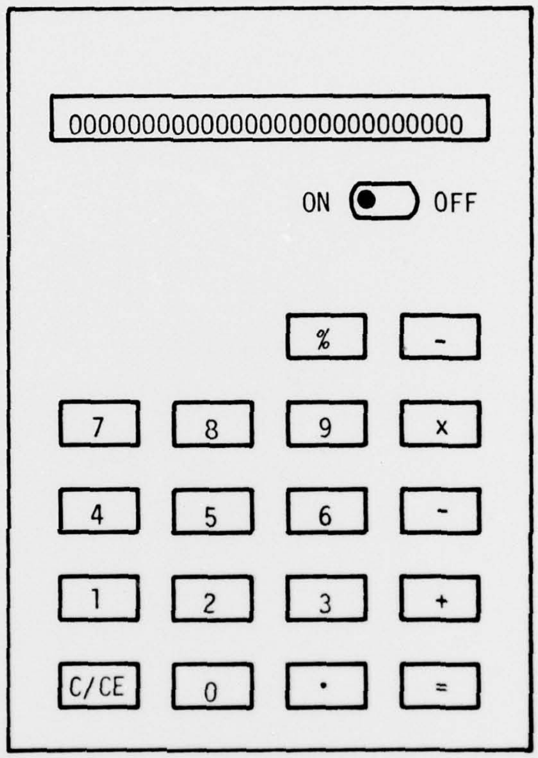
$H_R = 18.61$

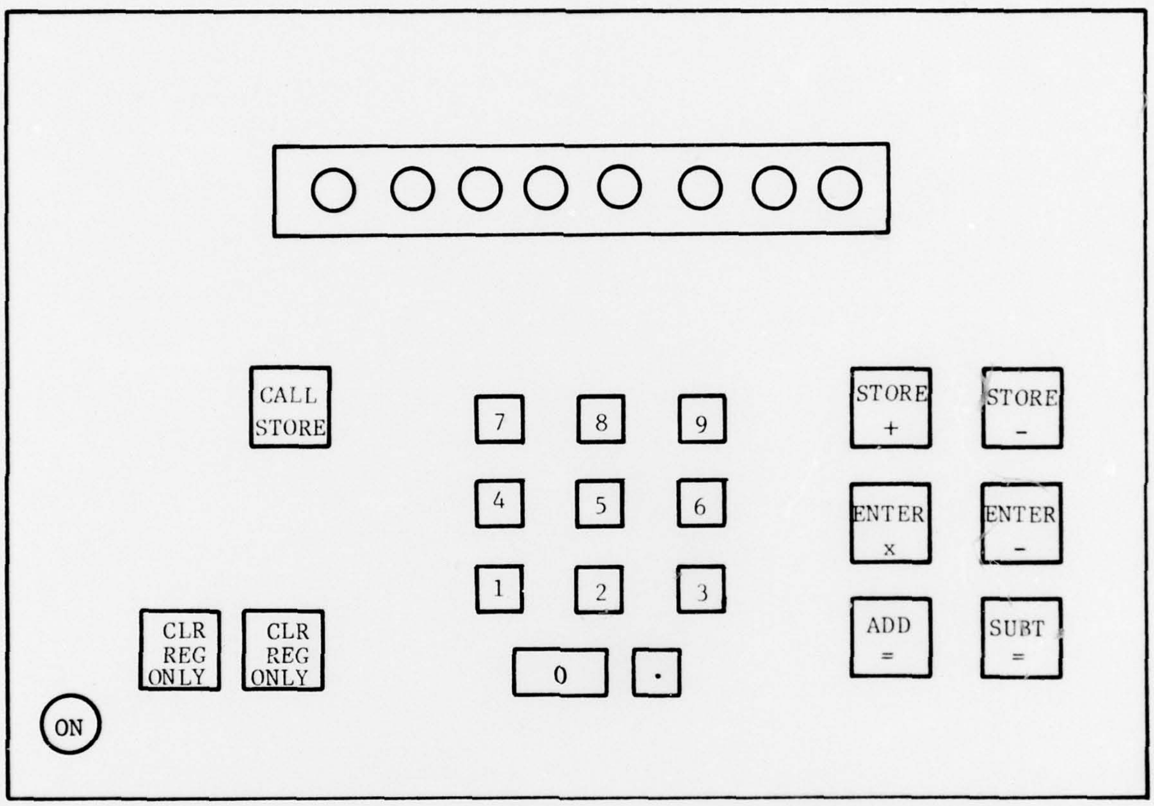
16 Total Translations

APPENDIX C

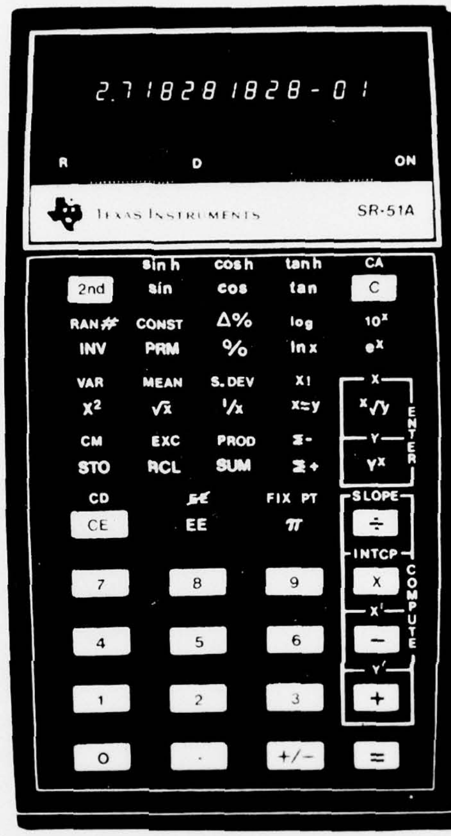
Calculator Keyboard Diagrams

Radio Shack EC-220





Commodore 1161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APPENDIX D

Problems Performed with Keyboard Diagrams
Following Actual Use of the Calculator

Problems Performed with Keyboard Diagrams Following Actual Use of the Calculator

Problem 1

a) Add 3 and 5 then multiply by 8

b) Subtract 2 from 3 then divide by 7

c) Subtract 5 from 9 then multiply by 2

Problem 2

a) compute $4! \times 1/5$

b) compute $\log 2 + 7^2$

c) compute $3! - \sqrt{2}$

Problem 3

NONE

Problem 4

a) compute $\frac{\tanh 2}{e^2}$

b) compute $\frac{4!}{\sqrt{3}}$

c) compute $\frac{\log 4}{6^2}$

Problem 5

a) compute the sine of the third power of 3

b) compute the natural log of the fourth power of 2

c) compute the tangent of the cube root of 3