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(Author/RH)
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AND/OR RULES ON COMPUTER-BASED LEARNING: A REPLICATION

Paul F. Merrill, Michael H. Steve, Stanley J. Kalisch, and Nelson J. Towle

Tech Memo No. 59
September 15, 1972
Tallahassee, Florida

Project NR 154-280
Sponsored by
Personnel & Training Research Programs
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Duncan N. Hansen
Director
CAI Center
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ABSTRACT

To replicate and extend the results of a previous study by the principal author, this study investigated the effects of behavioral objectives and/or rules on computer-based learning task performance. The 133 Ss were randomly assigned to an example-only, objective-example, rule-example, or objective-rule-example group. The availability of rules and/or objectives reduced the number of examples required to meet criterion performance and increased posttest performance. In addition, rules reduced display latency and test item response latency, and increased retention test performance. Rules also decreased the level of within task state anxiety.
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Florida State University

The effects of the availability of objectives and/or rules on the learning process were investigated by Merrill (1970) using an imaginary science as the learning task. Merrill found that the presentation of rules reduced the number of examples and total time required to complete the task and increased performance on a transfer test. The availability of objectives reduced test item response latency and the number of examples required to meet criterion performance. An objective by rule interaction with test item response latency as criterion revealed that objectives had a greater effect in reducing response latency when added to a task which had no other focusing or organizing stimuli than they did when added to a task which had other effective oriented stimuli such as rules. Ability by treatment interactions were obtained using test item response latency as criterion and reasoning ability test scores as covariates. These interactions showed that the availability of objectives and/or rules significantly reduced the requirements for reasoning ability in responding to test

items. The purpose of this study was to replicate and extend the results of the previous study using an actual classroom task rather than an imaginary science.

Based on the results of the previous study, it was hypothesized that the presentation of objectives and/or rules would significantly reduce the number of examples required to reach criterion performance and would reduce the requirements for reasoning ability. Rules were also expected to reduce display latency, reduce test item response latency, reduce post, retention, and transfer latencies, and increase performance on a transfer test. Objectives were expected to reduce test item response latency. As an extension to the previous study, it was further hypothesized that objectives and/or rules would reduce state anxiety within the task (Merrill & Towle, 1972).

Method

Subjects

The 140 S's who participated in this study were volunteers from introductory psychology and math education classes at The Florida State University. However, seven of the original Ss were eliminated from the data analysis because they failed to complete all phases of the study.

Aptitude Measures

Two cognitive ability tests and a trait anxiety scale were administered to all Ss in group testing sessions. Based on their relevance to the task, the Letter Sets and Ship Destination cognitive ability tests were selected from the Kit of Reference Tests for Cognitive Factors (French, Ekstrom, & Price, 1963). The trait anxiety
scale used was the STAI A-Trait scale developed by Spielberger, Gorsuch, and Lushene (1970). A short form of the STAI A-State scale (O'Neil, 1970) was given at three points during the task.

**Experimental Tasks and Materials**

The learning task used in this study was developed by the authors utilizing eight rules based on the primitive mixed functions of the APL Programming Language (McMurchie, Krueger, & Lippert, 1970). Rules from the APL language were selected as the learning task since APL is currently being taught in college courses across the country, while the uniqueness of APL makes it possible to easily screen Ss who have had previous experience with the language. The instructional program consisted of a module for each of the eight rules ordered in a subjectively determined easy-to-hard sequence. The materials for each module included a statement of an objective, a statement of a rule, five examples of the rule, and five short constructed response tests. Each test consisted of three items which required Ss to apply the appropriate rule. The rule and objective statements, examples, and sample test items may be found in Appendix A.

The post- and retention tests used in this study consisted of 24 constructed response items similar to the items used in the module tests. Both tests contained three items for each of the eight rules in the program. The transfer task consisted of two examples and three constructed response test items for eight new rules which were logical extensions of the rules used in the original task. The Ss were required to infer each new rule from the examples and apply the inferred rule in the three test items. The transfer test score was the total number of test items answered correctly by Ss. An example and test item for each of the eight transfer rules are included in Appendix B.
The instructional program and tests were written in the Course-
writer II language and presented on a cathode ray tube terminal by the
IBM 1500/1800 computer-assisted instruction system.

Procedure

After the administration of the two ability tests and the STAI
A-Trait scale, each S was randomly assigned to one of four treatment
groups: an example-only group (n = 33), an objective-example group (n = 33),
a rule-example group (n = 34), or an objective-rule-example group (n = 33).
Figure 1 is a graphical representation of the 2 x 2 factorial design
formed by these groups. In learning the APL rules, Ss in the example-only
group received an example of the first rule displayed on a cathode ray tube
terminal. After studying the example, each S responded to a three-item
constructed response test in which he was required to predict certain values
using the rule inferred from the example. If the S responded correctly to
at least two of the three test items, he was given an example of the next
rule in the sequence. Otherwise he was given another example of the same
rule followed by three more test items. This sequence of an example,
followed by a test, continued until the S answered at least two of the
three test items correctly, or until he received five examples of the rule.
This procedure was repeated for all eight modules of the task. A computer-
administered posttest was presented immediately following completion of
the learning task, and computer-administered retention and transfer tests
were presented two weeks later.

The Ss in the other three groups were presented the APL rules
by the same basic procedure, except for the following treatment differ-
ences. The objective-example group received a statement of an objective
in addition to the corresponding example; the rule-example group received a statement of the rule in addition to the corresponding example; and the objective-rule-example group received statements of both the objective and the rule in addition to the example. The five-item STAI A-State scale was presented via computer terminal to all Ss prior to the learning task, immediately following the fourth module, and again following the final module.

<table>
<thead>
<tr>
<th>OBJECTIVES</th>
<th>RULES</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td></td>
<td>EXAMPLE ONLY</td>
</tr>
<tr>
<td></td>
<td>(n = 33)</td>
</tr>
<tr>
<td>NO</td>
<td>RULE-EXAMPLE</td>
</tr>
<tr>
<td></td>
<td>(n = 34)</td>
</tr>
<tr>
<td>YES</td>
<td>OBJECTIVE-EXAMPLE</td>
</tr>
<tr>
<td></td>
<td>(n = 33)</td>
</tr>
<tr>
<td>YES</td>
<td>OBJECTIVE-EXAMPLE</td>
</tr>
<tr>
<td></td>
<td>(n = 33)</td>
</tr>
</tbody>
</table>

Figure 1: 2 x 2 Factorial Design Used in this Study.

Results

In addition to the total scores on the two cognitive ability tests, STAI A-trait scale, STAI A-state scale, posttest, retention test, and transfer test mentioned in the procedures section, data were obtained for each S on the following criteria: total number of examples required to learn the APL rules, display latency, post-, retention, and transfer test item response latencies. Test item response latency was the total time required by Ss to respond to the three-item tests following each example.
display. Display latency was the total time spent studying the examples, and depending upon S's treatment group, the corresponding rules and/or objectives.

Descriptive statistics and reliability coefficients for the ability tests, the A-Trait scale, and the three administrations of the A-State scale are found in Table 1. The reliability coefficients of the A-Trait and A-State scales were estimated using coefficient alpha. The reliability coefficients of the ability tests were estimated using the Kuder-Richardson Formula 20 (KR-20). Although the ability tests were not pure speeded tests, they were timed. Therefore, these reliability coefficients should be interpreted with caution. Using formula KR-20, the reliability coefficients of the post-, retention, and transfer tests, which were not speeded, were estimated to be .89, .85, and .87, respectively.

<table>
<thead>
<tr>
<th>TESTS</th>
<th>NUMBER OF ITEMS</th>
<th>MEANS</th>
<th>S.D.</th>
<th>RELIABILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Letter Sets Test</td>
<td>15</td>
<td>10.1</td>
<td>2.3</td>
<td>.69&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Ship Destination</td>
<td>24</td>
<td>12.8</td>
<td>4.5</td>
<td>.86&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>A-Trait</td>
<td>20</td>
<td>37.8</td>
<td>8.3</td>
<td>.87&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>A-State (Pre-task)</td>
<td>5</td>
<td>9.8</td>
<td>3.3</td>
<td>.84&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>A-State (Mid-task)</td>
<td>5</td>
<td>9.5</td>
<td>3.8</td>
<td>.88&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>A-State (Post-task)</td>
<td>5</td>
<td>11.8</td>
<td>4.8</td>
<td>.92&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup> KR-20  
<sup>b</sup> alpha
The means and standard deviations for each group on the number of examples received and post-, retention, and transfer test scores are reported in Table 2. These criterion measures were analyzed using a two-factor analysis of variance with objectives and rules as factors. The results with number of examples as criterion revealed a significant rule effect (F = 106.48, df = 1/129, p < .001) and a significant objective effect, (F = 4.38, df = 1/129, p < .05), wherein the presentation of rules and/or objectives reduced the number of examples required to learn the task.

Using posttest scores as criterion, a significant rule effect, (F = 30.58, df = 1/129, p < .001), and a significant objective effect, (F = 3.95, df = 1/129, p < .05), were obtained, where both rules and objectives increased posttest performance. Similar analyses conducted with retention test scores as criterion revealed a significant rule effect, (F = 17.78, df = 1/129, p < .001), with the rule groups obtaining the higher retention tests scores. No significant effects were obtained using transfer test scores as criterion.

The means and standard deviations for the four groups on the five latency criterion measures are found in Table 3. These latency measures also were analyzed using a two-factor analysis of variance. A significant rule effect was obtained for display latency (F = 6.59, df = 1/129, p < .05), and for test-item-response latency (F = 12.01, df = 1/129, p < .01) with the rule groups taking considerably less time to study the displays and respond to the criterion test items. Analyses using post-, retention, and transfer test-item-response latencies as
TABLE 2

Group Means and Standard Deviations for Number of Examples, Post, Retention, and Transfer Tests

<table>
<thead>
<tr>
<th>Group</th>
<th>Number of Examples</th>
<th>Posttest</th>
<th>Retention Test</th>
<th>Transfer Test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Example Only</td>
<td>24.8</td>
<td>3.7</td>
<td>5.2</td>
<td>3.2</td>
</tr>
<tr>
<td>Objective-Example</td>
<td>23.1</td>
<td>5.0</td>
<td>6.7</td>
<td>4.6</td>
</tr>
<tr>
<td>Rule-Example</td>
<td>15.9</td>
<td>5.6</td>
<td>9.9</td>
<td>5.8</td>
</tr>
<tr>
<td>Objective-Rule</td>
<td>14.0</td>
<td>5.6</td>
<td>11.9</td>
<td>6.4</td>
</tr>
</tbody>
</table>


TABLE 3

Group Means and Standard Deviations for Display Latency, Test-Item Response Latency, Post, Retention, and Transfer Test-Item-Response-Latencies

<table>
<thead>
<tr>
<th></th>
<th>Display Latency</th>
<th>Test-Item-Response Latency</th>
<th>Posttest-Item-Response Latency</th>
<th>Retention Test-Item-Response Latency</th>
<th>Transfer Test-Item-Response Latency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>Example Only</td>
<td>1226.3</td>
<td>504.9</td>
<td>656.9</td>
<td>297.2</td>
<td>292.7</td>
</tr>
<tr>
<td>Objective-Example</td>
<td>1254.9</td>
<td>468.1</td>
<td>578.9</td>
<td>217.8</td>
<td>359.5</td>
</tr>
<tr>
<td>Rule-Example</td>
<td>1106.1</td>
<td>587.5</td>
<td>500.3</td>
<td>252.2</td>
<td>436.6</td>
</tr>
<tr>
<td>Objective-Rule</td>
<td>917.8</td>
<td>480.2</td>
<td>442.1</td>
<td>197.3</td>
<td>447.2</td>
</tr>
</tbody>
</table>
criteria yielded a significant rule effect for posttest latency ($F = 13.3$, $df = 1/129$, $p < .01$), where the presentation of rules increased the amount of time Ss spent on the posttest. No significant differences were obtained on either retention or transfer tests—item-response latencies.

Regression analyses of the individual ability scores, A- Trait scores, and the criterion measures were conducted. However, no significant utility by treatment interactions were obtained.

The means and standard deviations on the pre-task, mid-task, and post-task A-State scales for the four experimental groups are presented in Table 1. These data were evaluated by a three-factor analysis of variance in which objectives, rules, and task periods were the independent variables with repeated measures on the last factor. The results of this analysis revealed a significant period effect, ($F = 28.53$, $df = 2/258$, $p < .01$) with the level of A-State generally increasing across periods, and a significant rule by period interaction, ($F = 4.24$, $df = 2/258$, $p < .05$). A graph of the interaction is found in Figure 3. An analysis of covariance with mid-task A-State scores and post-task A-State scores as criteria and pre-task A-State scores as the covariate resulted in a significant rule effect ($F = 4.24$, $df = 2/258$, $p < .05$) on mid-task A-State. No effect was obtained on post-task A-State. These results revealed that presentation of rules for the first four modules reduced the level of A-State for the rule groups while A-State increased over the same period for those who were given no rules. However, the level of A-State for the rule groups increased to about the same level as the other groups at the completion of the eighth module.
TABLE 4
Group Means and Standard Deviations for the A-State Scale of the State-Trait Anxiety Inventory

<table>
<thead>
<tr>
<th>Groups</th>
<th>Pre-Task A-State</th>
<th>Mid-Task A-State</th>
<th>Post-Task A-State</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example Only</td>
<td>Mean 9.2</td>
<td>10.2</td>
<td>12.7</td>
</tr>
<tr>
<td></td>
<td>SD 3.5</td>
<td>4.8</td>
<td>5.5</td>
</tr>
<tr>
<td>Objective-Example</td>
<td>Mean 9.5</td>
<td>9.8</td>
<td>11.6</td>
</tr>
<tr>
<td></td>
<td>SD 4.1</td>
<td>4.1</td>
<td>5.3</td>
</tr>
<tr>
<td>Rule-Example</td>
<td>Mean 10.3</td>
<td>9.3</td>
<td>11.8</td>
</tr>
<tr>
<td></td>
<td>SD 2.6</td>
<td>3.0</td>
<td>4.3</td>
</tr>
<tr>
<td>Objective-Rule Example</td>
<td>Mean 10.1</td>
<td>8.6</td>
<td>11.3</td>
</tr>
<tr>
<td></td>
<td>SD 2.9</td>
<td>3.1</td>
<td>4.3</td>
</tr>
</tbody>
</table>
Figure 2.—Interaction of Periods of Test Administration and No-Rule (NR) and Rule (R) Treatments with State Anxiety Score Means as Criterion
Discussion

The purpose of this study was to replicate and extend an earlier study by Merrill (1970), where the interactive effects of objectives and/or rules on the learning process were investigated using an imaginary science. On the basis of the results from the earlier study, it was hypothesized that rules and objectives would decrease the number of examples required to reach criterion performance on the new learning task. The results from the present study confirm the hypothesis and thereby replicate the findings of the earlier study. Results from both studies indicate that the presentation of verbal statements of enable most Ss to learn the task with a minimum number of examples. The availability of objectives has a similar but less pronounced effect.

Since the experimental procedure required all subjects to perform at a minimum criterion level on each rule before proceeding to the next, no group mean differences were expected on the posttest. However, the difficulty of the last four rules prevented several Ss from reaching criterion before all 5 examples were exhausted. An analysis of the Ss who failed to reach criterion revealed that the percentage of misses for the example-only, objective-example, rule-example, and objective-rule-example groups were 37.5, 29.2, 11.4, and 9.5 percent, respectively. Therefore, the significant differences on the posttest may reflect the fact that many Ss did not reach criterion level performance on some of the rules before proceeding to the following rules.

The hypothesis that the availability of rules would increase performance on the transfer test was not supported by the results.
Inasmuch as all Ss did not reach criterion performance on the original task, it is difficult to interpret their performance on the transfer test.

The significant rule effect on the latency measures replicates the findings of the earlier study and demonstrates that the availability of rules reduces the amount of time required to study the example displays and respond to criterion test items. However, the hypothesis that objectives would reduce test item response latency was not replicated in this study.

It was hypothesized that the availability of rules would decrease post-, retention, and transfer latency. However, the results showed that rules actually increased posttest latency. This unexpected result may be due to a higher frequency of guessing for the no-rule groups.

The significant periods effect with A-state scores as the repeated measure supports the results found in earlier studies (O'Neil, 1970; O'Neil, Hansen, & Spielberger, 1969) wherein state anxiety is increased as the difficulty of the task increases. The significant rule by periods interaction supports the hypothesis that the availability of rules reduces A-State within the task. The increase in the A-State level for the rule groups after the initial decrease may indicate that the availability of rules may be more effective in reducing A-State for easy rules than for difficult rules.
References


APPENDIX A

INSTRUCTIONAL MATERIALS
APPENDIX A: MATERIALS

MATERIALS FOR RULE 1

RULE

IF V IS A STRING OF NUMBERS, \( pV \) GIVES THE NUMBER OF ELEMENTS IN THE STRING.

OBJECTIVE

GIVEN 3 PROBLEMS WITH OPERATION \( p \) AND A STRING OF NUMBERS, V, YOU WILL COMPUTE \( pV \) FOR AT LEAST 2 PROBLEMS.

EXAMPLE 1:  \( p2 \ 31 \ 4 \ 17 \) GIVES 4
TEST ITEM 1:  \( p25 \ 43 \) GIVES
TEST ITEM 2:  \( p0 \ 1 \ 2 \) GIVES
TEST ITEM 3:  \( p2 \ 0 \ 0 \ 1 \) GIVES

EXAMPLE 2:  \( p123 \ 456 \) GIVES 2
TEST ITEM 1:  \( p28 \ 13 \ 21 \) GIVES
TEST ITEM 2:  \( p0 \ 1 \ 2 \ 3 \ 4 \) GIVES
TEST ITEM 3:  \( p4 \ 800 \) GIVES

EXAMPLE 3:  \( p28 \ 289 \ 2889 \) GIVES 3
TEST ITEM 1:  \( p236 \ 0 \ 14 \) GIVES
TEST ITEM 2:  \( p170 \ 17 \ 170 \ 17 \) GIVES
TEST ITEM 3:  \( p100 \ 1000 \) GIVES
EXAMPLE 4: \( p_0 \ 1 \ 2 \ 3 \) GIVES 4

TEST ITEM 1: \( p_{17} \ 15 \ 12 \ 2 \ 7 \) GIVES

TEST ITEM 2: \( p_1 \ 2 \ 3 \) GIVES

TEST ITEM 3: \( p_1 \ 0 \ 2 \ 0 \ 3 \ 0 \ 4 \) GIVES

EXAMPLE 5: \( p_{27} \ 72 \ 31 \ 13 \ 4 \) GIVES 5

TEST ITEM 1: \( p_3 \ 7 \ 2 \) GIVES

TEST ITEM 2: \( p_0 \ 1 \ 11 \ 3 \ 8 \ 1 \) GIVES

TEST ITEM 3: \( p_0 \ 1 \) GIVES
MATERIALS FOR RULE 2

RULE

IF \( N \) IS A WHOLE NUMBER LARGER THAN ZERO, \( N \) GIVES A STRING OF THE FIRST \( N \) WHOLE NUMBERS LARGER THAN ZERO.

OBJECTIVE

GIVEN 3 PROBLEMS WITH OPERATION \( \times \) AND A WHOLE NUMBER, \( N \), YOU WILL COMPUTE \( N \times N \) FOR AT LEAST 2 PROBLEMS.

EXAMPLE 1:
\[ 1 \times 2 \text{ gives } 12 \text{ gives } 1 \ 2 \ 3 \ 4 \ 5 \ 6 \ 7 \ 8 \ 9 \ 10 \ 11 \ 12 \]
TEST ITEM 1: \( 1 \times 4 \) GIVES

TEST ITEM 2: \( 1 \times 10 \) GIVES

TEST ITEM 3: \( 1 \times 1 \) GIVES

EXAMPLE 2:
\[ 1 \times 16 \text{ gives } 1 \ 2 \ 3 \ 4 \ 5 \ 6 \ 7 \ 8 \ 9 \ 10 \ 11 \ 12 \ 13 \ 14 \ 15 \ 16 \]
TEST ITEM 1: \( 1 \times 18 \) GIVES

TEST ITEM 2: \( 1 \times 13 \) GIVES

TEST ITEM 3: \( 1 \times 14 \) GIVES

EXAMPLE 3:
\[ 1 \times 13 \text{ gives } 1 \ 2 \ 3 \ 4 \ 5 \ 6 \ 7 \ 8 \ 9 \ 10 \ 11 \ 12 \ 13 \]
TEST ITEM 1: \( 1 \times 19 \) GIVES

TEST ITEM 2: \( 1 \times 15 \) GIVES

TEST ITEM 3: \( 1 \times 11 \) GIVES
EXAMPLE 4:  15  GIVES  1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
TEST ITEM 1:  17  GIVES
TEST ITEM 2:  12  GIVES
TEST ITEM 3:  16  GIVES

EXAMPLE 5:  11  GIVES  1 2 3 4 5 6 7 8 9 10 11
TEST ITEM 1:  14  GIVES
TEST ITEM 2:  14  GIVES
TEST ITEM 3:  19  GIVES
MATERIALS FOR RULE 5

RULE

IF V IS A STRING OF NUMBERS +/V GIVES THE SUM OF THE NUMBERS.

OBJECTIVE

GIVEN 3 PROBLEMS WITH OPERATION +/ AND A STRING OF NUMBERS, V, YOU WILL COMPUTE +/V FOR AT LEAST 2 PROBLEMS.

EXAMPLE 1:  +/2 3 6 2 GIVES 13
TEST ITEM 1:  +/1 3 2 GIVES ---------
TEST ITEM 2:  +/0 2 GIVES ---------
TEST ITEM 3:  +/12 23 1 GIVES ---------

EXAMPLE 2:  +/2 0 3 1 GIVES 6
TEST ITEM 1:  +/3 0 2 3 GIVES ---------
TEST ITEM 2:  +/1 1 GIVES ---------
TEST ITEM 3:  +/2 0 0 GIVES ---------

EXAMPLE 3:  +/2 4 GIVES 6
TEST ITEM 1:  +/10 100 3 GIVES ---------
TEST ITEM 2:  +/2 5 4 1 GIVES ---------
TEST ITEM 3:  +/2 2 2 GIVES ---------
EXAMPLE 4:  +/2 1 0 1 GIVES 4
TEST ITEM 1:  +/3 2 4 GIVES -------
TEST ITEM 2:  +/0 1 3 5 2 GIVES -------
TEST ITEM 3:  +/1 2 3 4 5 GIVES -------

EXAMPLE 5:  +/100 10 1 GIVES 111
TEST ITEM 1:  +/5 5 GIVES -------
TEST ITEM 2:  +/4 7 3 GIVES -------
TEST ITEM 3:  +/0 1 2 3 4 5 GIVES -------
MATERIALS FOR RULE 

RULE

IF V IS A STRING OF NUMBERS, \[ V \] GIVES THE LARGEST NUMBER OF THE STRING.

OBJECTIVE

GIVEN 3 PROBLEMS WITH OPERATION \[ / \] AND A STRING OF NUMBERS, \( V \), YOU WILL COMPUTE \( /V \) FOR AT LEAST 2 PROBLEMS.

EXAMPLE 1: \[ /2 3 0 1 \] GIVES 3
TEST ITEM 1: \[ /1 2 0 2 \] GIVES
TEST ITEM 2: \[ /1 3 0 \] GIVES
TEST ITEM 3: \[ /23 12 1 \] GIVES

EXAMPLE 2: \[ /2 0 1 \] GIVES 2
TEST ITEM 1: \[ /3 0 2 \] GIVES
TEST ITEM 2: \[ /3 31 33 31 \] GIVES
TEST ITEM 3: \[ /1 2 3 4 \] GIVES

EXAMPLE 3: \[ /4 5 3 2 \] GIVES 5
TEST ITEM 1: \[ /101 107 111 11 \] GIVES
TEST ITEM 2: \[ /5 5 4 4 \] GIVES
TEST ITEM 3: \[ /4 2 0 10 3 \] GIVES
EXAMPLE 4: \[ \frac{1}{2} 3 2 5 4 3 2 \] GIVES 5

TEST ITEM 1: \[ \frac{1}{2} 1 1 \] GIVES

TEST ITEM 2: \[ \frac{1}{4} 3 2 2 4 3 3 \] GIVES

TEST ITEM 3: \[ \frac{1}{2} 1 3 2 3 \] GIVES

EXAMPLE 5: \[ \frac{1}{0} 100 21 25 \] GIVES 100

TEST ITEM 1: \[ \frac{1}{10} 100 3 \] GIVES

TEST ITEM 2: \[ \frac{1}{2} + 3 + 5 1 4 \] GIVES

TEST ITEM 3: \[ \frac{1}{5} 4 3 2 \] GIVES
MATERIALS FOR RULE 5

RULE

IF V IS A STRING OF NUMBERS AND S IS A WHOLE NUMBER, S+V GIVES A STRING CONTAINING ALL BUT THE FIRST S ELEMENTS OF V.

OBJECTIVE

GIVEN 3 PROBLEMS WITH OPERATIONAL +, A WHOLE NUMBER, S, AND A STRING OF NUMBERS V, YOU WILL COMPUTE S+V FOR AT LEAST 2 PROBLEMS.

EXAMPLE 1: 2+4 1 3 6 2 GIVES 3 6 2
TEST ITEM 1: 3+9 6 8 4 7 GIVES
TEST ITEM 2: 1+6 8 10 3 5 7 GIVES
TEST ITEM 3: 5+1 2 3 4 5 6 GIVES

EXAMPLE 2: 4+1 3 2 1 GIVES 1
TEST ITEM 1: 1+2 8 3 GIVES
TEST ITEM 2: 4+2 4 6 8 10 12 14 GIVES
TEST ITEM 3: 3+1 2 1 3 1 4 GIVES

EXAMPLE 3: 1+3 5 8 7 GIVES 5 8 7
TEST ITEM 1: 2+3 3 4 5 GIVES
TEST ITEM 2: 5+0 1 2 3 4 5 GIVES
TEST ITEM 3: 3+1 2 3 4 5 6 GIVES
EXAMPLE 4:
3 + 5 4 3 2 1 GIVES 2 1

TEST ITEM 1: 5 + 5 4 3 2 1 0 GIVES

TEST ITEM 2: 2 + 1 0 0 0 GIVES

TEST ITEM 3: 3 + 1 0 1 2 3 4 GIVES

EXAMPLE 5:
5 + 1 3 2 4 9 7 6 8 GIVES 7 6 8

TEST ITEM 1: 2 + 3 1 2 GIVES

TEST ITEM 2: 4 + 6 5 4 3 2 1 0 GIVES

TEST ITEM 3: 1 + 0 1 2 3 4 GIVES
MATERIALS FOR RULE 6

RULE

IF A AND B ARE STRINGS OF NUMBERS, A+×B GIVES THE SUM OF THE PRODUCTS OF THE CORRESPONDING ELEMENTS OF A AND B.

OBJECTIVE

GIVEN 3 PROBLEMS WITH OPERATION +,×, A PAIR OF STRINGS OF NUMBERS, A AND B, YOU WILL COMPUTE A+×B FOR AT LEAST 2 PROBLEMS.

EXAMPLE 1: 1 2+.×5 3 GIVES 11
TEST ITEM 1: 1 0 3+.×2 4 1 GIVES
TEST ITEM 2: 0 0+.×1 3 GIVES
TEST ITEM 3: 2 3+.×2 1 GIVES

EXAMPLE 2: 2 3 2+.×3 4 2 GIVES 22
TEST ITEM 1: 0 4 0+.×3 0 1 GIVES
TEST ITEM 2: 2 3+.×1 2 GIVES
TEST ITEM 3: 0 5 0+.×0 5 1 GIVES

EXAMPLE 3: 3 2+.×0 2 GIVES 4
TEST ITEM 1: 1 5+.×5 0 GIVES
TEST ITEM 2: 2 3+.×2 3 GIVES
TEST ITEM 3: 1 2 3+.×3 2 1 GIVES
EXAMPLE 4: 1 2 3×2 3 1 GIVES 11
TEST ITEM 1: 1 0 1×0 1 0 GIVES
TEST ITEM 2: 1 5×2 3 GIVES
TEST ITEM 3: 0 1 2 4×4 3 2 0 GIVES

EXAMPLE 5: 2 4 3×5 3 2 GIVES 28
TEST ITEM 1: 1 0 2×0 9 3 GIVES
TEST ITEM 2: 1 1 2 2×1 1 0 1 GIVES
TEST ITEM 3: 5 4×3 2 GIVES
MATERIALS FOR RULE 7

RULE

If V is a string of numbers and S is a whole number, SΦV gives a string where the elements of V are rotated circularly S elements to the left.

OBJECTIVE

Given 3 problems with operation φ, a whole number S, and numbers V, you will compute SΦV for at least 2 problems.

Example 1: 4Φ5 12 6 13 7 14 gives 7 14 5 12 6 13

Item 1: 2Φ2 3 4 5 gives

Item 2: 7Φ5 10 15 20 gives

Test item 3: 1Φ1 2 3 4 5 gives

Example 2: 1Φ21 32 45 gives 32 45 21

Test item 1: 3Φ2 3 4 5 gives

Test item 2: 0Φ7 1 6 5 gives

Test item 3: 4Φ1 2 3 4 5 6 gives

Example 3: 2Φ6 14 8 gives 8 6 14

Test item 1: 3Φ9 8 7 6 5 gives

Test item 2: 4Φ35 28 3 2 gives

Test item 3: 2Φ2 0 1 0 gives
EXAMPLE 4: 301 3 2 4 5 GIVES 4 5 1 3 2
TEST ITEM 1: 102 3 4 5 GIVES
---------
TEST ITEM 2: 402 1 3 GIVES
---------
TEST ITEM 3: 207 3 3 1 GIVES
---------
EXAMPLE 5: 504 3 2 GIVES 2 4 3
TEST ITEM 1: 1015 20 25 30 GIVES
---------
TEST ITEM 2: 301 2 3 GIVES
---------
TEST ITEM 3: 503 1 GIVES
---------
MATERIALS FOR UNIT 8

RULE

IF Y IS A STRING OF NUMBERS, A V GIVES THE FORM:

THE ELEMENTS OF Y WHICH WOULD SELECT THE ELEMENTS FROM ORDER:


OBJECTIVE

GIVEN AN OPERAND WITH OPERATIONS A AND A STRING
SOLVE THESE FIRST TWO PROBLEMS.

EXAMPLE 1: 3 5 6 5 4

ITEM 1: 3 5 4 3 2 GIVES

ITEM 2: 3 5 4 3 2 GIVES

ITEM 3: 3 5 4 3 2 GIVES

EXAMPLE 2: 3 5 6 5 4

ITEM 1: 3 5 4 3 2 GIVES

ITEM 2: 3 5 4 3 2 GIVES

ITEM 3: 3 5 4 3 2 GIVES

EXAMPLE 3: 3 5 6 5 4

ITEM 1: 3 5 4 3 2 GIVES

ITEM 2: 3 5 4 3 2 GIVES

ITEM 3: 3 5 4 3 2 GIVES
EXAMPLE 4: 43 10 5 1 GIVES 4 1 3 2
TEST ITEM 1: 423 12 9 22 GIVES
TEST ITEM 2: 40 3 7 1 4 GIVES
TEST ITEM 3: 46 8 9 10 GIVES

EXAMPLE 5: 48 3 0 6 GIVES 3 2 4 1
TEST ITEM 1: 410 100 1 1000 GIVES
TEST ITEM 2: 46 5 4 3 2 1 GIVES
TEST ITEM 3: 42 8 5 6 9 GIVES
POSTTEST

1. \(+\frac{1}{2} 16\) GIVES
   
2. \(\frac{7}{5} 425917\) GIVES
   
3. 1023+.\times301 GIVES
   
4. \(4\phi31629\) GIVES
   
5. \(\Delta27913\) GIVES
   
6. \(\rho35142\) GIVES
   
7. \(19\) GIVES
   
8. \(2+987\) GIVES
   
9. \(\Delta0312\) GIVES
   
10. \(\rho34502\) GIVES
   
11. \(+/123456\) GIVES
   
12. \(5+612432810\) GIVES
   
13. \(3\phi31629\) GIVES
   
14. \(12\) GIVES
   
15. \(\frac{7}{5}143\) GIVES
16. \( 2 \times 1 \times 2 \times 3 \) GIVES 

17. \( 45 \div 3 \div 2 \div 4 \) GIVES 

18. \( 1+3 \div 2 \div 1 \div 0 \) GIVES 

19. \( 1+1+1 \times 9 \div 3 \) GIVES 

20. \( p15 \div 24 \) GIVES 

21. \( +/10 \div 2 \div 10 \) GIVES 

22. \( 0\Phi9 \div 6 \div 1 \div 3 \) GIVES 

23. \( 14 \) GIVES 

24. \( /0 \div 8 \div 3 \div 2 \) GIVES
RETENTION TEST

1. 210 21 GIVES

2. 17 GIVES

3. +/3 1 GIVES

4. f/0 9 4 2 GIVES

5. +2 1 3 4 GIVES

6. 3 4 +1 .x2 1 3 GIVES

7. 5\#1 2 3 4 5 GIVES

8. 4 2 1 7 3 4 GIVES

9. +/9 4 5 2 GIVES

10. f/28 17 29 26 27 GIVES

11. 2+1 7 6 5 9 GIVES

12. 2\# 0 3 1 4 GIVES

13. p1 0 2 3 5 1 GIVES

14. 16 GIVES

15. 1 2 1 3+.x3 1 0 2 GIVES

16. 43 1 2 4 GIVES
17. \(\frac{1}{15} \times 4\) GIVES

18. \(0 \times 8 \times 6\) GIVES

19. \(10 \times 100 \times .x \times 3 \times 4\) GIVES

20. \(45 \times 10 \times 0 \times 8 \times 6\) GIVES

21. \(12\) GIVES

22. \(182 \times 34 \times 61\) GIVES

23. \(+/0 \times 1 \times 2 \times 3 \times 4 \times 5\) GIVES

24. \(+/0 \times 3 \times 0 \times 1 \times 2\) GIVES
TRANSFER TEST

TRANSFER ITEM 1

EXAMPLE 1: \( \frac{1}{4} \ 3 \ 2 \ 1 \ 7 \) GIVES 1
EXAMPLE 2: \( \frac{1}{2} \ 6 \ 4 \ 3 \ 72 \ 6 \) GIVES 2

PROBLEM 1: \( \frac{1}{2} \ 5 \ 7 \ 9 \ 11 \) GIVES

PROBLEM 2: \( \frac{1}{4} \ 0 \ 3 \ 1 \ 7 \) GIVES

PROBLEM 3: \( \frac{1}{4} \ 43 \ 41 \ 46 \) GIVES

TRANSFER ITEM 2

EXAMPLE 1: \( \times \frac{1}{14} \) GIVES 24
EXAMPLE 2: \( \times \frac{1}{16} \) GIVES 720

PROBLEM 1: \( \times \frac{1}{13} \) GIVES

PROBLEM 2: \( \times \frac{1}{13} \) GIVES

PROBLEM 3: \( \times \frac{1}{12} \) GIVES

TRANSFER ITEM 3

EXAMPLE 1: 2 7 9 1 | 3 4 8 1 GIVES 3 7 9 1
EXAMPLE 2: 3 0 5 4 | 1 2 1 5 6 2 GIVES 3 1 5 6 2

PROBLEM 1: 3 1 2 4 | 3 2 1 3 GIVES

PROBLEM 2: 9 7 5 3 | 2 4 6 8 GIVES

PROBLEM 3: 25 4 32 | 21 3 32 GIVES
TRANSFER ITEM 4

EXAMPLE 1: \(7 \ 2 \ 6 \ 1 \ 3\) GIVES 1 3 5 2 4
EXAMPLE 2: \(7 \ 0 \ 3 \ 1 \ 2\) GIVES 2 4 3 1

PROBLEM 1: \(7 \ 2 \ 6 \ 3 \ 7\) GIVES

-----

PROBLEM 2: \(7 \ 2 \ 3 \ 4 \ 1\) GIVES

-----

PROBLEM 3: \(7 \ 5 \ 6 \ 3 \ 1 \ 4 \ 2\) GIVES

-----

TRANSFER ITEM 5

EXAMPLE 1: 2 4 9+.-2 3 5 GIVES 5
EXAMPLE 2: 9 7 6 4+.-8 5 3 2 GIVES 8

PROBLEM 1: 11 2 1+.-5 1 1 GIVES

-----

PROBLEM 2: 2 0 5 3+.-1 0 4 1 GIVES

-----

PROBLEM 3: 3 4 1+.-3 4 1 GIVES

-----

TRANSFER ITEM 6

EXAMPLE 1: -3+7 0 1 4 6 8 GIVES 7 0 1
EXAMPLE 2: -5+4 3 1 5 6 0 4 GIVES 4 3

PROBLEM 1: -1+2 1 3 6 GIVES

-----

PROBLEM 2: -2+9 7 5 GIVES

-----

PROBLEM 3: -4+2 4 3 0 2 1 GIVES

-----
TRANSFER ITEM 7

EXAMPLE 1: \(-3\leq 1 5 6 2 4\) GIVES \(6 2 4 1 5\)
EXAMPLE 2: \(-5\leq 2 1 3\) GIVES \(1 3 2\)

PROBLEM 1: \(-1\leq 4 2 0\) GIVES

PROBLEM 2: \(-4\leq 2 3 1 2\) GIVES

PROBLEM 3: \(-6\leq 1 2 8 1\) GIVES

TRANSFER ITEM 8

EXAMPLE 1: \(3+5 6 4 1 2\) GIVES \(5 6 4\)
EXAMPLE 2: \(5+2 1 7 3 4 0 12\) GIVES \(2 1 7 3 4\)

PROBLEM 1: \(2+3 7 4 5\) GIVES

PROBLEM 2: \(1+4 2 7 3\) GIVES

PROBLEM 3: \(3+2 7 17\) GIVES
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