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AN INFORMATION PROCESSING APPROACH TO PERFORMANCE ASSESSMENT. I--ETC(U)
NOV 78 T W ALLEN, A M ROSE, L J KRAMER N00014-76-C-0871
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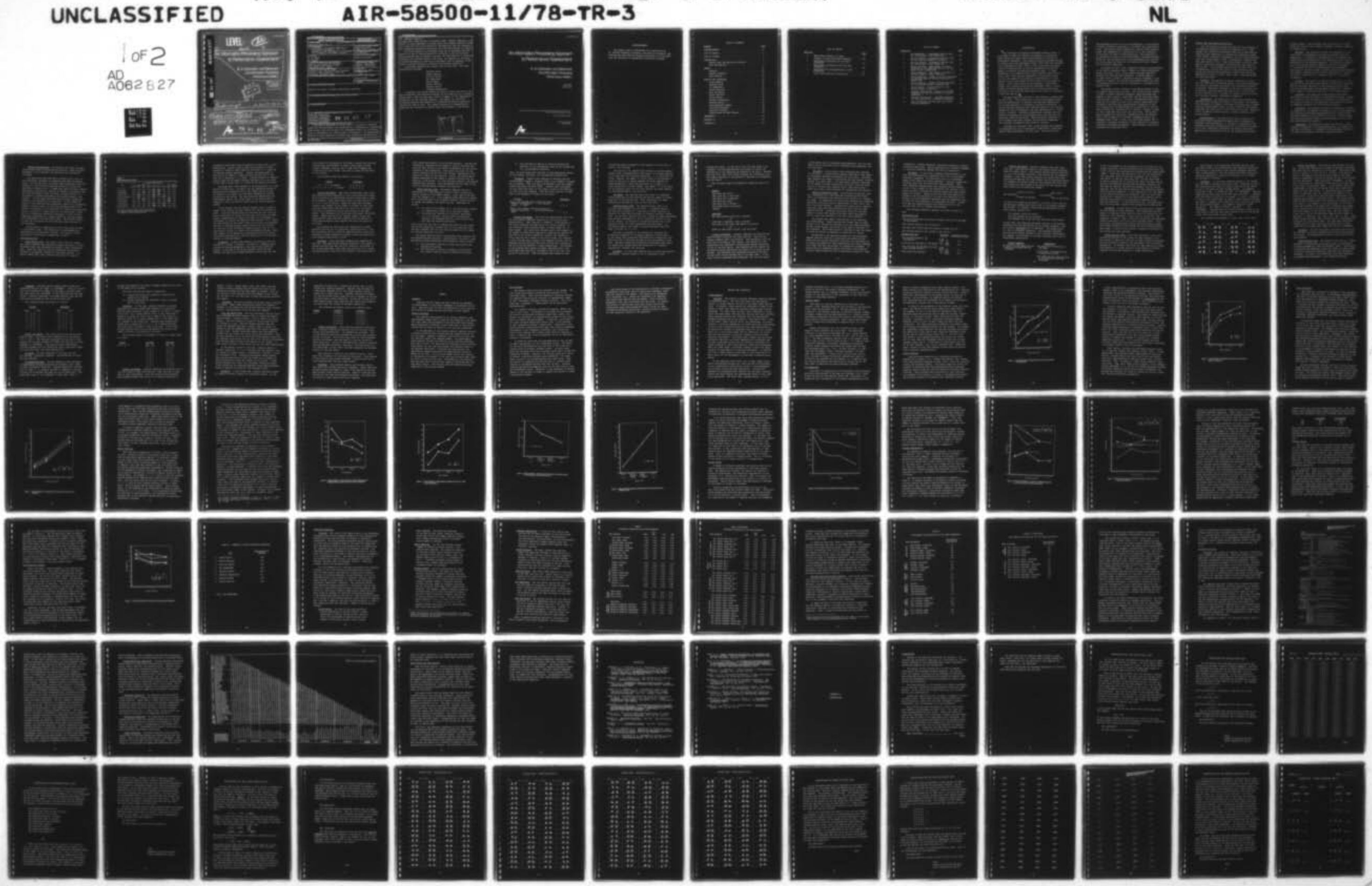

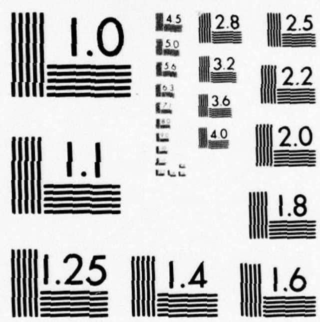

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An Information Processing Approach to Performance Assessment

III. An Elaboration and Refinement of an Information Processing Performance Battery.

Ted W. Allen
Andrew M. Rose
Leslie J. Kramer

Technical rept. no. 3, 16 Nov 77 - 30 Nov 78

Prepared for the Personnel and Training Research Programs, Psychological Sciences Division, Office of Naval Research, Arlington, Virginia.

AIR-58500-11/78-TR-3

Contract No. N00014-76-C-0871

RR042-04 RR042-04-01

TECHNICAL REPORT
Nov [redacted] 78

131p.

79 01 02 27

AMERICAN INSTITUTES FOR RESEARCH / 1055 Thomas Jefferson Street, NW, Washington, DC 20007

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Technical Report No. 3	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) "An Information Processing Approach to Performance Assessment: III. An Elaboration and Refinement of an Information Processing Performance Battery"		5. TYPE OF REPORT & PERIOD COVERED Technical Report 16 Nov. 1977 - 30 Nov. 1978 6. PERFORMING ORG. REPORT NUMBER AIR 58500-TR
7. AUTHOR(s) T. W. Allen A. M. Rose L. Kramer		8. CONTRACT OR GRANT NUMBER(s) N00014-76-C-0871
9. PERFORMING ORGANIZATION NAME AND ADDRESS American Institutes for Research 1055 Thomas Jefferson St., N.W. Washington, D.C. 20007		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 61153N; RR042-04-01; RR042-04; NR 150-391
11. CONTROLLING OFFICE NAME AND ADDRESS Personnel and Training Research Programs, Office of Naval Research - Code 458 Arlington, Virginia 22217		12. REPORT DATE November 30, 1978 13. NUMBER OF PAGES 125
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Personnel Technology
Individual Differences
Personnel Assessment
Information Processing
Cognitive Processing

79 01 02 27

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes the third study in a program of research regarding the development and validation of a comprehensive standardized test battery that can be used as an assessment device for the evaluation of performance in a wide variety of situations. The standardized battery is being designed to possess high reliability and predictive

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20. Abstract (Cont'd.)

validity for a wide variety of criterion tasks. Equally important, the battery is being designed to include tests that possess construct validity: there will be a firm theoretical and empirical base for inferring the information processing structures that the tests purport to measure.

The major purpose of the present study was to determine the properties of a set of tasks selected for inclusion in the test battery. Three questions were of primary interest: the replicability of previous findings with alternate forms of the tasks, the adequacy of the tasks to provide measures of individual differences, and the adequacy of the tasks to provide measures of information processing operations.

Sixty-eight subjects were tested twice on each task. The tasks investigated included:

Physical Match
Letter Rotation
Scan and Search
Set Membership
Letter Recall
Mental Addition
Sentence Recall
Sentence Recognition

In general, the results showed the forms of tasks used here to be quite compatible with previous findings for all tasks but one, Sentence Recognition. Even for this task, there is support in the experimental literature for the obtained findings. The support for individual difference measures and measures of information-processing operations varied from task to task. The summary presents our recommendations regarding the inclusion of various tasks and measures in the battery.

AIR 58500-11/78-TR

An Information Processing Approach to Performance Assessment:

III. An Elaboration and Refinement of an Information Processing Performance Battery

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TECHNICAL REPORT
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AMERICAN INSTITUTES FOR RESEARCH / 1055 Thomas Jefferson Street, NW, Washington, DC 20007

ACKNOWLEDGMENTS

The authors wish to acknowledge the contribution of Dr. Tetsuro Motoyama of American Institutes for Research, who authored the data scoring programs and guided us in the selection and derivation of appropriate statistical analyses.

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INTRODUCTION

The Information Processing Performance Battery (IPPB) is an attempt to apply the theories and methods of laboratory-based studies of human cognitive performance to the area of performance assessment. The primary rationale developed through an ongoing series of experiments (Rose, 1974; Rose and Fernandes, 1977; Fernandes and Rose, 1978) is that individuals can potentially be characterized in terms of parameters derived from models of selected information processing tasks. If these parameters can be demonstrated to meet standard test-item criteria, then a test battery comprised of such measures would not only be potentially predictive of performance on a wide variety of real-world tasks but would also be firmly based in theory. Such a test battery would represent a significant advance over standard selection and placement tests; it would promote increased understanding of the cognitive operations involved in any criterion task shown to be related to constructs in the test battery.

The basic approach involved in this research is exemplified by Rose (1974). The strategy was to select experimental tasks from the psychological literature that had been demonstrated to be valid measures of information processing constructs. A set of tasks was selected; each task was adapted to fit logistic demands of time and equipment, and then administered to a large group of subjects. Extensive correlational analyses were conducted to determine the relationships among the tasks and the individual task reliabilities. These procedures resulted in a set of tasks which were reliable, statistically independent, and (arguably) possessing high construct validity.

The Rose and Fernandes (1977) study extended this approach by hypothesizing a set of constructs ("operations") which were used to model performance for each task. Since most of the task parameters could be cast as time measures, it was possible to employ regression techniques to "converge" upon these operations. Some fairly simple assumptions, such as linear additive stages and independence of operations, led to the estimation of durations for some of these operations. More importantly, the generation of these constructs provided a valuable heuristic device for the interpretation of task performance and provided an initial empirical basis for the isolation of basic information processing components.

Fernandes and Rose (1978) attempted to extend the methodology to the realm of memorial tasks. Based on a study by Underwood, Boruch, and Malmi (1977), several memory-related tasks were selected for more detailed evaluation. Although modeling of these tasks in terms of operations was not attempted, it was possible to examine the obtained relationships among the tasks for commonalities that could be interpreted in information processing terms.

The present study is similar to the above studies in that the general approach was the same: the literature was reviewed in order to select candidate paradigms, these paradigms were adapted to meet logistic limitations, and the tasks were administered twice to subjects. The major differences between this study and the others are that first, several tasks previously included in the IPPB were readministered, primarily to test for alternate-form consistencies and to capitalize on the previous findings for interpretation of results. Second, a number of "new" treatments were built into this study. These treatments extended the theoretical underpinnings of the selected tasks, thus allowing for "stronger" interpretations of the phenomena under study. Third, this study made greater use of analysis of variance techniques for the isolation of potential individual difference parameters. These changes in analytical procedures are discussed below.

General Task and Operations Overview

The task selection process was based upon an extension of the approach advocated by Rose and Fernandes (1977). They suggest that information processing tasks can be described as requiring some combination of information manipulation operations, where an operation represents a set of control processes that must be performed in order to successfully complete the task (see Carroll, 1974). Rose and Fernandes arrived at eight specific operations necessary to describe the tasks used in their study. In the present study we have refined their list of operations, limiting the scope of some operations, more clearly delineating the boundaries of others, and adding new operations in order to cover a wider range. These operations are described below.

Encoding: The operation by which information is input into the information processing system. The encoding processes are primarily concerned with making the preliminary analysis of external information necessary to get that information into the system. Some processes that might occur in the context of this operation are: attribute or feature extraction, selection, erasure, masking, and temporal summation.

Abstraction: The operation by which new structures are generated from information already in the system. The abstraction processes are primarily concerned with generation of higher level structures beyond those initially encoded in the system. Processes that might occur in this operation include: Neisser's (1967) synthesis, schema formation, concept formation, and categorization.

Transformation: The operation by which information is converted into an equivalent structure that is required for successful task performance. In contrast to abstraction, the processes involved in transformation do not involve the generation of new (unencoded) information but rather require the application of some stored rules to the information structure already present. Some processes that could occur in a transformation operation are: rotation, chunking, chaining, updating, and segmentation.

Recoding: The operation by which the information is converted into a corresponding structure of different form or composition. In contrast to transformation, the recoding processes require the generation of new information that is not an end-product of the encoding operation. In contrast to abstraction, the recoding operation does not require a "synthesis" or "formation" so much as a substitution of corresponding structures of different types. Recoding processes would include, for example, changing the structure of information in the system from a verbal form to an imaginal form, or from acoustic to semantic.

Storage: The operation by which new information is integrated into the existing organization of information structures and the processes impinging on the information while there. Storage processes might include: decay, degradation, displacement, tagging, unlearning, and Estes' (1972) reverberation.

Retrieval: The operation by which previously stored information is made available to the processing system. Whether it is indicative of the extent of research on the operation or the primitive nature of the operation, the literature contains no exemplary processes for the retrieval operation.

Searching: The operation by which an information structure is examined for the presence or absence of one or more properties. The information structure examined may be one already in the processing system or one external to it (e.g., a visual array). The searching operation might include processes such as attribute verification and scanning.

Comparison: The operation by which two entities, either internal or external to the processing system, are judged to be the same or different. An example of the processes involved in the comparison operation would be a matching process.

Decision and Response: The operation by which the appropriate motor action is selected and executed. Among the many processes in this operation are monitoring and evaluation processes.

The operations described above represent only a part of the information necessary to completely describe task performance. At the very least, one might need information about the contents or form of the information structure to which the operation is applied (e.g., a comparison operation might respond differently to pictorial, acoustic or semantic information) and one needs information about the state of system stress (i.e., the amount of incoming information and required speed of processing). For the tasks described below we shall assume that content of the operations is irrelevant. In most cases the design of the tasks and data comparisons support this assumption; however, since we cannot at this time precisely specify the effects of contents or the interaction of contents and operations we have a problem of "identifiability" and would have to make this or an equivalent assumption regardless of task and data comparison considerations. System stress can also be assumed to be comparable in the different tasks. The possible effects of these two variables will be entertained where relevant in the discussion.

Listed below is a description of the eight tasks included in the present study. Each description is accompanied by a discussion of the operations involved. The nature of their involvement in each task is summarized in Table 1.

Task Descriptions

Letter Recall Task. The letter recall task is a serial, short-term retention task designed to embody the spirit of both the memory span task and Waugh and Norman's (1965) probe-digit task. These two tasks are used to investigate the limited (storage or processing) capacity of the memory system. In a typical memory span task, subjects study lists of items of

TABLE 1.
Operational Analysis of Tasks

Tasks	Information Processing Operations								
	Encoding	Abstraction	Transformation	Recoding	Storage	Retrieval	Search	Comparison	Decision-response
1. Letter recall	minor	minor	minor	minor	**major**	**major**	minor	minor	minor
2. Mental addition	minor	minor	**major**	minor	**major**	**major**	minor	minor	minor
3. Sentence recall	minor	**major**	minor	minor	**major**	**major**	minor	minor	minor
4. Sentence recognition	minor	**major**	minor	minor	**major**	minor	**major**	minor	minor
5. Letter rotation	minor	minor	**major**	minor	minor	minor	minor	**major**	minor
6. Physical match	minor	minor	minor	minor	minor	minor	minor	**major**	minor
7. Set membership	minor	minor	minor	minor	**major**	minor	**major**	minor	minor
8. Scan and search	minor*	minor	minor	minor	**major**	minor	**major**	minor	minor

major = operation is of MAJOR importance in determining task performance.
minor = operation is of MINOR importance in determining task performance.
* For degraded stimuli, encoding is of MAJOR importance

increasing length which must be recalled in order from a single presentation. Typical results show the percentage of items recalled to remain at about 100% for the first 4 ± 1 items and to decrease rapidly thereafter. Usually the memory span is defined as the number of items recalled correctly 50% of the time and is typically 7 ± 2 items. A better measure of capacity however might be the amount recalled correctly at or near 100% of the time in which case 4 ± 1 would be the capacity estimate.

The probe-digit task consists of the presentation of a long series of items (e.g., 14 digits) and the immediate probing of retention by re-presenting one of the items from the series. The subject is to recall the item which immediately followed the probe in the series. The task typically demonstrates the displacement effect, that later items in the series tend to displace or knock out earlier items from the limited capacity system.

In the present task the subject studies lists of varying length (5-10 letters) and must recall the last five letters in order. Since the subject does not know when the list will end and is instructed to retain only the last five items, we would expect, theoretically at least, the subject to be engaged in a procedure of filling the system to near capacity (4 ± 1 items) and then displacing the oldest items as new items are processed. Variance in task performance should result from two sources: (1) the size of the individual's memory capacity and (2) the individual's ability to control the displacement process. Thus with respect to the operations discussed previously we expect the storage operations and retrieval operations to be the major factors in task performance.

Procedure. In this task subjects recalled the last five letters of a series of letters. In each trial subjects heard a series of letters presented at the rate of one letter per second. At the end of the series subjects heard the word "RECALL" and were given fifteen seconds to write down the last five letters of the series in the order in which they occurred. Instructions told subjects to leave a blank space if they couldn't remember a letter, and if they could remember the letters but not their order, they were to guess the positions of the letters.

The following shows the events of two trials:

STIMULI	RESPONSES
"K C M T N, Recall"	K C M T N
"A M G S K P F C, Recall"	S K P F C

Stimuli and design. This task was presented twice a day. Each administration consisted of five trials explicitly designated as practice and twenty-two critical trials with no feedback provided. There were three trials for each series of 5, 6, 7, 8, 9, and 10 letters. These 18 trials were arranged randomly with respect to the number of letters in each trial with the restrictions that the first trial be a five-letter trial and no consecutive trials have stimuli of the same length. The remaining four trials were non-scored five-letter series. These occurred as the second, fourth, sixth, and twenty-second trials and were inserted with the purpose of discouraging subjects from ignoring the first few letters of any trial.

The stimulus for each trial was constructed by random selection from the set of consonants, excluding W and Y, with the constraints that no letter be repeated during a trial and a maximum of three acoustically similar letters be permitted to occur consecutively within a trial.

Variables. Three principal measures were computed for the task. The order-recall measure consisted of the number of letters recalled from the last five letters in the series in the correct positions; thus credit was given only if a letter recalled was one of the last five letters in the series and if that letter was recalled in its correct position. The derived-free-recall consisted of the number of letters recalled from the last five letters in the series irrespective of the correspondence of their positions. Here credit was given for any letter recalled from the last five letters, regardless of the position in which it was recalled. Lastly, the series-recall measure consisted of the number of letters recalled from any position in the series. For each principal measure, two derived measures were obtained: mean performance and the slope of the function relating amount recalled and condition.

Mental Addition Task. The mental addition task is a replication of a task designed by Hitch (1978) to study processing capacity in the memory system. Hitch read to his subjects two numbers (e.g., "four hundred eighty-seven plus twenty-six") which they had to add together mentally, without writing or seeing the addends, and report the sum. Separately he varied:

(1) the size of the addends (i.e., two three-digit numbers or a three-digit number and a two-digit number),

(2) the amount and location of "carrying" operations (i.e., no carrying, carrying into tens position, carrying into hundreds position, and carrying into both tens and hundreds positions).

Hitch found that the time to complete the addition was greater for the two three-digit addends than for the three-digit and two-digit addends, and that the time increased with the number of carrying operations required.

The mental addition task in the present study combines the two above-mentioned variables. Theoretically, variance in task performance across individuals should depend on three factors:

(1) The individual's ability to store and maintain the addends and carries,

(2) The individual's ability to rapidly retrieve both the rules of addition and the addends and carries,

(3) The individual's ability to actually perform the addition; in our terminology, this can be categorized as a transformation operation.

Thus, the major operations involved in task performance should be the storage, retrieval, and transformation operations.

Procedure. Subjects were required to mentally add two multiple-digit numbers. Subjects heard a cue ("READY") followed by two numbers. They then had five seconds to add the numbers before they heard the word "STOP". Subjects were instructed to write down each digit of the answer as soon as the addition for that digit was complete. They were also told not to guess. Here is the sequence of events of two trials:

STIMULI	RESPONSES
"Ready, two hundred fifty-eight plus three hundred twenty-seven, ... (five second pause) ..., STOP"	5 8 5
"Ready, four hundred ninety-two plus two hundred forty-one, ... (five second pause) ..., STOP"	7 3 3

Stimuli and design. This task was administered twice each day and subjects completed twenty-four trials during each administration. They received no feedback. Fifty percent of the trials required the addition of two 3-digit numbers; in the remaining trials subjects added a 2-digit number to a 3-digit number. The trials were divided equally with respect to the number of carry-overs required to complete the addition so that 25% of the trials required no carries, 25% required a carry from the one's column to the ten's column, 25% required a carry from the ten's column to the hundred's column, and 25% required carries from both the one's and the ten's columns to the ten's and the hundred's columns respectively. The answers to the problems were chosen at random (excluding zero), and each answer was arbitrarily assigned to one of the four categories of carry-over. Then the addends were chosen so that the problem would correspond to the category of carry-over to which it was assigned.

The digits of the addends were modified to provide approximately equal representation of each digit 1-9 in each position of the sum, with the following exceptions: 1) in sums with two 3-digit addends, the number "9" is not found in the hundred's place of the first or second addends and large numbers are underrepresented in those two positions; 2) in sums of a 3-digit addend plus a 2-digit addend, the number "9" is not found in the hundred's place (of the first addend) and large numbers are underrepresented in this position.

Variables. The main data were the number of uncomputed (blank) positions in the reported sum and the number of correct positions in the reported sum. Mean performance for these measures was obtained for each of the conditions.

Sentence Recall Task. The sentence recall task is an original task designed for this study. It embodies much of the theoretical essence of a free-recall cluster analysis in studying the individual's attempt to organize incoming information. In the task, subjects are read a series of simple sentences, each sentence expressing an idea or attribute relating to one of four topics. At the end of the series subjects are to contiguously recall the ideas associated with each topic. In the present design, the number of ideas associated with each topic is varied (4, 5, or 6).

The task is designed to get subjects to integrate the information presented in the simple sentences on each topic. To the extent that individuals performed such integration, they should be able to decrease the memory load requirements of the task. The major operations determining performance then should be: abstraction (organization and integration of sentence information), storage, and retrieval.

Procedure. In this task subjects had to recall and organize information. Subjects heard a list of sentences on four alternating topics. At the end of the list they heard a cue ("RECALL") and had approximately two minutes to recall the information in the sentences and organize it by topic. Subjects were told that they could either organize the information into one complex sentence or use phrases to describe the information they had heard.

The following shows the sequence of events for part of a trial:

STIMULI

"The party was loud."
"The snake was in the cage."
"The party was a surprise."
"The cage was glass."
"The party was a success."
"The snake shook its rattles."
"RECALL"

RESPONSES

The loud surprise party was a success.

OR

Party was a surprise, loud, a success.

The snake in the glass cage shook its rattles.

OR

Snake in cage shook rattles, cage was glass.

Stimuli and design. Subjects completed one practice and three critical trials of this task each day. They did not receive feedback after the practice. The acquisition list for each trial was based on four topics. Each sentence in the acquisition list explained a relationship between attributes of one of the four topics. Each sentence had one subject and one word or phrase describing the subject or an action by the subject. The sentences were presented alternately by topic so that every fourth sentence was on the same topic. In the first trial 16 sentences were presented, four for each topic;

in the second trial 20 sentences were presented, five for each topic; and in the third trial 24 sentences were presented, six for each topic.

Variables. Two principal recall measures were obtained for the task. A cluster recall measure consisted of the number of attributes recalled contiguously for each topic. This measure reflects the number of attributes that the subject correctly assigns to a given topic. The item recall measures consisted of the number of nouns, adjectives, and verbs (with the exception of *TO BE*) that were recalled from a topic description. Credit was given in both measures for paraphrases and synonyms.

Sentence Recognition Task. The sentence recognition task is a replication of a task designed by Bransford and Franks (1971) to investigate the acquisition and retention of linguistic ideas. On acquisition in their study subjects were presented sentences containing various combinations of ideas from a complex, four-idea sentence. Retention was tested with a recognition test using only new sentences with ideas from the same complex sentence. Bransford and Franks found that the more ideas in a (new) test sentence the more likely the subjects were to judge that sentence as old with high confidence.

The present task added a modification to the Bransford and Franks design. Where Bransford and Franks used the same syntax in all the derived sentences as in the complex sentence, we have varied whether the syntax is the same or different in the sentences. This modification is intended to show the extent to which the effect is dependent on repetition of syntax.

Performance on the sentence recognition task presumably depends upon the individual integrating and organizing the ideas from the various sentences, such that the individual can no longer distinguish the idea combinations that were presented from those that were the product of integration processes. If syntas does not completely explain the effect, then whatever variance remains should be due to abstraction operations (idea integration), storage operations (retaining sentences in memory) and search operations. Search operations are involved as opposed to retrieval operations because the test is recognition.

Procedure. In this task, subjects decided whether or not they had heard particular sentences from a list of sentences previously presented. An acquisition list of 12 sentences based on two topics was orally presented. Fourteen recognition sentences about the two topics were then presented. After each recognition sentence was read, subjects decided whether or not it was a member of the acquisition list and gave a confidence rating to indicate how certain he/she was that his/her answer was correct. Subjects were told that the wording of a sentence from the recognition list had to be identical to the wording of the corresponding sentence from the acquisition list in order for the sentences to be considered the same. A practice task was completed before each administration of the critical task, but no feedback was provided.

The following shows the sequence of events of part of a task.

ACQUISITION LIST

"The rock rolled down the mountain crushing the hut at the edge of the woods."

"The actress looked at her reflection."

"The rock that rolled down the mountain crushed the hut."

"The actress wearing a hat looked in the mirror."

RECOGNITION LIST	RESPONSE	CONFIDENCE RATING
"The actress looked at her reflection."	(Yes) No	1
"A hut was at the edge of the woods."	Yes (No)	2
"The rock that rolled down the mountain crushed the hut."	(Yes) No	3
"The mirror was cracked."	Yes (No)	4

Stimuli and design. Subjects completed this task twice each day. Each task was based on two primary complex sentences about different topics. Each primary sentence had two subjects. In one of the primary sentences, each subject had two modifying phrases; in the other primary sentence one subject had three modifying phrases and the other subject had one modifying phrase. For example, the primary sentence "The teenager who lives next door broke the large window on the porch" has two subjects and each subject has two modifying phrases.

The teenager → lives next door.
The teenager → broke the window.

The window → was large.
The window → was on the porch.

In each of the remaining sentences in the task, one or more of the modifying phrases which were found in the primary sentence was deleted. For example, some sentences generated from the above primary sentence are:

The teenager broke the window.
The large window was on the porch.
The teenager who lives next door broke the large window.

In each task, the sentences generated from one of the primary sentences used the same wording as the primary sentence. This was called a consistent set of sentences. The example above is a set of consistent sentences. The sentences generated from the other primary sentence in the task were inconsistent. For example, the following is a primary sentence with a set of inconsistent generatives:

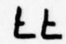
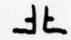
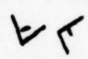
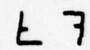
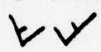
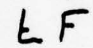
PRIMARY SENTENCE	GENERATIVES
The executive who drank the hot coffee at his desk had his briefcase.	The executive was sitting at his desk.
	At his desk, the executive was drinking hot coffee.
	The coffee was hot and was drunk by the executive with the briefcase.

Of the 14 sentences in the recognition list, two were the two primary sentences, six were sentences from the acquisition list ("OLD") and six were sentences the subjects had not heard before ("NEW"). Thus, both the acquisition list and the recognition list contained twelve non-primary sentences, six on each of two topics; of the six, half were "OLD" and half were "NEW". Of the six generatives of a particular topic, two were made by deleting one modifying phrase from the primary sentence, two were made by deleting two modifying phrases from the primary sentence, and two were made by deleting three modifying phrases from the primary sentence. In the acquisition list, the topics of the twelve sentences were alternated, that is, every other sentence was a generative of the same primary sentence and no generative was based on the same primary sentence as the previous generative. In the recognition list, the generatives plus the two primary sentences were presented in random order.

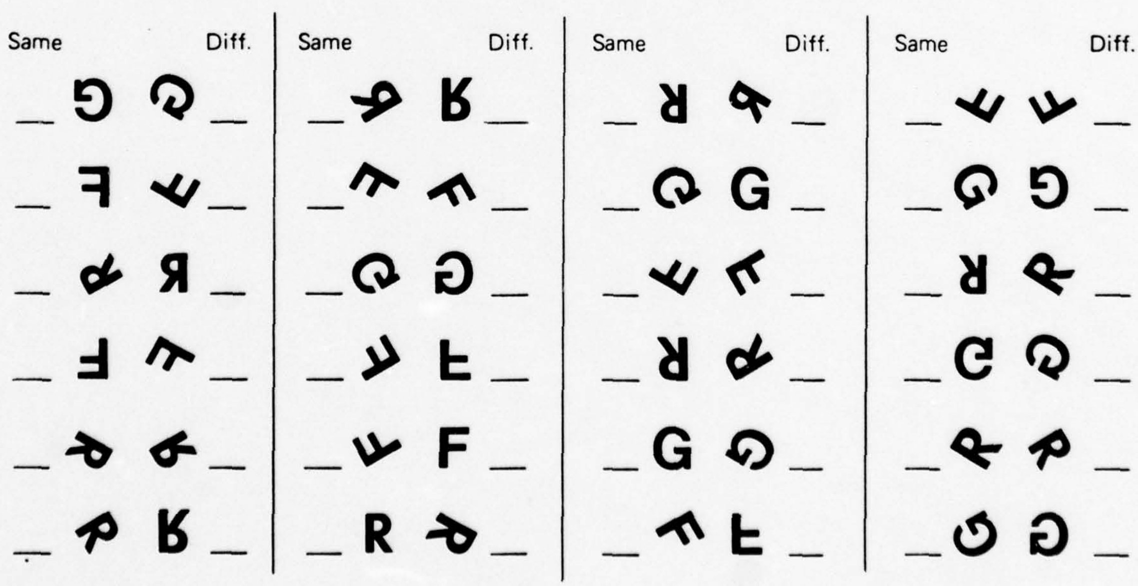
Variables. In this task the data were the yes-no judgments and the ratings of those judgments. The information was combined in a modified rating scale by giving all ratings for the subject's "old" responses a "plus" and all ratings for "new" responses a "minus". Thus, a 10-point rating scale was developed ranging from minus five to plus five (excluding zero). Using this scale, the best-fitting linear functions relating rating and sentence complexity were derived for old and new sentences. Mean number of errors and the overall frequency distribution of the ratings were also obtained.

Letter Rotation Task. This task replicates a task investigated extensively by Lynn Cooper and Roger Shepard (1973). The subject is shown two items and is asked to determine whether they are different objects or the same object from a different perspective. It has been found that the time required to answer this question is a linear function of the degree of rotation required to bring the figures to a common orientation.

With respect to the operations discussed earlier, this task would involve the transformation and comparison operations. The rotation of the objects would involve processes subsumed under transformations. Once the objects have been rotated the comparison operation is required to determine if the objects are the same or different.

Procedure. In this task, subjects decided if two letters were the same or different using two rules. According to Rule 1, two letters were the same if a subject could slide one letter on top of the other and they matched exactly. For example, using Rule 1  is "SAME" and  is "DIFFERENT". Subjects completed the first page of the task using only Rule 1. Subjects were instructed to use Rule 2 for pages 2, 3, and 4. According to Rule 2, two letters were the same if, after mentally rotating one letter, a subject could slide one letter on top of the other and they matched exactly. For example, using Rule 2  and  are "SAME" and  and  are "DIFFERENT". Subjects were given thirty seconds to work on the first page of this task and sixty seconds to work on the second, third, and fourth pages of this task.

The following are examples of trials used in this task:



Stimuli and design. This task was administered once each day. During each administration subjects completed four pages. Each page had four columns of 18 trials each. The stimuli were pairs of capital F's, G's, and R's. In half of the pairs of letters, the second letter was a mirror image of the first, making it impossible to slide the letters on top of one another and have them match. These pairs were "DIFFERENT". In the rest of the pairs of letters one letter was not a mirror image of the other, so they were "SAME". In the second, third, and fourth pages of the task the second letter was rotated with respect to the first letter. On the second page, the second letter of each pair had a 60° rotation with respect to the first letter, on the third page the second letter had a 120° rotation with respect to the first letter. And on the fourth page the second letter had a 180° rotation with respect to the first letter. For example, on the third page, if the first letter was oriented at an angle of 60° clockwise with respect to the vertical axis, the second letter would be oriented at 180° with respect to the vertical axis. The left member of a pair was in one of six positions clockwise with respect to vertical: 0° (vertical), 60°, 120°, 180°, 240°, or 300°. Since three letters were used, each item was one of 72 possible combinations for a particular page. The items were distributed randomly within a page, with the restriction that in each column 50% of the items were "SAME" and 50% were "DIFFERENT".

Variables. The data consisted of the mean time per item for the same - different judgments across the varying degrees of rotation. The percentage of errors in each condition was also computed.

Physical Match Task. The physical match task is a "same-different" classification task derived from an experimental paradigm developed by Posner and Mitchell (1967). The subject is presented two uppercase letters and asked to respond "same" if the two letters are physically identical and "different" otherwise. In terms of our operations, this task represents an uncomplicated assessment of the comparison process.

Procedure. Subjects saw two letters side by side and classified the pair as "SAME" or "DIFFERENT". A pair of letters was to be classified as "SAME" if the items in the pair were the same letter and "DIFFERENT" if the items were not the same letter. Subjects completed a non-timed practice task and then were given 45 seconds to work on the critical task.

The following shows the events of 7 trials:

STIMULI				RESPONSES			
Same			Diff.	Same			Diff.
___	E	E	___	✓	E	E	___
___	T	T	___	✓	T	T	___
___	E	H	___	___	E	H	✓
___	H	H	___	✓	H	H	___
___	T	E	___	___	T	E	✓
___	A	A	___	✓	A	A	___
___	E	A	___	___	E	A	✓

Stimuli and design. This task occurred once during each session (day). The stimuli were combinations of the letters A, E, H, and T. The task was constructed so that half of the stimuli had a correct response of "SAME" and half had a correct response of "DIFFERENT". The various letter combinations occurred randomly with the restriction that a particular answer not occur more than four times consecutively.

Variables. The data consisted of the mean time per for the same - different judgments. The percentage of errors was also obtained.

Set Membership Task. The set membership task replicates an experimental paradigm developed by Sternberg (1967, 1969) to study information retention. Subjects memorized a sub-span list of items (1 - 4 letters) and had to respond to a series of probes as to whether the probe was in the memory set. Subjects made "yes" or "no" responses to each item. Time to process and respond to the probe increased linearly as the size of the memory set increased.

This task involves two types of operations:

(1) Storage operations are required to maintain the memory set in memory.

(2) Search operations are required to scan the target set for the probe.

Procedure. In this task, subjects decided if letters presented in printed columns were members of a target set. Subjects were instructed to put a check to the left of a stimulus letter (in a column labeled "YES") if the letter was a member of a target set and to put a check to the right of a stimulus letter (in a column labeled "NO") if the letter was not a member of the target set. Subjects were verbally presented with a target set of 1, 2, 3, or 4 letters and were then given thirty seconds to work on the task. After thirty seconds subjects were told to stop working and to write the target letter(s) at the bottom of the page.

The following shows the sequence of events for eight items of a task:

TARGET	STIMULUS			RESPONSE		
	Yes		No	Yes		No
"B P Q N"	___	L	__	___	L	✓
	___	N	__	✓	N	__
	___	P	__	✓	P	__
	___	M	__	___	M	✓
	___	N	__	✓	N	__
	___	Q	__	✓	Q	__
	___	V	__	___	V	✓
	___	C	__	___	C	✓

Stimuli and design. Subjects completed two practice and 12 critical trials of this task each day. They received no feedback on their performance. Both the stimuli and the targets were randomly chosen from the set of 19 letters exclusive of vowels, Y and W. Target sets of one, two, three, and four letters occurred randomly with the restriction that no two consecutive targets had the same number of letters. Half of the letters in each stimulus list were members of the target set for that list, and the order in which the letters occurred was random.

Variables. The data consisted of the mean time to process each probe. These times were plotted against the number of elements in the target set and the best-fitting linear function derived. The percentage of errors was also computed.

Scan and Search Task. The scan and search task was originally developed by Ulric Neisser (1967) to assess the memory search process. Subjects search a list of letters for target letters. The list contains a column of letters with four to six letters to a row. Here the subject searches down the column and responds only when a target letter is found, as opposed to the set membership task where the subject responds to every item. Neisser found that search time increased the further down the column the target letter was positioned. Also, and most important to us, he found that with extensive practice, his subjects could search for any one of ten targets simultaneously with the same speed as they could search for one target. In other words, the size of the target set did not affect search times.

In the present version of the task, subjects memorize a sub-span target set (1, 2, or 4 letters) and then search a list of letters for target letters. Performance is tested on "clear" and "degraded" lists. Individual performance should depend upon storage operations to hold the target set in memory and search operations to scan the column for the target. A comparison between the "clear" and "degraded" conditions should reveal effects of the encoding operation since these processes would be required to "clean up" the degraded stimuli.

Procedure. In this timed task, subjects searched columns of groups of letters looking for particular letters. At the beginning of each trial, a target set of one, two, or four letters was verbally presented. Subjects then searched for items which contained one of the target letters, placing a check next to those that did. Subjects received 20 seconds for the one-letter target condition and 30 seconds for the two and four-letter target conditions. At the end of each trial, each subject drew a line under the last item he had looked at and wrote down the letters he had been looking for.

The following are events of part of a typical trial:

TARGET	STIMULUS	RESPONSE
B, F	A U M F Z	A U M F Z ✓
	L N D Q G	L N D Q G
	K L J D P	K L J D P
	Y K T M F	Y K T M F ✓
	X V D B Y	X V D B Y ✓

Stimuli and design. This task was completed twice each day. Subjects received two practice and six critical trials during each administration. No feedback was provided. Half of the stimulus pages were degraded by printing them through a series of filters. The filters were Xerox No. 8R535 Document Carrier and Screens, and were made of a regular pattern of small white dots. During an administration, subjects completed the non-degraded one-letter, two-letter, and four-letter target conditions, in that order, and then completed the degraded targets in the same order.

Each item was a string of five capital letters. There were four columns of 16 items each on each page. Fifty percent of the items in each column contained a target letter and no item contained more than one target letter.

Variables. The principal measure was the mean time to scan each item and make the yes-no judgments. These times were plotted against the number of items in the search set and the best-fitting linear function derived. Separate functions were derived for the clear and degraded conditions. The percentage of errors for each condition was also computed.

METHOD

Subjects

Subjects were 68 female and male students who answered an advertisement in the school newspaper at Georgetown University. They were paid for their participation in the study and were tested in groups ranging from three to eight people.

General Procedure

The subjects participated in two testing sessions, each approximately three hours in duration and scheduled a day apart. All eight tasks were presented in the same order each session. Where appropriate, different stimuli were used in each testing session and the order of stimuli in the task was randomized.

At the beginning of the testing sessions subjects received a booklet containing the instructions and response sheets for all the tasks. Appendix A presents instructions for each task and selected stimuli and response sheets. The experimenter paced subjects through this booklet as the subjects performed each task in turn. For each task the following events occurred. Instructions for the task were played from cassette tapes as the subjects read along. Following the instructions, the experimenter answered questions and administered a practice sample of the task. This practice sample served the function of introducing the subject to the task and providing some "warm-up" prior to the critical task. Performance on the practice task was monitored to ensure that subjects understood what the task would require. The critical task was administered upon completion of the practice sample.

Data Analysis

The general analytical plan consisted of two stages. The first stage was primarily concerned with analyses of the individual tasks. Each task was examined to determine whether the expected (from previous findings) or hypothesized (based on "new" treatments) phenomena actually occurred. This first stage was, in essence, a "forms check" for our particular implementations.

As a general analysis, analysis of variance (ANOVA) was used in this stage. The purpose of the ANOVA was to describe and confirm the previous findings on each task, namely, the pattern of significant and nonsignificant effects of the treatments on overall task performance. In addition, since some of the tasks included repetitions within a day, it was possible to test treatment-by-subject interactions. Significant treatmeny-by-subject interactions would mean that subjects responded differently to the treatments; therefore, this interaction effect would indicate that further study would be required in order to identify two or more parameters for use in describing subjects' differences.

An ANOVA for each task was performed both on the raw data and where appropriate, on the transformed scores. The reason for the data transformation was that some of the tasks had a limited range of possible reaponse scores. On those tasks, means and variances would be correlated, which would violate the assumption of ANOVA. Moreover, the limited ranges were likely to produce interaction effects among treatments. For those tasks, arcsin or log transformations were used (Winer, 1962). The reason for analyzing the raw data was to increase understanding of parameters derived from the raw data. Previous research has derived parameters from the raw data and not from the transformed scores. Therefore, it was necessary to perform ANOVAs on the raw data in order to compare the results to those from previous studies.

The second stage of the analysis was to estimate individuals' parameters on each task, such as slopes and intercepts, based upon the results of the ANOVAs. The selection of parameters to be estimated (e.g., slopes and intercepts) was dependent upon significant effects from the ANOVAs. After estimating parameters, they were correlated with each other. In theory, the pattern of correlations would show higher correlation coefficients among those parameters which involve the same information processing operations, thereby providing evidence for the construct validity of the operation.

RESULTS AND DISCUSSION

Group Measures

Overview. The results of several different types of analyses are presented below. The first set deals with the general results, or group effects, for each of the eight tasks individually. In general, these results are evaluated in terms of the degree to which they replicate previous findings using similar paradigms. For those tasks to which "new" treatments or conditions have been added, more detailed analyses have been conducted. These analyses describe and elaborate upon the hypothesized phenomena demonstrated by the results. More specifically, three of the tasks, namely Physical Match, Set Membership, and Letter Rotation, are direct adaptations of tasks previously investigated as part of this research program and have been demonstrated to be potentially valuable as candidate tasks for the test battery. Their use in the current study will be essentially to investigate the replicability of previous findings using different materials and formats. Two other tasks, namely Scan and Search and Mental Addition, are direct adaptations of paradigms used by other investigators who were not primarily concerned with issues relating to test construction or individual differences. Thus, for these tasks, a principal concern is again the demonstration of replicability of the major phenomena. In addition, all five of these tasks are evaluated in later sections as to their value for the development of individual difference parameters.

Of the remaining three tasks, two of them, namely Letter Recall and Sentence Recognition, while derived from paradigms in the literature, are sufficiently unique in this implementation to merit fairly detailed examination. Analyses and arguments are presented which describe the principal treatment effects and which discuss the hypothesized nature of the underlying operations. The final task, Sentence Recall, is of a slightly different sort: it has been developed primarily as a potential source of individual difference parameters. The "group effects" per se, although presented, are not particularly germane to the evaluation of the usefulness of this task with respect to individual measures.

Physical Match

This task is a partial replication of the Posner and Mitchell (1967) paradigm which was also included in the previous study (Rose and Fernandes, 1977). The main purpose for its inclusion in the present study was to ascertain whether a paper-and-pencil format would produce baseline (i.e., physical match) performance compatible with previous findings from studies which used alternate testing procedures. Such a result would potentially increase the flexibility of administration for a test battery.

Posner and Mitchell (op. cit.) reported a mean "same" physical match response time of 549 msec. The equivalent condition in the Rose and Fernandes (op. cit.) study resulted in a mean response time of 585 msec for Day 1 and 547 msec for Day 2. The mean processing time per item in the present study was 713 msec on Day 1 and 579 msec on Day 2. In terms of other descriptive measures, the present implementation produced slightly larger standard deviations and ranges than the Rose and Fernandes study [i.e., s.d. = 80 msec (present), 57 msec (Rose and Fernandes); range = 480 msec (present), 277 msec (Rose and Fernandes)]. Overall error rate was less than 1%. Thus, although no formal statistical methods were used for evaluating the compatibility of findings, it is apparent that the results obtained by the second day of testing are of the same order of magnitude as those previously reported.

Set Membership

This task is a replication of the Sternberg (1975) paradigm which was also included in the Rose and Fernandes (1977) study. As was the case for the Physical Match task, the primary consideration was to determine if the present implementation would result in effects compatible with other testing formats. The basic finding to be replicated is the demonstration of a linearly-increasing function relating time per item to set size. Figure 1 shows this relationship for the present study, for each day of testing. As can be seen, the expected result was obtained. This indicates that the processing of the memory set was serial and exhaustive, as was true in the previous studies.

In terms of the parameters of the function (slope and intercept), the results from the three studies are highly similar. For example, on Day 1 in the Rose and Fernandes study, the obtained slope and intercept were 63 msec and 496 msec, respectively; in the present study, these values were 60 msec and 500 msec. Sternberg (1975), using more practiced subjects, obtained values of about 38 msec (slope) and about 400 msec (intercept). For other descriptive measures, the present study and the Rose and Fernandes results are very similar. For example, for comparable slope measures, the obtained standard deviations and ranges are 21 msec and 97 msec (Rose and Fernandes) versus 20 msec and 110 msec (present study, Day 2). For the intercept measure, the standard deviations and ranges are 78 msec and 471 msec (Rose and Fernandes) versus 69 msec and 374 msec (present study, Day 2). Proportions of errors were less than 2% for both studies. Thus, we are confident that a paper-and-pencil version of this task produces results which are equivalent to previous implementations.

Letter Rotation

This particular adaptation of a paradigm developed by Shepard and co-workers (e.g., Shepard and Metzler, 1971; Snyder, 1972) was previously employed by Rose (1974), using the identical stimuli and response formats. The primary empirical finding of interest is the previously observed, monotonically-increasing function relating time per item and degrees of stimulus rotation required. There has been some controversy in the literature as to whether this function is linear or bow-shaped and whether the function reflects the subjects truly "mentally rotating"

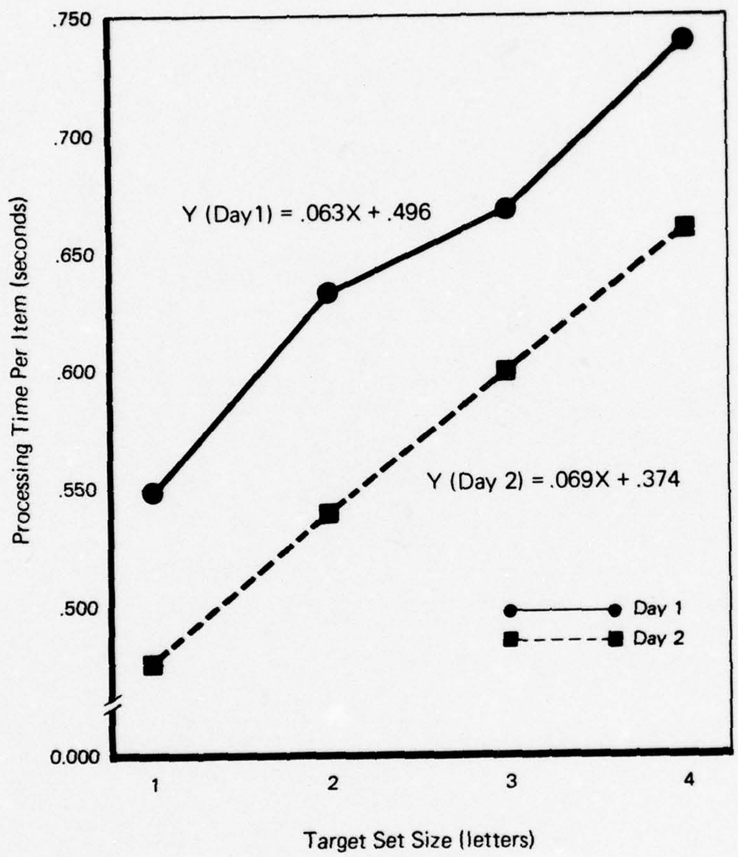


Figure 1. Set Membership: Processing Time per Item for the Letters in the Target Set.

a visual representation or performing some other operation. However, there is no disagreement (and numerous replications) regarding the observed monotonic increases. With regard to the "true" nature of the operations involved, this particular implementation avoids the controversy by instructing the subjects to mentally rotate the letters. This instruction presumably limits the use of alternate strategies.

Figure 2 shows the mean processing time per item for the four degrees of rotation. As can be seen, the basic result was obtained: the time per item monotonically increases with the degrees of required rotation. The shapes of these functions are clearly bow-shaped, with the larger degrees of rotation showing faster than expected response times. Without getting into the controversies concerning the bow-shaped finding, the simplest explanation is a within-day practice effect: subjects performed these conditions in increasing order of difficulty. Thus, the latter conditions would have benefited from earlier practice. Also, the fact that all the trials for a given rotation were presented at the same time probably enabled subjects to improve performance if compared to a randomly presented stimulus set. If it could be assumed that more difficult conditions would benefit more than easier conditions, a bow-shaped function could be predicted.

These results (including the bow-shaped function) mimic in all important aspects the findings of Rose (1974). In both experiments, the obtained slopes (approximately 15 msec per degree), standard deviations (less than 10 msec per degree) and ranges (approximately 40 msec per degree) were virtually identical. Also, no subject in either study produced a negative slope. Thus, while these results suggest a future methodological adjustment (i.e., the use of randomly-presented stimuli), the primary empirical result was obtained; furthermore, the paradigm has retained its value as a potential source of important individual-difference parameters.

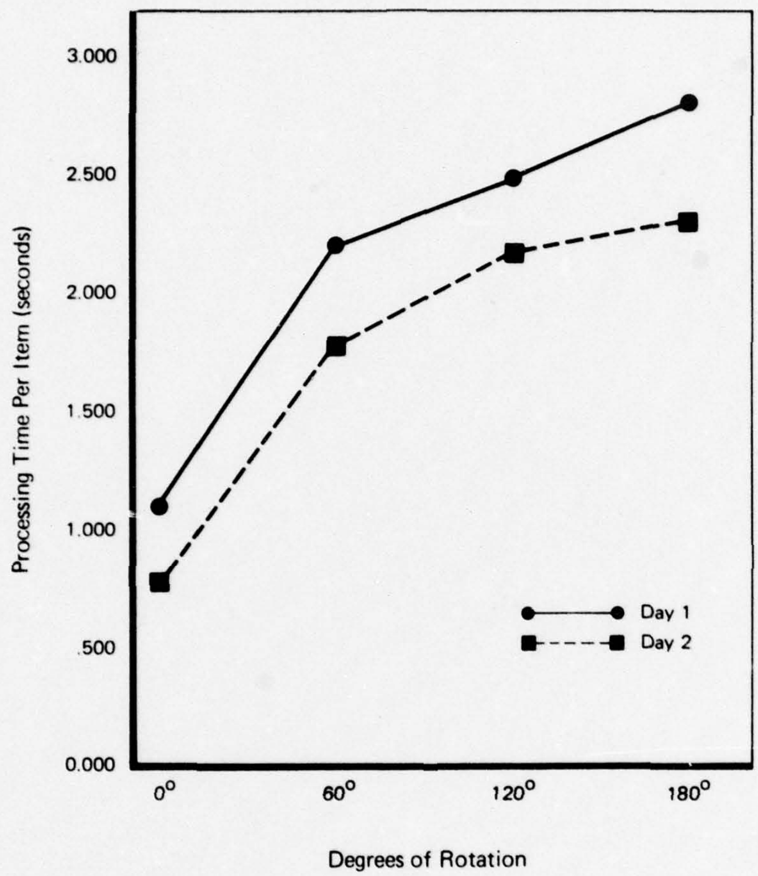


Figure 2. Letter Rotation: Processing Time per Item for the Varying Degrees of Rotation.

Scan and Search

This task was a variation of Neisser's (1967) procedure for estimating scanning rate. In the present implementation, the task is a direct replication of one used by Rose (1974), with the addition of a degraded stimulus condition. Thus, there were two major reasons for including this task: first, to confirm previous findings concerning the effect of set size on search rate; and second, to explore the effects of an additional condition (clear and degraded stimuli), both as an indicant of additional processing demands and as a source of individual difference parameters that would reflect these additional demands.

It should be noted that the original Neisser paradigm was different in focus from the current task, primarily in terms of the "role" that target set size plays in the theoretical analysis of performance. For example, one of his most widely-cited findings is that, for well-practiced subjects, target set size was not of direct importance. Conversely, the current task is directly concerned with this variable; potential individual difference parameters reflecting searcn operations in part depend upon finding increasing times-per-item as a function of target set size. Furthermore, since provision for extensive practice is not feasible within the context of a test battery, it is preferable to consider performance as occurring at the subject's initial exposure to the task. It might be possible to develop a "degree of parallel processing" measure for each subject (e.g., a measure of the decrease in slope across repeated administrations), but again we prefer to evaluate this task as a "static" assessment.

The mean processing time per item for the three levels of target set size is shown in Figure 3. There is a very strong effect showing processing time per item to increase with target set size. The figure also reveals that degraded stimuli tend to increase the processing time per item. There is an interaction between the target set size and the type of stimuli

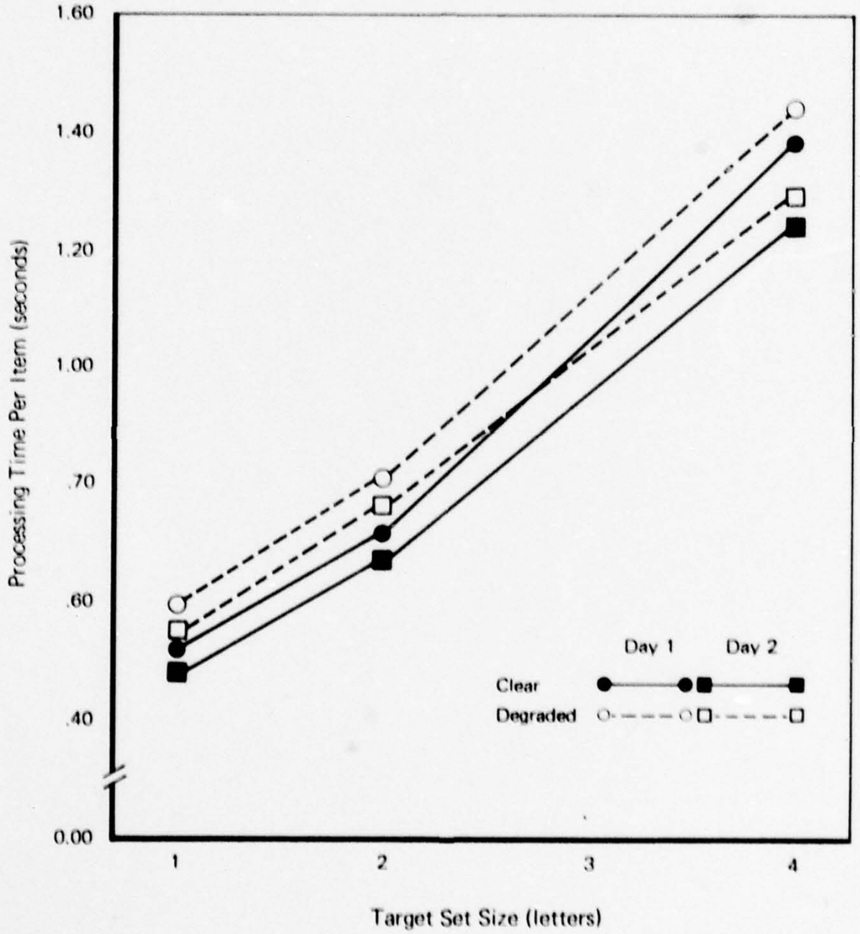


Figure 3. Scan and Search: Processing Time per Item for the Letters in the Target Set.

(see Appendix B) suggesting that processing time on the four-letter target set was least affected by the level of stimulus degradation. Also, the data demonstrated that practice tends to be differentially effective, decreasing processing time most for the four-letter target set. These data suggest that at the stage of practice used in this study, subjects are serially processing items in the target set, and that as practice increases subjects approach a parallel processing mode.

As might be expected, results from the clear stimulus conditions are virtually identical to those obtained by Rose (1974). For example, the slope measure (excluding errors) in the present study has a mean of 330 msec per item, a standard deviation of 90 msec and a range of 38 msec per item. Comparable results from Rose (op. cit., Day 2) are 338 msec per item (mean), 86 msec (standard deviation), and 48 msec per item (range).

Mental Addition

This task was an adaptation of Hitch's (1978) paradigm; as such, a primary concern of the present study was to replicate the previously reported results. Of principal interest in this regard would be the demonstration of an increasing number of errors with increasing number of carry operations. In addition, this task was included to test an extension of the theory concerning processing requirements. Further evidence for the presence of storage, retrieval, and transformation operations could be obtained by a slightly different casting of the observed data. For example, a "3 + 2, carry in tens and hundreds" problem hpothetically requires seven items be stored at some time: the five digits and the two carry "markers". Likewise, a " 3 + 3, carry in tens" problem requires storage of seven items: the six digits and the carry "marker". Using similar logic, all the problems can be categorized as requiring memory storage for 5, 6, 7, or 8 items. If the hypothesized operations are important to task performance, then performance should decrease (due to the constant 5-second deadline) as processing requirements increase.

Evidence for the replication issue is shown in Figures 4 and 5. These figures differ with respect to the dependent variable plotted; since the present implementation employed a deadline condition rather than a response time measure (as Hitch used), it was not apparent whether a mean number of correct positions or the number of blank positions was more appropriate as a comparison measure to Hitch's results. In fact, both measures reflect Hitch's findings in every important aspect: the problems with larger addends produced more errors (fewer correct positions; more blanks) and errors increase with an increase in number of carry operations. Of particular interest is the indication of a "flattening" of these functions at the "tens" and "hundreds" points. This was also reported in the Hitch study. Thus, for purposes of replication, there is good reason to believe that subjects in the present study performed the task in much the same manner as Hitch's subjects.

Regarding our extended interpretation of the results, Figures 6 and 7 present the two dependent variables as a function of the hypothesized number of operations (storage requirements) required. In this interpretation, problems that were previously considered separately were combined in the manner discussed above; for example, a "3 + 2, carry in tens", "3 + 2, carry in hundreds", and a 3 + 3, no carry" were considered as equivalent. As can be seen in Figures 6 and 7, the predicted behavior is indeed obtained. A Scheffé test found that problems requiring storage for six items did not differ significantly among themselves, nor did problems requiring storage of seven items.* Another rather startling finding is the obvious linearity of these functions (especially for "number of blanks" performance). This linearity would perhaps argue for a strict, linear-additive model of the operations involved, or alternatively that the operations necessary for a "carry" step are equivalent in processing requirements to those necessitated by an additional digit in the problem. Although fits to models developed by Hitch (op. cit.) were not attempted, these

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*For blanks, critical difference = .204, $\alpha = .01$, df = 7, 201; for correct positions, critical difference = .253, $\alpha = .01$ df = 7,201.

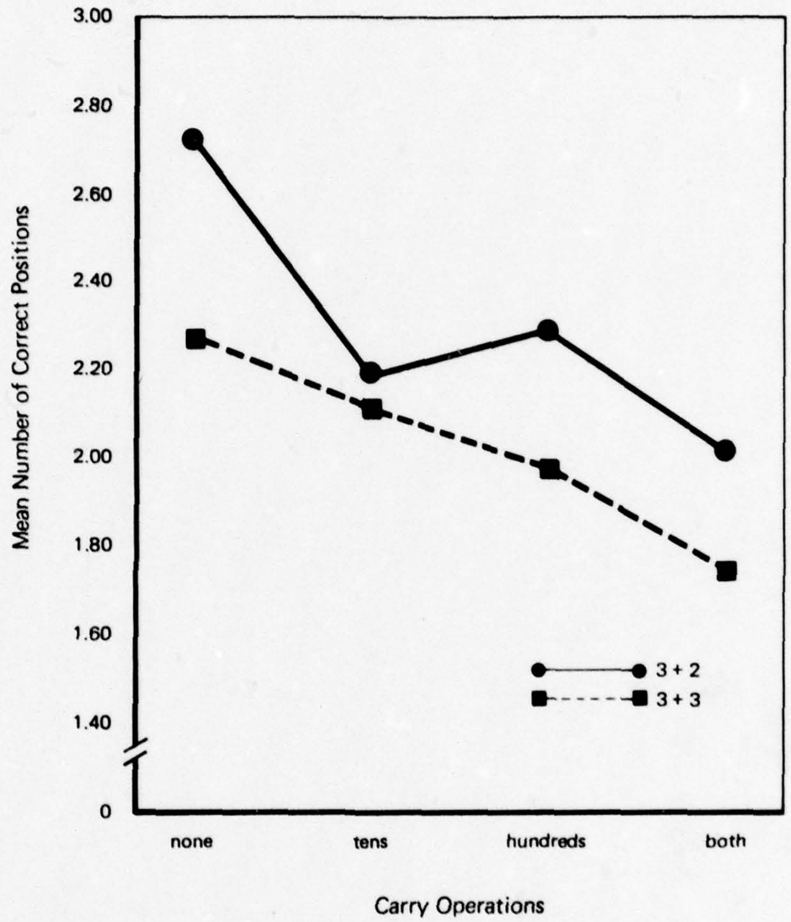

Figure 4. Mental Addition: Mean Number of Correct Positions in the Reported Sums for the Four Types of Carry Operations.

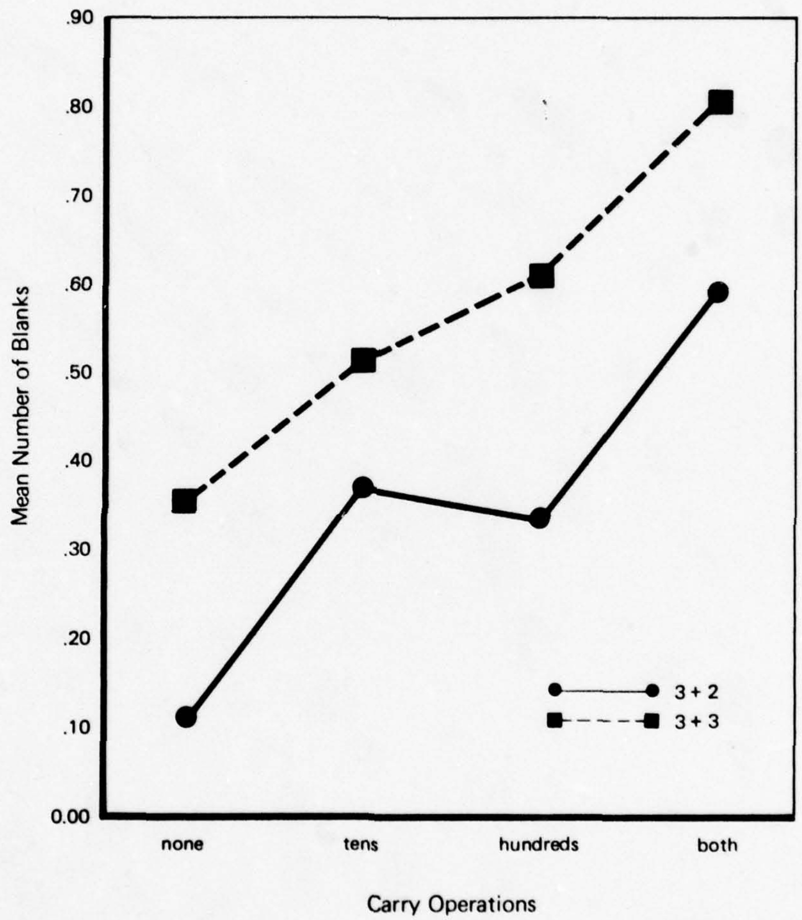

Figure 5. Mental Addition: Mean Number of Blanks for the Four Types of Carry Operations

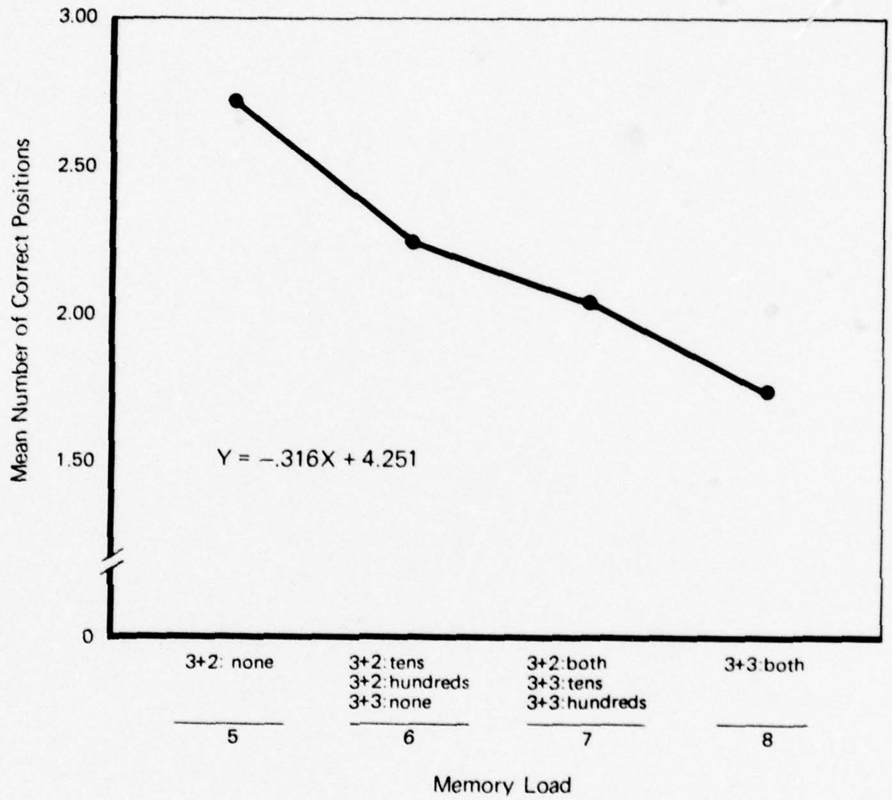

Figure 6. Mental Addition: Number of Correct Positions in Reported Sums for the Derived Levels of Memory Load.

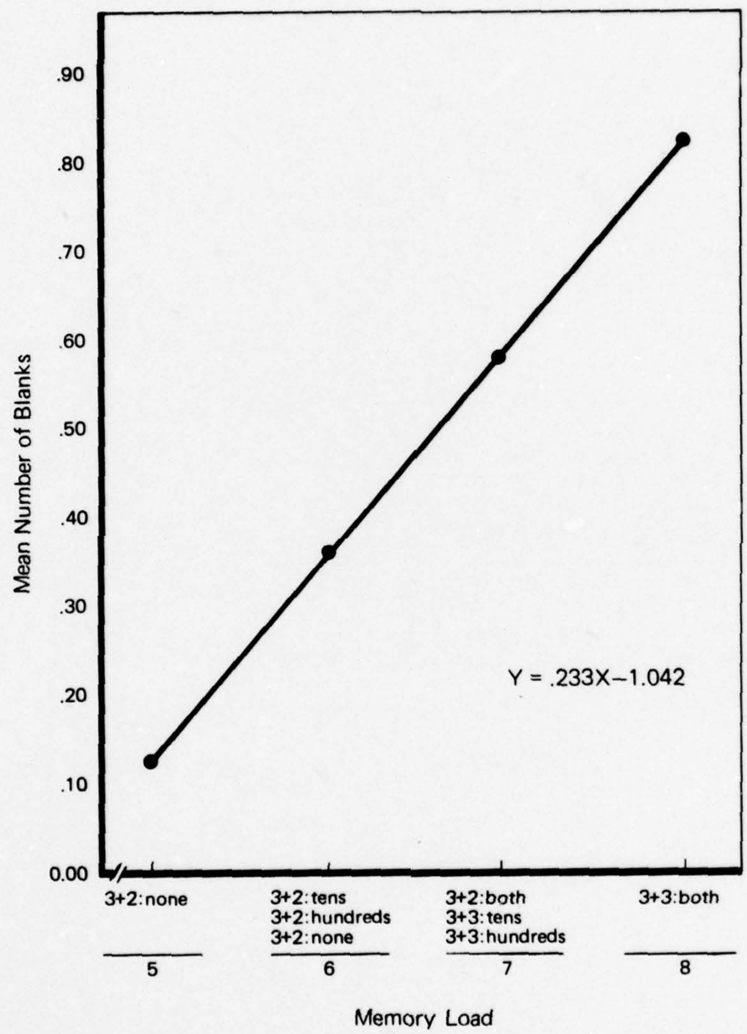

Figure 7. Mental Addition: Number of Blank Positions for the Derived Levels of Memory Load

analyses and results provide very strong evidence that our recasting of the data could potentially provide "good" measures of individual differences in information-processing operations.

It is worth mentioning that while both behavioral measures, number of correct positions and number of blank positions, reflect the underlying operations, there is reason to think that the number of blanks is a better measure. The number of correct positions is influenced to an indeterminant extent by guessing; if subjects who are unable to complete an operation prior to deadline use the partial information to guess, then guessing probabilities could vary markedly. At the same time one is assuming that in all positions where the subjects respond the same processes are involved and, more importantly, that these processes have all been completed. On the other hand, if a position is blank then it is reasonably safe to conclude that minimal, if any, operations have been applied, or that subjects have not completed enough computation to even make a guess. Thus in a deadline situation, the number of blanks should be more reflective of system stress. This is evidenced in the better fit of blanks (Figure 7) to predictions.

Letter Recall

A number of different paradigms and theories lead to consistent predictions about performance in the Letter Recall task. The memory span studies, the studies and theories of proactive interference, and theoretical explanations of displacement (e.g., Atkinson and Shiffrin, 1968) all suggest that performance should deteriorate as the length of the series is increased. Thus we should expect mean performance to decrease as the number of letters is increased.

Figure 8 summarizes the performance on recall of the last five letters with and without regard for order. The series recall measure was discarded when preliminary analyses showed it to be influenced by a ceiling effect. Data are presented as a function of the number of updates required, the assumption

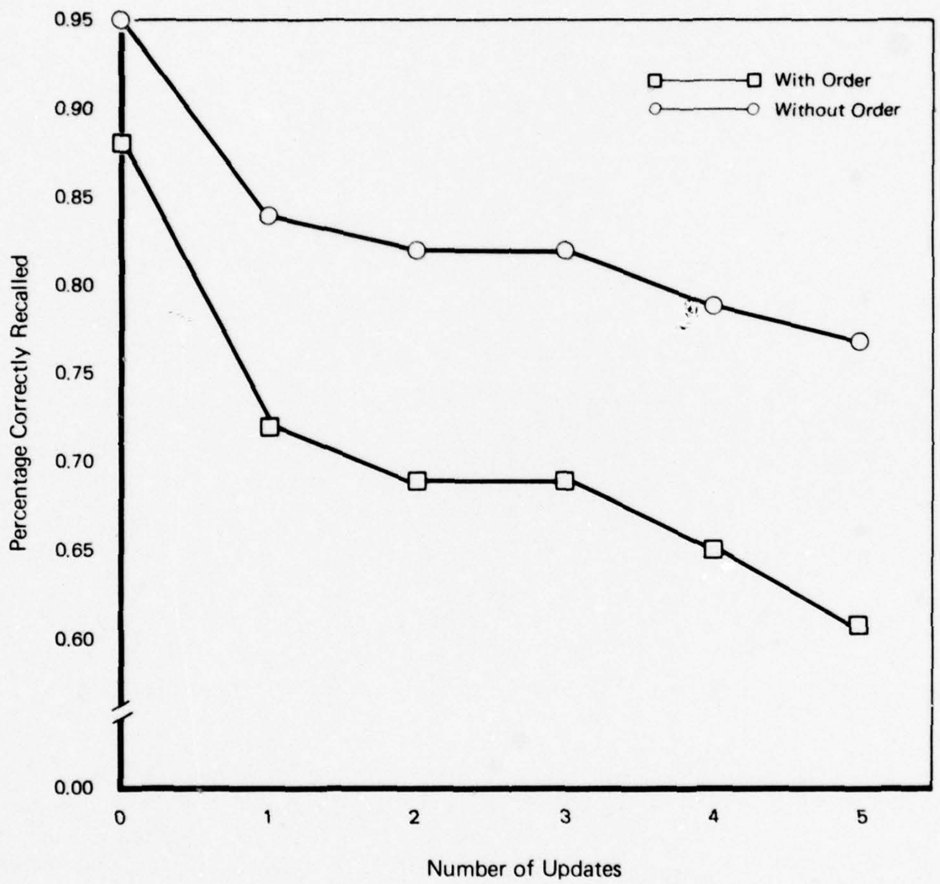

Figure 8. Letter Recall: Correct Recall for the Varying Number of Updates.

being that when five letters are presented recall requires only that the letters be held in memory and retrieved but when six or more letters are presented the subject must manipulate or update the information (e.g., dropping and adding letters, or tagging letters as "FORGET" and "REMEMBER"). Thus, the important variable is the number of updates rather than the number of letters presented, even though one is a linear function of the other.

The functions look very much as one would expect from predictions, with the curves reflecting the subjects' increasing inability to control the displacement or updating process. Analyses of variance for recall with and without regard for order showed a significant effect for the number of letters ($F = 80.32$ and 89.82, respectively; $df = 5,335$; $p < .01$). Complete ANOVA summary tables appear in Appendix B.

Sentence Recognition

Two measures of behavior were analyzed, the accuracy of the subjects' "OLD" or "NEW" judgments and the confidence rating given each judgment. Following the procedure of Bransford and Franks (1971), confidence ratings were transformed so that the ratings were integer values on a scale from -5 to +5, excluding zero. Figures 9 and 10 summarize the findings for these two measures. Since both reflected essentially the same results, in-depth analyses were performed on only the rescaled rating data, the measure of primary concern to Bransford and Franks.

The results of the ANOVA are presented in Appendix B, Table B. Of primary interest in the present context is whether our data exhibit the effect found by Bransford and Franks; in other words, they found that confidence ratings on new-consistent sentences increased in value as sentence complexity increased. Our own results indicate a significant interaction among sentence complexity, newness/oldness and consistency ($\underline{F} = 11.44$; $df = 2,134$; $p < .01$) but as shown in Figure 10, confidence

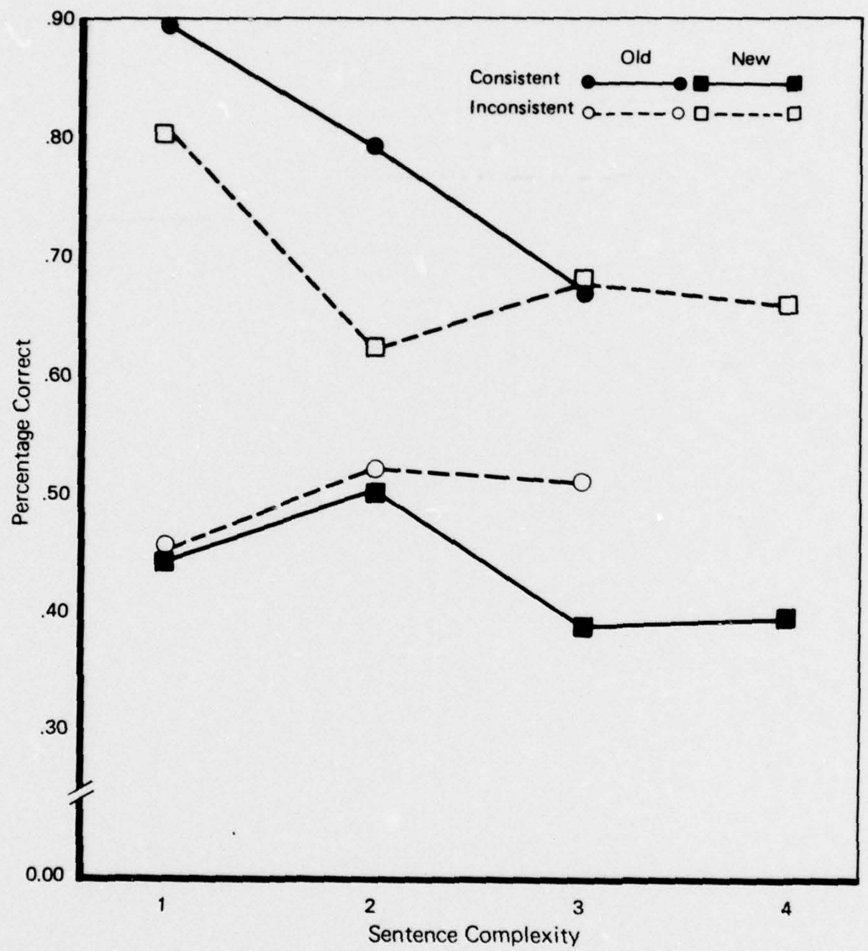

Figure 9. Sentence Recognition: Accuracy of Old-New Responses for the Four Levels of Sentence Complexity

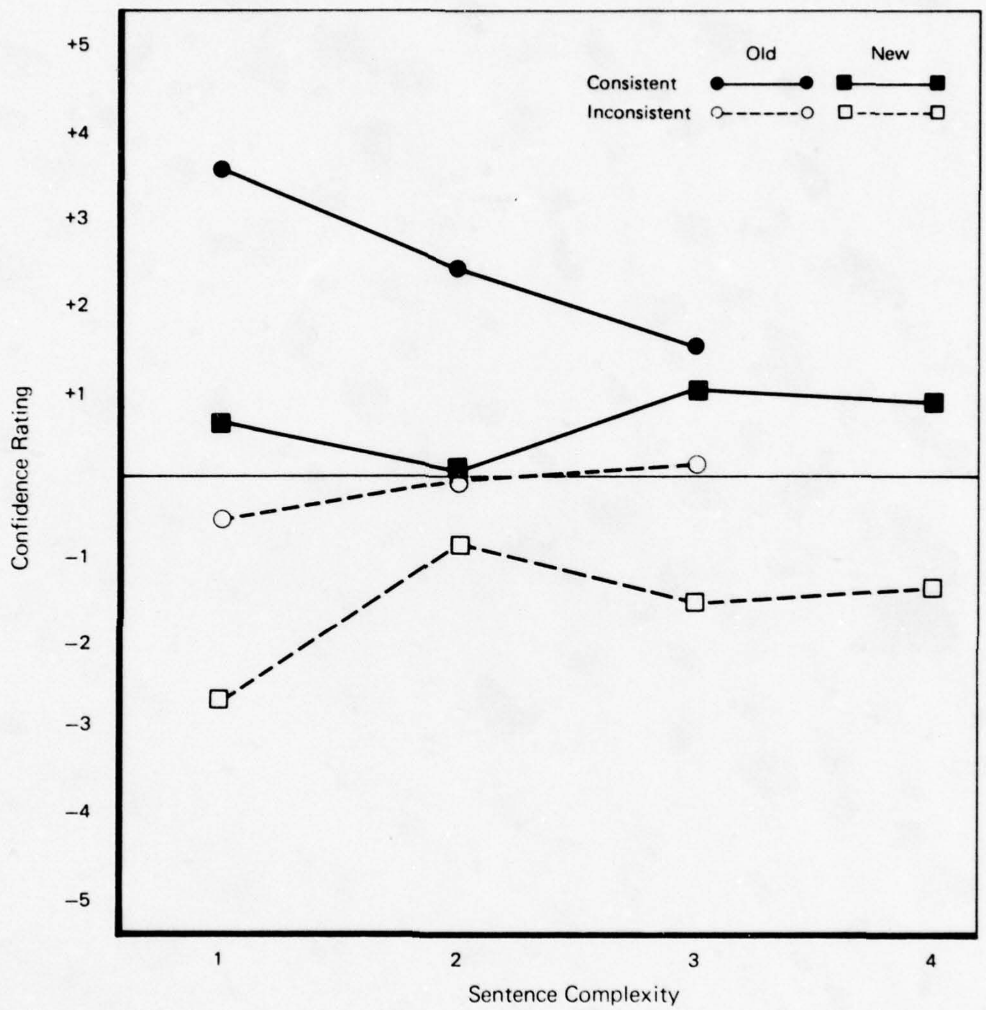

Figure 10. Sentence Recognition: Confidence Ratings for the Four Levels of Sentence Complexity

ratings for the new-consistent condition do not increase with increasing sentence complexity. Other studies (e.g., Parks and Whitten, 1977) also fail to find the Bransford and Franks effect, or find a diminished effect, when the subjects know the nature of the subsequent recognition test beforehand.

Failure to find the Bransford and Franks effect requires that a different approach be used to determine whether the data are representative of the abstraction operation. Fortunately, one can make a good argument for using the means data in the new-old, consistent-inconsistent interaction table. The pattern of performance in these cells should vary according to the abstraction, storage and search processes of the individual. For example, recognition of the old-consistent sentences should depend upon the storage and search processes while false recognition of the new-inconsistent sentences should depend upon the abstraction processes (i.e., matching of abstracted concepts from the new sentence with previously abstracted concepts). To illustrate how such a procedure might work at the group level consider the following predictions. A comparison of accuracy on the consistent- and inconsistent-old sentences should show higher accuracy on the consistent-old sentences since the number of retained stimulus dimensions (i.e., event, syntax, semantics) necessary for task performance is fewer. On the other hand for the consistent- and inconsistent-new sentences accuracy should be higher for the inconsistent-new sentences since these sentences provide distinctive syntactic cues which can be used as the basis of correct rejection. To the extent that subjects abstract a kernel representation of the sentences, the trends should be that the inconsistent-old should be difficult (since their representations would be similar to the encoding of the sentence when presented again), as should the consistent-new. Similarly, abstraction would be beneficial for the consistent-old, since in that case the similarity of representations would lead to a correct answer. To test these predictions the appropriate treatment interaction means were computed using the relative-frequency-correct data. This interaction table, presented below, shows the obtained means for the old/new and consistency conditions collapsed across complexity:

	CONSISTENT	INCONSISTENT
OLD	.788	.494
NEW	.447	.705

This table is entirely in line with the above predictions, showing highest accuracy on the consistent-old and the inconsistent-new sentences. Thus these data provide support for the hypothesized operation of abstraction processes in the task.

Sentence Recall

This task was included for different primary purposes than the other tasks. Based on our literature review, there seemed to be an apparent "gap" in the research concerning recall and clustering processes for sentences. And, although the stimuli were derived partially from the Bransford and Franks (1971) work, the tasks developed here are theoretically and practically different. Therefore, a "new" task was developed as a potential source of individual difference measures of information-processing operations.

For this task, there are no predictions about the nature of the group data. There are no previously existing findings to replicate, since there does not appear to be a comparable task in the experimental literature. While it is tempting to make predictions using subjective cognitive computations based on other paradigms and stimuli, we firmly believe that the differences in important dimensions between the paradigms and stimuli make these comparisons meaningless. Further, the task manipulations here were not designed to produce any particular group effect. Thus the task functions solely in the development of the individual difference measures.

For the sake of completeness, the group data on this task are shown in Figure 11. Two variables were used to measure behavior, an item recall measure and a cluster recall measure. The item recall procedure counted the number of nouns, verbs, and adjectives reproduced in recall from the original sentences, while the cluster recall procedure tallied the number of contiguously recalled ideas or attributes from a particular topic. Mean performance (percentage correct) on the two measures for each day of testing as a function of the number of attributes (4, 5, and 6) is shown in Figure 11. This figure indicates no clear pattern of results for either measure, especially with respect to consistency across days. Tables B-7 & 8 in Appendix B present the analyses of variance summary tables.

Group Measures Summary

Table 2 provides a general summary of the findings with the group measures data. The results indicate that, where applicable, the major group effects were replicated in almost every paradigm. For two of the tasks, Sentence Recall and Physical Match, replication was not an issue. The Sentence Recall task was a new task of our design so there was no previous literature of results to replicate. The Physical Match task involved a single treatment condition, so this task could only be compared to previous results at a general level. Of the remaining tasks only the Sentence Recognition task failed to replicate previous findings, an outcome which appears to result from a change in the subject's knowledge about the test that was necessary for our purposes. Even in this case, the literature provides some support for the obtained results under conditions of prior knowledge about the test.

Therefore, we are confident that these tasks, as implemented, are "solid" paradigms. They produce phenomena that are consistent with previous findings or are demonstrably capable of straightforward interpretations at the group level. As such, these results add additional logical support for the interpretation of task performance as representing the operations shown in Table 1.

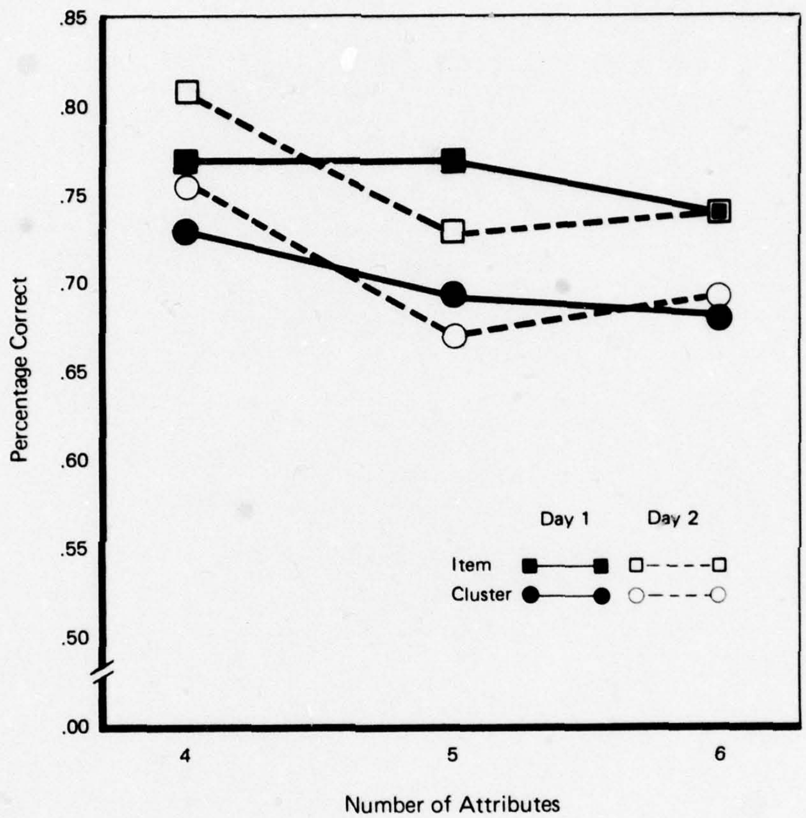

Figure 11. Mean Performance for the Item and Cluster Scoring Procedures

Table 2. Summary of Group Performance Measures.

TASK	REPLICATION OF RESULTS
1. Letter Recall	Yes
2. Mental Addition	Yes
3. Scan and Search	Yes
4. Set Membership	Yes
5. Sentence Recall	N/A
6. Sentence Recognition	No
7. Physical Match	N/A
8. Letter Rotation	Yes

* N/A - Not Applicable

Individual Measures

Overview. The value of the tasks as part of an information processing test battery depends primarily on the usefulness of measures derived from the tasks as indices of individual differences. The group measures discussed earlier serve mainly to affirm that the present forms of the tasks can indeed produce the behavior extant in the literature and to substantiate our judgments about the theoretical processes involved. The individual measures discussed in this section serve to illustrate the ability of the tasks to detect individual differences in an interpretable manner. The primary considerations are the reliability of task effects, the presence of practice effects, and some index of construct validity. These measurement issues are discussed below.

For the examination of individual performance and construct validity, a set of 59 indices was generated from the data. Most of these indices were derived to capture the essential features of the basic phenomena in each paradigm; as will be discussed below in the context of construct validity, each of these indices is interpretable in terms of the information processing "operations" vocabulary. The remaining indices were derived as summary measures in a particular task or task condition; these indices were thought to be more general indicators of a particular subject's operational capabilities and hence might be valuable as individual difference parameters. A few indices were added to the set for tasks previously studied in the course of this research project; these consist of separate Day 1 and Day 2 measures, and were included primarily to facilitate comparison with previous data. These 59 indices are as follows.

Letter Recall. For each of the three principal scores (percentage of letters correct in order, percentage of letters correct without regard to order, and percentage of letters correct with respect to the entire series), three indices were computed: the slope and intercept of the best-fitting linear function* relating percentage correct and number required updates, and a summary percentage correct (collapsed across number of updates).

Mental Addition. For the two principal scores (number of blanks and number correct), five indices were computed: the slope and intercept of the best-fitting linear function relating the principal score and the "memory load", the summary mean scores of the 3 + 2 problems and the 3 + 3 problems collapsed across number of carries; and a summary mean performance score, collapsed across all problems.

Sentence Recall. For the cluster measure, three indices were derived: the number of clusters recalled correctly weighted by cluster size and averaged across the number of sentence attributes; a "maximum correct score" which indicated the largest (average) number of clusters recalled correctly for any number of sentence attributes; and the attribute level where this maximum score occurred. For example, suppose a subject correctly recalled three out of four 4-attribute clusters, two out of four 5-attribute clusters, and one out of four 6-attribute clusters. The mean cluster score would be 3 (i.e., 3 x 4/4) + 2.5 (i.e., 2 x 5/4) + 1.5 (i.e., 1 x 6/4) = 7/3 or 2.3. The maximum correct score would be 3.0, and the attribute level score would be 4.

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* These functions do not include the five-letter (no update) conditions because of the marked non-linearity of this point from the remaining conditions.

Sentence Recognition. A total of five indices were derived, four of which consisted of the mean ratings for each of the sentence types (old-consistent, old-inconsistent, new-consistent, and new-inconsistent). The fifth index was a summary measure (mean percentage of errors collapsed across sentence types) of subjects' accuracy.

Letter Rotation. Two basic indices were derived, namely the slope and intercept of the best-fitting linear function relating time per item and number of degrees of rotation. Since it is unclear whether including or excluding errors is the more appropriate measure, both have been included in the set. Also, since previous data are available for these indices, both Day 1 and Day 2 scores are included.

Physical Match. The single index derived for this task is the mean time per item. Again, since it is unclear whether errors should be included or excluded, both have been retained, as have Day 1 and Day 2 scores.

Set Membership. The two indices derived for this task are the slope and intercept of the best-fitting linear function relating time per item to memory set size. For the reasons mentioned above, both including and excluding errors have been included, as have Day 1 and Day 2 scores.

Scan and Search. The indices derived for this task are identical to the Set Membership indices (with "target set size" replacing "memory set size") for both the clear and degraded stimulus conditions. However, it was not considered necessary to include both Day 1 and Day 2 scores individually, since the direct comparison with previous data would be questionable.

Table 3 presents detailed descriptive information for each of these 59 individual parameters. This information

Table 3

Descriptive Statistics for the Task Parameters

	Task Parameter	Mean	Std. Dev.	Min.	Max.
Letter Recall	With Order, Intercept	0.75	0.15	0.44	1.06
	With Order, Slope	-0.03	0.03	-0.12	0.03
	Without Order, Intercept	0.86	0.09	0.56	1.02
	Without Order, Slope	-0.02	0.02	-0.07	0.03
	Within Series, Intercept	0.90	0.07	0.62	1.00
	Within Series, Slope	-0.00	0.01	-0.04	0.03
	With Order, Mean	0.67	0.09	0.45	0.91
	Without Order, Mean	0.81	0.07	0.57	0.93
	Within Series, Mean	0.89	0.07	0.65	0.98
Mental Addition	Blanks, Intercept	-0.34	0.19	-0.74	0.03
	Blanks, Slope	0.08	0.04	-0.00	0.17
	Blanks, 3 + 2	0.12	0.09	0.00	0.35
	Blanks, 3 + 3	0.19	0.12	0.00	0.47
	Blanks, Overall Mean	0.16	0.10	0.00	0.39
	Correct, Intercept	1.37	0.21	0.81	1.78
	Correct, Slope	-0.10	0.04	-0.17	-0.02
	Correct, 3 + 2	0.77	0.10	0.49	0.93
	Correct, 3 + 3	0.68	0.11	0.42	0.88
	Correct, Overall Mean	0.73	0.10	0.49	0.90
Sentence Recall	Mean Cluster	1.38	0.80	0.00	2.92
	Max. Cluster	2.00	1.04	0.00	3.75
	Cluster Level	4.95	0.85	4.00	6.00
Sentence Recognition	Mean Error	0.40	0.07	0.27	0.55
	Rating by Condition, New/Incon.	-1.60	0.97	-3.25	1.69
	Rating by Condition, Old/Incon.	-0.18	1.16	-3.00	3.50
	Rating by Condition, New/Consist.	0.59	1.16	-1.75	3.00
	Rating by Condition, Old/Consist.	2.45	1.04	-1.42	4.83

Table 3 (Continued)

Descriptive Statistics for the Task Parameters

Task	Task Parameter	Mean	Std. Dev.	Min.	Max.
Letter Rotation	Inc. Errors, Intercept, Day 1	1.35	0.51	0.63	2.83
	Inc. Errors, Slope, Day 1	0.01	0.01	0.00	0.04
	Inc. Errors, Intercept, Day 2	1.03	0.34	0.49	2.41
	Inc. Errors, Slope, Day 2	0.01	0.00	0.00	0.02
	Exc. Errors, Intercept, Day 1	1.60	1.02	0.57	6.40
	Exc. Errors, Slope, Day 1	0.01	0.01	0.00	0.04
	Exc. Errors, Intercept, Day 2	1.13	0.62	0.31	4.21
	Exc. Errors, Slope, Day 2	0.01	0.00	0.00	0.03
Physical Match	Inc. Errors, Day 1	0.71	0.11	0.50	0.98
	Inc. Errors, Day 2	0.58	0.08	0.42	0.75
	Exc. Errors, Day 1	0.71	0.12	0.50	1.00
	Exc. Errors, Day 2	0.58	0.08	0.42	0.75
Set Membership	Inc. Errors, Intercept, Day 1	0.50	0.10	0.27	0.71
	Inc. Errors, Slope, Day 1	0.06	0.02	0.01	0.12
	Inc. Errors, Intercept, Day 2	0.42	0.07	0.22	0.59
	Inc. Errors, Slope, Day 2	0.06	0.02	0.02	0.13
	Exc. Errors, Intercept, Day 1	0.49	0.10	0.25	0.69
	Exc. Errors, Slope, Day 1	0.06	0.03	0.02	0.15
	Exc. Errors, Intercept, Day 2	0.41	0.07	0.22	0.59
	Exc. Errors, Slope, Day 2	0.07	0.03	0.03	0.16
Scan and Search	Inc. Errors, Clear, Intercept	0.19	0.12	-0.25	0.51
	Inc. Errors, Clear, Slope	0.28	0.09	0.12	0.54
	Exc. Errors, Clear, Intercept	0.12	0.11	-0.27	0.37
	Exc. Errors, Clear, Slope	0.33	0.09	0.18	0.56
	Inc. Errors, Clear, Overall Mean	0.84	0.14	0.57	1.21
	Exc. Errors, Clear, Overall Mean	0.91	0.14	0.60	1.27
	Inc. Errors, Degraded, Intercept	0.30	0.13	-0.01	0.71
	Inc. Errors, Degraded, Slope	0.26	0.09	0.11	0.54
	Exc. Errors, Degraded, Intercept	0.19	0.17	-0.33	0.63
	Exc. Errors, Degraded, Slope	0.36	0.13	0.16	0.86
	Inc. Errors, Degraded, Overall Mean	0.91	0.16	0.63	1.36
	Exc. Errors, Degraded, Overall Mean	1.04	0.20	0.72	1.68

includes the mean, standard deviation, and maximum and minimum scores. These data are included for comparison with previous and future replications and for future use as an information-processing data base.

It should be noted that there is an apparent "scale" problem associated with most of the slope indices. For example, consider the Letter Rotation slopes. Although the interpretation of the absolute time value of the slope (i.e., seconds per degree of rotation) is in line with previous research, the descriptive data in the table are truncated. In fact however (as will be shown in succeeding sections), there is sufficient variance in subjects' scores to produce substantial correlations. It was perhaps inappropriate to present the slope score to the nearest hundredth of a second (rather than in msec); however, we chose to avoid the complication of changing the units of measurement both within this table and between this table and previous presentations of results.

Reliabilities and Practice Effects. *Test-retest reliabilities* for selected indices are presented in Table 4. Omitted from this table are the "summary" indices. In line with our general approach, we would probably not ultimately recommend such indices be incorporated in an information processing assessment battery. Since our objective is to design a test battery which measures individual differences in cognitive operations, indices which summarize a subject's synthesis of several operations (or more generally, task performance collapsed across different conditions) are, in our judgment, relatively less desirable.

It should be kept in mind that test-retest correlations are not commonly used as a reliability criterion. Typically, split-half, odd-even, or alternate-form correlations are reported.* Also, it should be noted that we were unable to

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*These calculations were precluded for the tasks in this study due primarily to the group-administration format.

Table 4

Test-Retest Correlations for the Task Parameters

Task	Parameter	Test-Retest Correlation
Letter Recall	With Order, Intercept	.51
	With Order, Slope	.21
	Without Order, Intercept	.49
	Without Order, Slope	.19
	Within Series, Intercept	.41
	Within Series, Slope	.24
Mental Addition	Blanks, Intercept	.39
	Blanks, Slope	.61
	Correct, Intercept	.14
	Correct, Slope	.35
Sentence Recall	Mean Cluster	.37
	Max Cluster	.41
	Cluster Level	.12
Sentence Recognition	Errors	.18
	New-Consistent	.14
	New-Inconsistent	.27
	Old-Consistent	.30
	Old-Inconsistent	.31
Letter Rotation	Inc. Errors, Intercept	.72
	Inc. Errors, Slope	.53
	Exc. Errors, Intercept	.64
	Exc. Errors, Slope	.75
Physical Match	Inc. Errors, Mean	.85
	Exc. Errors, Mean	.85

Table 4 (Continued)

Test-Retest Correlations for the Task Parameters

	Task Parameter	Test-Retest Correlation
Set Membership	Inc. Errors, Intercept	.66
	Inc. Errors, Slope	.81
	Exc. Errors, Intercept	.66
	Exc. Errors, Slope	.79
Scan and Search	Inc. Errors, Clear, Intercept	.77
	Inc. Errors, Clear, Slope	.76
	Inc. Errors, Degraded, Intercept	.70
	Inc. Errors, Degraded, Slope	.71
	Exc. Errors, Clear, Intercept	.63
	Exc. Errors, Clear, Slope	.68
	Exc. Errors, Degraded, Intercept	.55
	Exc. Errors, Degraded, Slope	.60

find in the literature any reported reliability measures for the tasks or task parameters investigated in this study.

The reliabilities shown in Table 4 range from r = .12 (Sentence Recall, cluster level) to r = .85 (Physical Match, time per item). Four of the tasks--Physical Match, Set Membership, Letter Rotation, and Scan and Search--have indices which show "good" (in our judgment) reliabilities of r = .70 or above. We believe that these reliabilities are acceptable, even from the perspective of standard test development. Interestingly, these are the tasks that use a (derived) time metric, as opposed to the other tasks that use a percent-correct metric. These other tasks--Sentence Recall, Mental Addition, Letter Recall, and Sentence Recognition--while occasionally showing an index with a moderately high reliability (r = .40 or above), are generally disappointing. Clearly, from a test-development standpoint, further work must be done before these tasks and measures would be recommended for inclusion in a test battery. This work might include the generation of a different set of indices, longer tests, or modifications of testing conditions (e.g., different treatments, instructional variations, etc.). A further consideration is that these tasks seem to be more sensitive to shifts in subjects' strategies between administrations than are the other tasks. Indeed, the possibility that shifts did occur was partially confirmed during informal conversations with the subjects.

In light of the above discussion of reliability, the interpretation of practice effects is perhaps superfluous. The data showed significant practice (Day) effects for all tasks except Sentence Recall (see Appendix B for statistical confirmation and critical values). These practice effects resulted from an increase in accuracy or a decrease in required processing time. Generalizations about the practice effects must also be tempered because of the significant interactions with other treatment conditions. Implications of these practice effects for test development and/or test battery implementation are twofold:

first, as implied by the reliability discussion above, more research must be done to eliminate or regulate "unwanted" (i.e., strategy shift) practice effects; and second, care must be taken in the design of an experimental implementation. That is, proper control groups must be employed, proper statistical procedures (e.g., analyses of covariance) must be used, and so on.

Construct Validity

Overview. The concept of construct validity is relatively new in experimental psychology. While the concept is of critical importance to any research concerned with test development, individual differences, and performance assessment, there is no formal statistical procedure for its evaluation. Typically suggested procedures are general and involve procedures like: (1) specification of observables relevant to the construct, (2) determination of extent to which observables measure the same thing, and (3) determination of the extent to which supposed measures of the construct produce results predicted from accepted theoretical hypotheses about the construct (Nunnally; 1978, p. 98).

The approach used here follows fairly closely the procedures outlined by Nunnally, with some allowances for the particular situation and operations involved. A sample from the domain of observables has been specified; these are the 59 individual parameters listed in Table 5. The table also shows the major operations involved (derived primarily from Table 1) and the psychological interpretations for the measures. The extent to which the observed data from tasks comply with theoretical predictions was demonstrated in the foregoing discussion of group measures. Thus all that remains is to demonstrate the ability of the different observables to measure the same construct (operation). The redundancies in Table 5 were included for just this purpose.

An inspection of Table 5 (or even more clearly, Table 1)

TABLE 5.
Operations and Interpretations of Task Parameters

Task Parameter		Interpretation
1. Letter Recall: Operations–storage and retrieval (short-term retention)		
• with order:	• slope	rate of item and order information loss with each update
	• intercept	projected item and order information capabilities in absence of updates
	• mean	summarized item and order retention capabilities
• without order:	• slope	rate of item information loss with each update
	• intercept	projected item information capabilities in absence of updates
	• mean	summarized item retention capabilities
• within series:	• slope	rate of series information loss with each update
	• intercept	projected series information retention capabilities in absence of updates
	• mean	summarized retention from series
2. Mental Addition: Operations– transformation, storage and retrieval (short-term retention)		
• number blanks:	• slope	rate of information loss with increasing memory load
	• intercept	*unclear*
	• mean: 3+2 mean: 3+3 mean: overall	summarized capabilities for retention and transformation operations
• number correct:	• slope	rate of information loss with increasing memory load
	• intercept	*unclear*
	• mean: 3+2 mean: 3+3 mean: overall	summarized capabilities for retention and transformation operations
3. Sentence Recall: Operations–abstraction, storage, retrieval		
• cluster recall:	• mean completely correct	capabilities for abstraction and retention
	• maximum completely correct	capabilities for abstraction and retention
	• level with maximum completely correct	capabilities for abstraction and retention
4. Sentence Recognition: Operations–abstraction, storage, search		
• mean error		abstraction and retention capabilities
• rating old/inconsistent		retention of details for old sentences
• rating old/consistent		retention and abstraction for old sentences
• rating new/inconsistent		abstraction of concepts
• rating new/consistent		abstraction of concepts and details
5. Letter Rotation: Operations–transformation, comparison		
• slope (with errors) without errors)		time required to transform per degree of rotation
• intercept (with errors, without errors)		time required to make a comparison
6. Physical Match: Operation–comparison		
• mean (with errors, without errors)		time required to make a comparison
7. Set Membership: Operations–storage, search		
• slope (with errors, without errors)		time required to search storage per item in storage
• intercept (with errors, without errors)		time required to maintain access to memory set and encode probe
8. Scan and Search: Operations–storage, search, encoding		
• clear stimuli:	• slope (with errors, without errors)	time required to search per item in target set
	• intercept (with errors, without errors)	time required to maintain access to target and encode stimuli
	• mean (with errors, without errors)	summarized processing time for operations
• degraded stimuli:	• slope (with errors, without errors)	time required to search per item in target set
	• intercept (with errors, without errors)	time required to maintain access to target and encode stimuli
	• mean (with errors, without errors)	summarized processing time for operations

reveals that, with the exception of encoding, recoding, and decision-response, each operation is involved in at least two tasks. If the "major" operations are indeed significant factors in task performance, then one might hope that measures from tasks sharing the same operations would be correlated. At the risk of appearing pedantic, it must be repeated that such an expectation depends upon a chain of inferences, each link of which relies primarily upon interpretation and judgment. Table 1 is essentially a series of theoretical hypotheses about operations. As such, these hypotheses reflect the authors' particular (or peculiar) theoretical biases, vocabulary, and task analyses. The next judgment concerns the interpretation of the individual tasks' group effects as more or less supportive of the underlying operational descriptions. For the most part, we have considered "phenomenon replicability" as presumptive evidence for these interpretations; confidence has been increased not only from the present results but also from the results of other investigators who have performed empirically-based converging operations. The next judgment, represented in Table 5, is the designation of measures as reflecting one or more operations. For the many measures that adequately represent task performance, the judgment was made as to the relevance of each to the operational construct. The final step in the chain of inferences is the correlational hypothesis that two measures sharing the same operation will be statistically related. Of course, if each parameter was hypothesized to measure only one operation, the evidence would be direct. However, the evidence becomes shakier when both parameters measure more than one operation. Without assumptions concerning relative weights or correlations among the operations themselves, the interpretation of the observed correlations is indirect. Nonetheless, using Table 5 as a guide, we expect that parameters supposedly measuring the same process (e.g., physical match-mean and letter rotation-intercept) would be correlated. Thus using Table 5 a number of "expected" significant correlations can be generated. Table 6 presents the obtained correlations. Their correspondence to selected predictions is discussed below.

Storage/Retrieval Operations. Storage/retrieval operations should show up as significant correlations in comparing letter recall, mental addition, and sentence recall. Sentence recall produced significant correlations with all the letter recall means and some of the intercept measures for letter recall. With mental addition, sentence recall correlated significantly with the means for blank positions. For letter recall and mental addition, almost all of the correlations with the letter recall intercept measures are significant as well as the correlations between mental addition means and letter recall means. Thus, there is good inferential support for the construct validity of the storage/retrieval operations and measures reflecting them.

Comparison Operation. The comparison operation should produce significant correlations between physical match and letter rotation. Indeed Table 6 shows significant or marginally significant correlations in many of the possible comparisons of physical match and letter rotation, the major exceptions being those cells involving the letter rotation intercept excluding errors on Day 1. Again, there is good support for the construct validity of the comparison operation.

Abstraction Operation. By investigating the correlation between sentence recall and sentence recognition, we can get some idea of the construct validity for abstraction. Unfortunately, this measure is contaminated by confounding with storage operations. Disregarding the cluster level score, we again find some significant correlations.

Search Operation. The search operation should produce significant correlations between set membership and scan and search. Again, the storage operation is a confounding. The majority of correlations here are significant. That a similar effect is not seen when we compare set membership and letter

Test	Measure	LETTER ROTATION: Including errors, Intercept, Day 1	LETTER ROTATION: Including errors, Slope, Day 1	LETTER ROTATION: Including errors, Intercept, Day 2	LETTER ROTATION: Including errors, Slope, Day 2	LETTER ROTATION: Excluding errors, Intercept, Day 1	LETTER ROTATION: Excluding errors, Slope, Day 1	LETTER ROTATION: Excluding errors, Intercept, Day 2	LETTER ROTATION: Excluding errors, Slope, Day 2	PHYSICAL MATCH: Including errors, Day 1	PHYSICAL MATCH: Including errors, Day 2	PHYSICAL MATCH: Excluding errors, Day 1	PHYSICAL MATCH: Excluding errors, Day 2	LETTER RECALL: With order, Intercept	LETTER RECALL: With order, Slope	LETTER RECALL: Without order, Intercept	LETTER RECALL: Without order, Slope	LETTER RECALL: Within series, Intercept	LETTER RECALL: Within series, Slope	LETTER RECALL: With order, Mean	LETTER RECALL: Without order, Mean	LETTER RECALL: Within series, Mean	MENTAL: Blanks, Intercept	MENTAL: Blanks, Slope	MENTAL: Blanks, 3 + 2	MENTAL: Blanks, 3 + 3	MENTAL: Blanks, Overall Mean
LETTER ROTATION	Including errors, Intercept, Day 1																										
	Including errors, Slope, Day 1	−24																									
	Including errors, Intercept, Day 2	53	29																								
	Including errors, Slope, Day 2	05	71	21																							
	Excluding errors, Intercept, Day 1	81	−10	61	07																						
	Excluding errors, Slope, Day 1	−33	89	12	66	−34																					
	Excluding errors, Intercept, Day 2	48	23	88	20	75	−01																				
	Excluding errors, Slope, Day 2	04	52	07	80	−03	64	−04																			
PHYSICAL MATCH	Including errors, Day 1	−22	−33	−32	−29	−14	−25	−23	−17																		
	Including errors, Day 2	−22	−29	−32	−24	−12	−20	−20	−19	85																	
	Excluding errors, Day 1	−22	−33	−32	−29	−14	−24	−23	−17	100	85																
	Excluding errors, Day 2	−22	−29	−33	−24	−12	−21	−21	−20	85	100	85															
LETTER RECALL	With order, Intercept	−02	−19	−20	−14	−12	−20	−22	−06	−03	−10	−03	−09														
	With order, Slope	−13	24	−01	14	−06	30	02	13	10	07	10	06	−81													
	Without order, Intercept	−09	−05	−14	−06	−09	−11	−14	−10	05	10	05	11	80	−63												
	Without order, Slope	−05	19	−04	09	−05	27	−02	16	−03	−13	−02	−14	−54	74	−72											
	Within series, Intercept	−09	01	−17	−03	−05	−05	−12	−07	09	20	09	20	59	−41	90	−61										
	Within series, Slope	−13	13	−05	00	−10	13	−03	−03	−07	−17	−07	−17	−25	34	−36	64	−47									
	With order, Mean	−17	−04	−33	−07	−27	00	−34	04	05	−08	05	−07	77	−24	63	−09	−38	95								
	Without order, Mean	−16	08	−23	−02	−18	06	−21	−01	05	04	05	04	69	−29	83	−20	78	01	82							
	Within series, Mean	−19	10	−22	−03	−11	02	−16	−10	05	12	05	12	50	−24	80	−29	83	09	56	89						
MENTAL ADDITION	Blanks, Intercept	−16	06	−17	−15	−12	−05	−10	−21	13	11	12	11	22	−24	32	−26	25	04	10	25	32					
	Blanks, Slope	25	03	26	14	17	02	15	17	−13	−14	−13	−13	−27	21	−38	23	−33	−05	−22	−35	−40	−95				
	Blanks, 3 + 2	−28	−06	27	01	14	−07	14	−01	−08	−11	−08	−11	−25	04	−32	07	−30	−04	−38	−40	−36	−41	66			
	Blanks, 3 + 3	37	−02	39	11	25	−03	24	11	−12	−16	−12	−16	−31	10	−42	13	−40	−06	−39	−48	−50	−68	87	88		
	Blanks, Overall Mean	34	−04	35	07	21	−05	20	06	−10	−14	−11	−14	−29	08	−39	11	−37	−05	−40	−46	−46	−59	80	96	98	
	Correct, Intercept	−05	11	12	22	−02	07	14	18	−08	−11	−07	−11	−16	29	−18	23	−12	07	05	−06	−10	−51	45	08	24	18
	Correct, Slope	−08	−09	−21	−21	−08	−04	−19	−17	07	11	06	11	28	−29	32	−25	25	−05	15	24	25	66	−68	−43	57	−53
	Correct, 3 + 2	−27	03	−24	00	−18	07	−11	−02	00	05	00	05	31	−07	34	−07	30	−01	43	42	34	41	−63	−89	−81	−87
	Correct, 3 + 3	−31	01	−31	−09	−25	06	−23	−09	−01	02	−01	02	37	−14	43	−15	38	04	46	49	45	61	−78	−80	−90	−89
	Correct, Overall Mean	−31	02	−29	−05	−23	07	−18	−06	−01	04	00	04	36	−11	37	−12	36	02	46	47	41	54	−74	−87	−90	−91
SET MEMBERSHIP	Including errors, Intercept, Day 1	05	37	09	28	−07	35	−01	15	−69	−73	−69	−73	−05	01	−16	18	−20	25	−07	−08	−07	−10	14	16	17	17
	Including errors, Slope, Day 1	32	−19	05	−05	26	−23	07	04	−02	−04	−02	−04	00	−04	−17	08	−11	−13	−04	−18	−21	−30	30	17	25	22
	Including errors, Intercept, Day 2	11	28	18	27	−04	31	07	19	−65	−70	−65	−70	−07	09	−24	26	−27	18	−02	−13	−19	−19	22	16	23	21
	Including errors, Slope, Day 2	15	−01	10	−06	13	−07	04	−02	−10	−12	−10	−12	−18	07	−22	06	−17	00	−22	−27	−20	−18	22	21	23	23
	Excluding errors, Intercept, Day 1	03	37	08	27	−07	35	−01	15	−69	−72	−69	−72	−06	02	−17	19	−21	27	−08	−08	−07	−10	13	16	16	16
	Excluding errors, Slope, Day 1	35	−19	07	−02	26	−22	08	06	−02	−06	−02	−06	02	−05	−15	04	−10	−16	−02	−18	−22	−30	30	17	25	23
	Excluding errors, Intercept, Day 2	12	27	18	24	−03	29	07	16	−63	−67	−63	−67	−07	09	−23	26	−26	18	−01	−11	−17	−18	21	18	23	22
	Excluding errors, Slope, Day 2	15	00	07	01	12	−04	03	05	−12	−14	−12	−14	−15	05	−20	04	−17	−02	−19	−26	−20	−19	20	14	19	17
SCAN AND SEARCH	Including errors, Clear, Intercept	05	09	13	10	05	13	13	08	−40	−42	−40	−42	11	−05	06	13	06	25	12	20	22	03	−08	−13	−14	−14
	Including errors, Clear, Slope	16	01	12	−05	06	−08	03	−13	05	03	06	03	−11	04	−18	02	−19	−15	−15	−24	−30	−24	32	34	40	39
	Excluding errors, Clear, Intercept	−06	14	06	05	00	16	09	04	−37	−37	−37	−38	15	−08	16	07	16	21	17	27	31	08	−13	−16	−20	−19
	Excluding errors, Clear, Slope	26	−04	17	00	11	−10	07	−08	00	−04	01	−03	−15	07	−26	09	−28	−10	−17	−30	−37	−27	35	36	43	41
	Including errors, Clear, Overall Mean	27	09	29	01	13	−01	16	−12	−26	−32	−26	−31	−06	01	−21	14	−22	−01	−11	−18	−26	−32	41	39	47	45
	Excluding errors, Clear, Overall Mean	33	06	31	03	15	−02	17	−09	−29	−35	−29	−34	−10	03	−26	18	−28	02	−12	−22	−30	−34	42	39	48	45
	Including errors, Degraded, Intercept	−03	41	24	21	02	36	16	17	−38	−39	−37	−39	−08	14	−02	23	01	32	02	15	22	−06	00	−10	−11	−11
	Including errors, Degraded, Slope	23	15	09	−09	06	−18	02	−16	00	−05	00	−05	−01	−05	−13	−01	−15	−15	−07	−19	−27	−18	28	34	41	39
	Excluding errors, Degraded, Intercept	−14	34	11	12	−04	32	07	13	−20	−23	−20	−23	−06	13	03	18	07	29	05	19	26	00	−06	−14	−15	−15
	Excluding errors, Degraded, Slope	30	−12	16	−01	10	−15	07	−10	−11	−13	−11	−13	−01	−04	−15	01	−17	−15	−07	−20	−29	−21	29	33	39	38
	Including errors, Degraded, Overall Mean	28	13	32	05	09	05	15	−09	−31	−38	−31	−38	−08	05	−19	17	−19	05	−08	−13	−18	−29	37	38	46	44
	Excluding errors, Degraded, Overall Mean	34	11	33	09	11	04	17	−04	−34	−40	−34	−39	−07	04	−20	17	−20	01	−06	−14	−22	−32	40	38	47	44
SENTENCE RECOGNITION	Mean Error	33	−23	18	−05	15	−22	07	−01	−03	01	−04	02	−15	08	−07	−03	01	−13	−16	−13	−07	−21	25	24	27	28
	Rating by Condition, New/Inc.	05	−02	15	00	−03	−04	−03	06	02	10	02	10	−24	19	−20	10	−14	03	−19	−20	−14	−23	26	23	26	28
	Rating by Condition, Old/Inc.	−16	08	−13	−05	−05	−06	−13	−04	04	03	05	04	−03	09	−01	02	−04	15	06	00	04	−08	07	01	04	02
	Rating by Condition, New/Con.	15	−09	−05	−01	13	−14	−08	05	−09	−04	−08	−03	−03	04	09	−07	18	−07	−01	07	16	−19	19	12	16	15
	Rating by Condition, Old/Con.	−32	18	−19	−01	−18	18	−16	05	−13	05	−12	04	16	−08	24	−06	26	09	18	29	35	08	−17	−26	−29	−29
SENTENCE RECALL	Mean Cluster	−24	11	−14	−09	−13	09	−15	−07	02	00	03	00	12	06	26	−05	30	−02	27	32	33	04	−12	−20	−26	−24
	Maximum Cluster	−29	16	−13	00	−16	18	−15	00	12	08	13	08	04	12	18	−01	24	−04	20	24	24	03	−11	−22	−24	−25
	Cluster Level	11	−11	18	−21	17	−18	13	−20	18	07	18	08	01	00	04	00	02	09	02	06	08	−09	07	−02	04	02

[a] Pearson product-moment correlations rounded to the nearest hundredth; decimals omitted. For df = 64, a value of r>31 is significant at the .01 (two-tailed) level and a value of r>24 is significant at the .05 (two-tailed) level.

TABLE 6. Intra- and Intertask Correlations [a]

MENTAL ADDITION									SET MEMBERSHIP								SCAN AND SEARCH												SENTENCE RECOGNITION					SENTENCE RECALL		
Blanks, Slope	Blanks, 3 + 2	Blanks, 3 + 3	Blanks, Overall Mean	Correct, Intercept	Correct, Slope	Correct, 3 + 2	Correct, 3 + 3	Correct, Overall Mean	Including errors, Intercept, Day 1	Including errors, Slope, Day 1	Including errors, Intercept, Day 2	Including errors, Slope, Day 2	Excluding errors, Intercept, Day 1	Excluding errors, Slope, Day 1	Excluding errors, Intercept, Day 2	Excluding errors, Slope, Day 2	Including errors, Clear, Intercept	Including errors, Clear, Slope	Excluding errors, Clear, Intercept	Excluding errors, Clear, Slope	Including errors, Clear, Overall Mean	Excluding errors, Clear, Overall Mean	Including errors, Degraded, Intercept	Including errors, Degraded, Slope	Excluding errors, Degraded, Intercept	Excluding errors, Degraded, Slope	Including errors, Degraded, Overall Mean	Excluding errors, Degraded, Overall Mean	Mean Error	Rating by Condition, New/Inc.	Rating by Condition, Old/Inc.	Rating by Condition, New/Con.	Rating by Condition, Old/Con.	Mean Cluster	Maximum Cluster	Cluster Level
66																																				
87	88																																			
80	96	98																																		
45	08	24	18																																	
–68	–43	57	–53	–91																																
–63	–89	–81	–87	01	39																															
–78	–80	–90	–89	–30	65	85																														
–74	–87	–90	–91	–17	55	95	97																													
14	16	17	17	02	–05	–10	–07	–09																												
30	17	25	22	16	–20	–12	–19	–16	–29																											
22	16	23	21	17	–18	–05	–12	–09	81	–20																										
22	21	23	23	–06	–03	–23	–17	–21	–07	66	–32																									
13	16	16	16	02	–05	–09	–07	–08	100	–31	81	–09																								
30	17	25	23	17	–21	–12	–19	–17	–25	98	–17	65	–29																							
21	18	23	22	14	–16	–06	–12	–09	79	–22	99	–36	79	–20																						
20	14	19	17	00	–06	–17	–14	–16	–05	65	–30	97	–08	66	–36																					
–08	–13	–14	–14	19	–10	15	12	14	38	–26	41	–32	38	–25	40	–27																				
32	34	40	39	–06	–07	–27	–30	–30	02	36	–08	49	01	35	08	44	–76																			
–13	–16	–20	–19	07	01	16	18	18	36	–36	36	–37	37	–35	36	–35	93	–76																		
35	36	43	41	–04	–16	–28	–33	–32	05	43	–01	52	36	42	–02	50	63	93	–76																	
41	39	47	45	07	–19	–28	–33	–32	35	31	23	45	34	30	22	42	–26	82	–33	84																
42	39	48	45	11	–23	–28	–34	–32	35	35	27	47	35	34	25	45	–18	76	–32	86	97															
00	–10	–11	–11	24	–16	10	09	10	34	–29	35	–22	36	–29	34	–19	76	–53	70	–44	–14	–08														
28	34	41	39	–04	–09	–26	–32	–30	10	37	02	42	08	38	02	37	–57	84	–57	79	76	71	–67													
–06	–14	–15	–15	19	–11	11	12	12	21	–37	24	–29	22	–38	24	–28	63	–56	61	–51	–29	–26	91	–76												
29	33	39	38	–02	–10	–23	–29	–27	15	42	06	45	13	44	05	42	–43	76	–48	76	76	73	–58	94	–78											
37	38	46	44	14	–25	–27	–35	–33	41	27	30	39	40	27	30	35	–15	70	–20	71	91	88	–10	80	–29	79										
40	38	47	44	13	–24	–26	–34	–32	40	33	29	43	38	34	28	41	–12	68	–20	73	90	90	–11	79	–35	85	97									
25	24	27	26	03	–13	–26	–20	–24	–03	11	00	15	–03	10	–01	17	10	03	–04	16	13	18	07	10	–05	18	21	23								
26	23	26	26	15	–24	–26	–24	–26	–11	09	02	11	–01	07	03	09	–04	03	–12	11	02	07	–01	06	–04	07	06	08	50							
07	01	04	02	13	–13	–02	–07	–05	–03	–04	11	–19	–03	–05	12	–20	–12	–07	–07	–12	–20	–13	–01	–09	06	–16	–22	–19	–15	41						
19	12	16	15	–05	–06	–14	–10	–12	09	02	12	–03	09	01	11	–01	08	–01	05	00	04	09	05	03	00	05	04	09	57	27	33					
–17	–26	–29	–29	–05	17	30	31	32	05	–07	02	–10	06	–10	03	–12	–04	–06	06	–15	–12	–13	–02	–09	03	–12	–18	–17	–43	–09	24	15				
–12	–20	–26	–24	–03	12	18	26	23	–05	–13	–17	00	–04	–15	–16	–04	–08	01	08	–15	–06	–16	04	–01	05	–05	01	–04	–23	–32	01	–04	32			
–11	–22	–24	–25	–05	13	19	25	23	–08	–15	–16	–05	–08	–16	–14	–09	–14	01	02	–14	–10	–19	00	–03	05	–09	–03	–10	–27	–31	–02	–10	29	94		
07	–02	04	02	15	–16	–08	–11	–10	–23	25	–26	32	–25	25	–28	33	–08	11	–09	10	10	08	–05	13	04	09	13	09	–03	11	05	05	10	18	21	

recall or mental addition, or in comparing scan and search and letter recall, suggests that more than simply storage effects are operating here.

Implications for Test Battery

From the above results, certain tasks stand out as strong candidates for inclusion in an information processing performance test battery. These tasks are the Physical Match, Scan and Search, Set Membership, and Letter Rotation tasks. These four tasks replicated published findings, showed good reliability, and appeared to possess construct validity. Further, the tasks are easy to administer, eacy to score, and alternate forms can be easily constructed. Recommendations are that these tasks be given strong consideration for inclusion in any application of the battery.

The Letter Recall task and Mental Addition task comprise a second group of more marginal candidates. These tasks produced significant effects consistent with expectations and appeared to have some degree of construct validity but reliability was moderate to low. The tasks are easy to score and alternate forms are easily constructed. However, administration is more difficult than for the tasks discussed just previously. Both tasks require good mechanisms for timing stimulus presentation and intervals consistently. Thus while the tasks are innovative approaches to measuring information processing operations, they are also flawed. Recommendations are that the tasks be included in any application of the battery but that attempts be made to improve them.

The final, most marginal candidates for the test battery are the Sentence Recall and Sentence Recognition tasks. The Sentence Recognition task produced significant treatment effects but failed to replicate the desired finding. The task produced very low reliability and alternate forms are difficult to construct. The Sentence Recall task produced significant treatment effects but showed low to moderate reliability and was also moderately difficult to construct. The difficulty in construction with these tasks stems from a difficulty in controlling extraneous variables such as sentence complexity, sentence length, vocabulary, and any other variable that might influence subject strategies from sentence to sentence. The tasks also are moderately difficult to administer, requiring moderate consistency in the timing of events. Construct validity appeared to be good, but scoring, especially for the Sentence Recall task, is cimplex and time consuming. Recommendations are that these tasks be replaced with other tasks designed to converge on the abstraction operation.

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APPENDIX A

INSTRUCTIONS

INTRODUCTION

Welcome to the American Institutes for Research. The research you are about to take part in is one phase of a larger project designed to help understand basic human information processing capabilities and limitations.

The results of this project will be used to improve educational and vocational guidance programs. The project will, for example, contribute to the matching of individual qualifications and characteristics as needed for specific jobs and to the development of training programs for various occupations and professions.

Your participation in this project will require attendance at two sessions, consisting of approximately three hours each session. At the end of the second session you will be paid $30 for your participation.

During each session you will be asked to complete a series of simple tasks. These tasks involve simple matching and memory decisions, and do not test your knowledge of general information, your intelligence, nor your personality.

Every effort has been undertaken to insure your privacy with respect to performance on these tasks. Your name will never be associated with the scores. Before the tasks are scored your responses will be assigned a number and that number will be used to refer to the individual task performance. At no point will your name be associated with the assigned number. For our ease in handling your responses, we would like you to make up a pseudonym that you can write wherever the response sheets say "NAME". Please use the same name throughout every task for both days. Do not use your real name.

NAME (pseudonym) ____________________________, sex: male
female

You should be able to complete today's tasks in about three hours. There will be a break about halfway through the tasks. Remember you will be paid only if you complete the tasks for both days. Any questions?

Read with me through the following description of the first task and ask any questions you may have.

INSTRUCTIONS FOR THE LETTER RECALL TASK

In this task we are interested in your ability to remember letters from a series of letters. We shall read a series of letters to you, one letter at a time. At the end of that series we shall ask you to recall the last five letters in the order in which they occurred in the series.

Each of the series we shall read will contain a varying number of letters. Most of the time there will be more than five letters in the series. You will not know beforehand the number of letters in any particular series. At the end of the series we will say the word "RECALL"; you are to then recall only the last five letters of the series. We want you to try to remember the order in which the last five letters were presented. You will notice that on the response sheet there are five blanks for each series. Write your five letters in these five blanks. For example, if we read the following letters to you "D O Y R L C E", in that order, your recall in the blanks should ideally look like

Y R L C E.

If you forget some letters you should leave those blanks empty. For example:

Y R _ C E

If you cannot remember the position of a letter in the five letters, guess, but try to be as accurate as you can in recalling the last five letters and their positions.

Any questions?

We shall now give you some practice.

STOP.

INSTRUCTIONS FOR PHYSICAL MATCH TASK

In this task we are interested in how accurately and rapidly you can make a series of simple judgments. We shall be concerned with your ability to decide whether two letters are the same or different. On the task sheet, you will see columns of pairs of letters. If the two letters in a pair are the same put a check mark in the space to the left of the letters; if the two letters are different put a check mark in the space to the right of the letters. For example, if the letter pair were:

__ A A __

Then you should put a check mark to the left of the pair

✓ A A __.

If the letter pair were:

__ A B __

Then you should put a check mark to the right of the pair

__ A B ✓.

You are to work down each column putting a check in the appropriate place beside each pair until you hear the word "STOP". Please work as accurately and as quickly as possible.

Any questions?

We shall begin by giving you a few practice problems.

STOP.
PLEASE DO NOT TURN THE PAGE
UNTIL INSTRUCTED TO DO SO.

Day 2 RESPONSE SHEET: PHYSICAL MATCH ____________________

SAME		DIFF	SAME		DIFF	SAME		DIFF	SAME		DIFF	SAME		DIFF
__	A H	__	__	E T	__	__	H T	__	__	A T	__	__	H H	__
__	T A	__	__	A A	__	__	T T	__	__	T T	__	__	E E	__
__	E E	__	__	A A	__	__	T E	__	__	T T	__	__	T T	__
__	H T	__	__	E E	__	__	E E	__	__	A E	__	__	H T	__
__	E E	__	__	A E	__	__	H H	__	__	E T	__	__	E E	__
__	A A	__	__	H H	__	__	A T	__	__	E E	__	__	E A	__
__	A A	__	__	A E	__	__	T E	__	__	A A	__	__	H H	__
__	H E	__	__	H H	__	__	T T	__	__	H H	__	__	T E	__
__	T T	__	__	E H	__	__	T T	__	__	E T	__	__	H E	__
__	H A	__	__	E E	__	__	H T	__	__	A H	__	__	H H	__
__	E T	__	__	H A	__	__	E E	__	__	A E	__	__	H H	__
__	T H	__	__	E E	__	__	A A	__	__	A A	__	__	E H	__
__	A A	__	__	T H	__	__	T E	__	__	E A	__	__	A A	__
__	E H	__	__	A T	__	__	A A	__	__	E E	__	__	T T	__
__	T T	__	__	A E	__	__	T A	__	__	T E	__	__	E A	__
__	T T	__	__	A A	__	__	H A	__	__	T T	__	__	E H	__
__	H H	__	__	H E	__	__	H T	__	__	H H	__	__	A A	__
__	H E	__	__	T T	__	__	E E	__	__	H H	__	__	E E	__
__	E E	__	__	T A	__	__	E H	__	__	E T	__	__	A H	__
__	H H	__	__	A T	__	__	A A	__	__	A T	__	__	T H	__
__	E E	__	__	E H	__	__	T T	__	__	E E	__	__	A T	__
__	E T	__	__	H H	__	__	A E	__	__	T T	__	__	A A	__
__	A A	__	__	A A	__	__	A A	__	__	H H	__	__	H A	__
__	T A	__	__	T E	__	__	T H	__	__	H T	__	__	E E	__
__	E A	__	__	E A	__	__	T T	__	__	E E	__	__	A A	__
__	H H	__	__	A H	__	__	A A	__	__	T H	__	__	T T	__
__	T T	__	__	H H	__	__	T A	__	__	H H	__	__	H T	__
__	A H	__	__	H A	__	__	T A	__	__	H A	__	__	E H	__
__	E A	__	__	T H	__	__	T T	__	__	H E	__	__	H H	__
__	T T	__	__	H H	__	__	A H	__	__	H E	__	__	T A	__

STOP.

INSTRUCTIONS FOR THE SENTENCE RECALL TASK

In this task we are interested in your ability to organize and recall the information presented in a list of sentences. On any one trial we are going to present you a list of sentences on four topics. Each sentence will describe some aspect of one of the four topics. At the end of the list of sentences you are to recall as much as you can about the four topics. For example, I might read you sentences like the following:

The carpenter fixed the roof.
The letter was typed by the secretary.
The shoes were in the closet.
The carpenter stood on a ladder.
The shoes were made of canvas.
The carpenter was an apprentice.
The letter was lengthy.
The roof was leaking.
The shoes had wooden heels.
The closet was upstairs.

.
.
.
etc.

These sentences deal with the topics of *the carpenter*, *the shoes*, and *the letter*. Your recall on the topic of *the carpenter* might be as follows: "The apprentice carpenter stood on the ladder to fix the leaking roof." For *the shoes* you might write: "The canvas shoes with the wooden heels were in the upstairs closet." And so on for each of the four topics. Your recall does not have to be complete sentences; you may use pharses to express the ideas. For example, if you wrote "apprentice carpenter stood on ladder, fixed leaking roof" that would be fine. However, to write "carpenter ladder apprentice roof leaking fixed" would not be sufficient. If you use phrases make sure that you give sufficient information in the phrase to adequately express the ideas associated with each topic. Try to make sure you recall as much as you can remember about the four topics keeping the information about each topic separate from the other topics. You will notice on the response sheets that we have provided four spaces for you to write your recall, one space for each topic. You are to work down the sheet, recalling everything you can about one topic before going on to the next.

So then, we shall read you some sentences about four topics. At the end of the list we will say the word recall. You will then have about two minutes in which to recall all that you can about the topics. You are to recall the information by topic, keeping each topic separate.

Any questions?

We shall begin by giving you some practice.

STOP.
PLEASE DO NOT TURN THE PAGE
UNTIL INSTRUCTED TO DO SO.

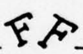
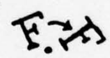
INSTRUCTIONS FOR THE LETTER ROTATION TASK

In this task we are interested in your ability to handle and compare letters in various orientations. You will see columns of pairs of letters and have to decide if the letters in each pair are the same or different. You are to use two rules in making your decision. RULE 1: If the two letters in a pair are exactly the same such that you can simply slide the first letter over on top of the second letter and they match exactly then put a check to the left of that pair (in the SAME column). For example, according to Rule 1 the following pairs are the same:

✓ F F __ AND ✓  __.

RULE 2: If the first letter can be rotated like the hands of a clock so that it will slide over and exactly match the second letter, then check "SAME" for this pair. For example, according to Rule 2 the following pairs are the same:

✓ F Ⅎ __ SINCE 

✓  __ SINCE 

The following pairs however are different since neither Rule 1 nor Rule 2 will work.

__ F  ✓ AND __ F  ✓.

You cannot rotate the first letter like the hands of a clock rotate to make it match the second letter. Thus the pairs should be marked "DIFFERENT."

For any pair if Rule 1 or Rule 2 applies you should mark the pair as same by putting a check to the left of the pair. If Rule 1 or Rule 2 will not work then you should mark the pair as different by putting a check to the right of the pair. You should go down the columns of pairs being as accurate and rapid as you can. When you hear the word "STOP" you should lift your pencil and wait for further instruction.

Any questions?

In the first column of the practice response sheet you need only apply Rule 1, that is, no rotation is necessary. You should now work through the first column of practice problems. Even though we won't be timing you for these practice problems you should still try to work as fast as you can without making errors. Please look up when you finish the first column.

Any questions?

All the other practice problems require that you apply Rule 2, to varying degrees. That is, you will have to rotate the first letter to see if it matches the second. You should now work the last three columns on the practice response sheet. Again try to work as fast as you can without making errors. Please look up when you have done the three columns.

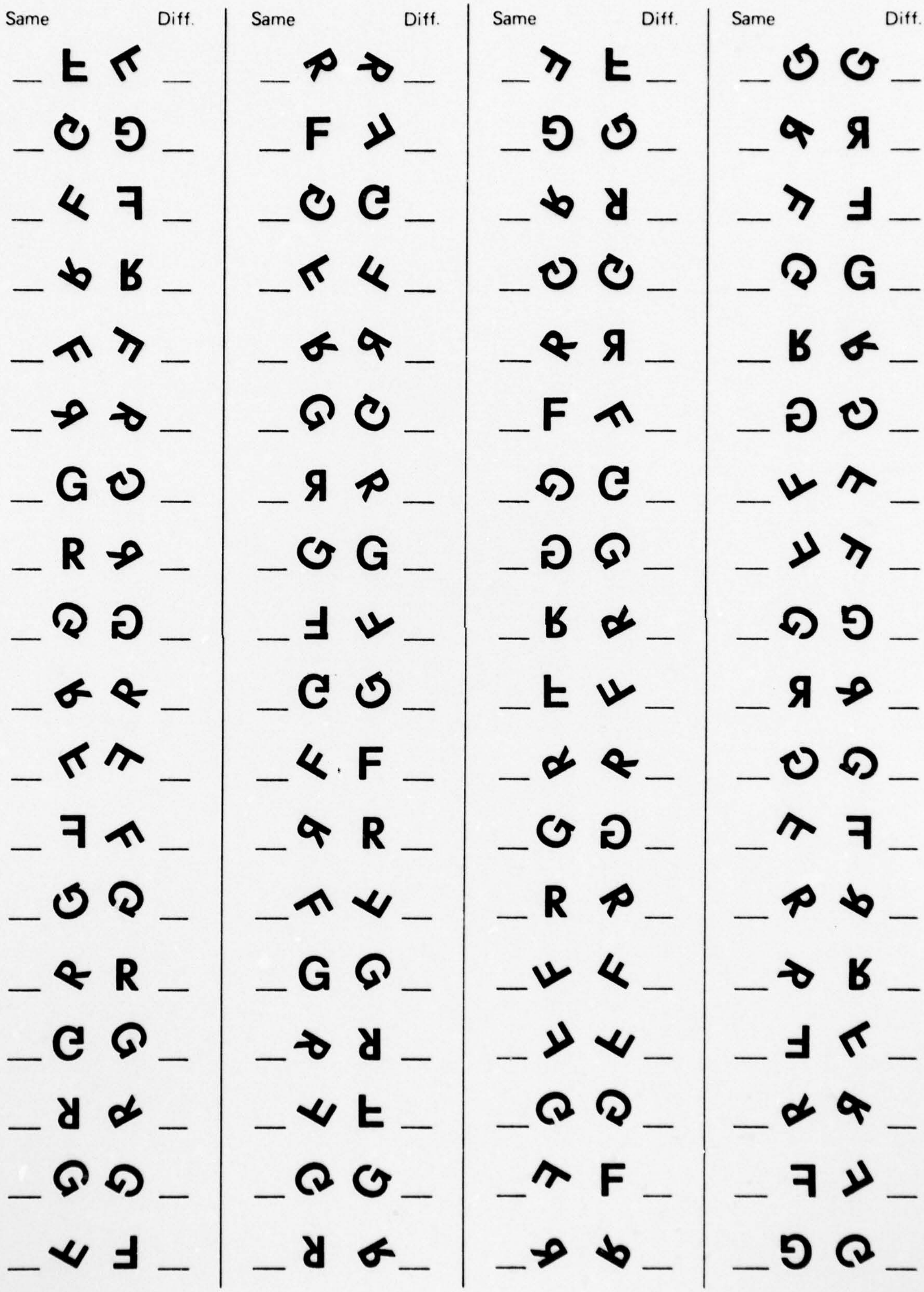
Any questions?

The first set of problems in the task will be a page of problems just like the problems in column one. YOu will not have to rotate letters. When I say "READY" you are to turn the page, when I say "START" you are to work as many of these problems as you can before I say "STOP".

STOP.

RESPONSE SHEET: LETTER ROTATION TASK A

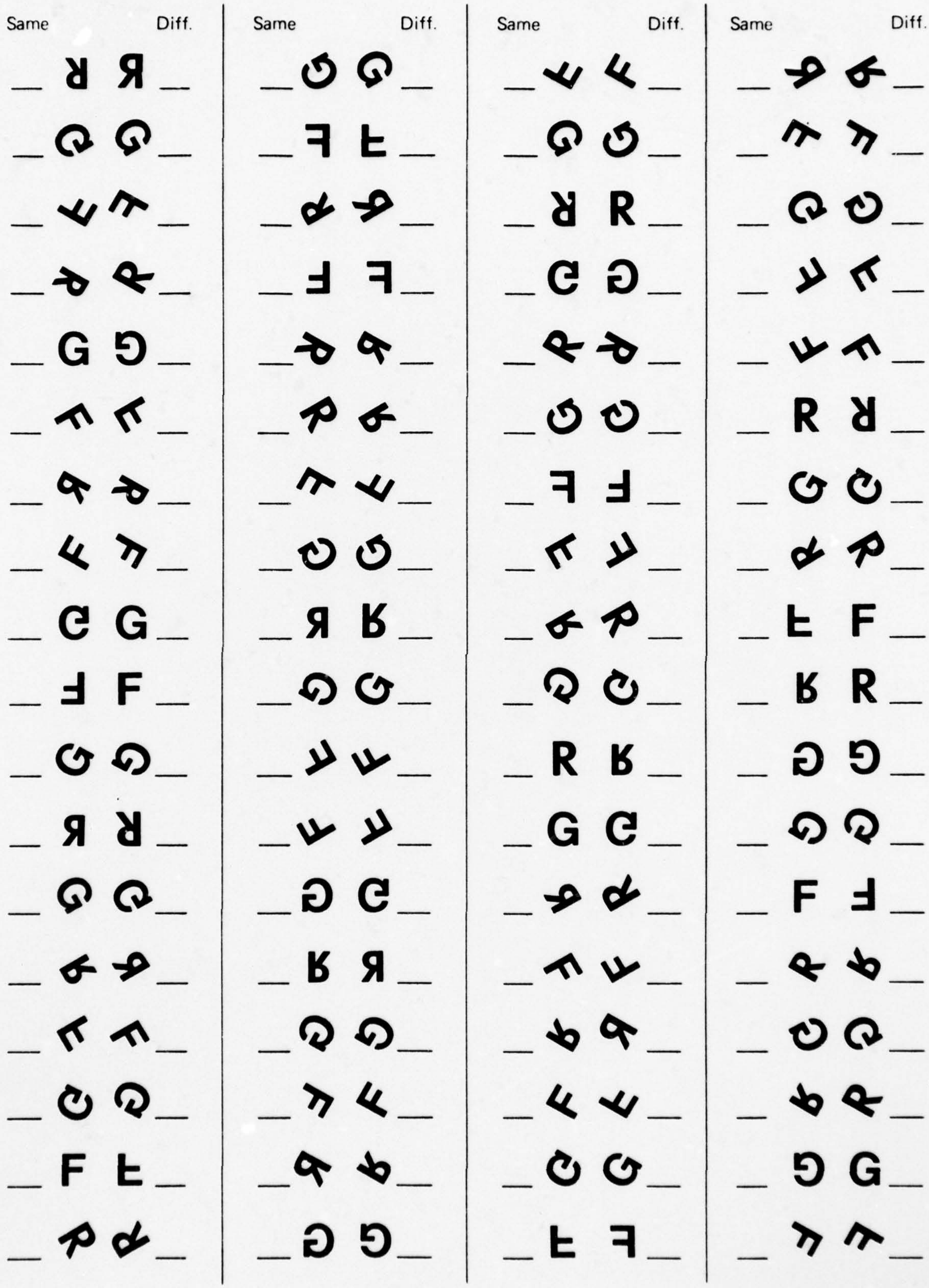
RESPONSE SHEET: LETTER ROTATION TASK B



RESPONSE SHEET: LETTER ROTATION TASK C

Same	Diff.	Same	Diff.	Same	Diff.	Same	Diff.

RESPONSE SHEET: LETTER ROTATION TASK D



INSTRUCTIONS FOR MENTAL ADDITION TASK

In the following task we are interested in your ability to add numbers "in your head" when the numbers you are adding are not written down. We shall read two numbers which you are to add together. For example, we might say: "Two hundred ninety-five plus four hundred fifty-eight." You will have a fixed amount of time in which to do the addition. Try to write down as much of the answer as you can during the time interval. Write the sum down as you get each part of it. When you hear the word "STOP", you should stop working on the problem and get ready for the next problem.

We are not concerned with whether or not you can complete the problems; in fact for most of the problems we really don't expect you to complete them. We are most interested in your writing down the parts of the answer as you get them. On your response sheets, there are three blanks for each problem, representing the units, tens, and hundreds positions in the sum. As you get a part of the sum write that part in the appropriate blank. Do not hold part of the sum in memory waiting to complete the addition; write out the answer as you get it. It is important that you be as accurate as possible in your sums, so please do not guess about parts of the answer you have not worked out.

Any questions?

We shall begin by giving you some practice problems.

STOP

INSTRUCTIONS FOR THE SCAN AND SEARCH TASK

In this task we are interested in your ability to search columns of letters looking for particular letters. At the beginning of each trial you will be given a set of letters. This set may have 1, 2, or 4 letters. These will be the target letters you will search for on that trial. You will work down columns of groups of letters looking for those target letters. If you find a group of letters that contains a target letter put a check beside that group. For example, if the target set were "L or K" then you should mark the following as illustrated:

Q X M V S	
T R N L O	✓
K M D A T	✓
C P F X R	
P K T S W	✓
L A R T D	✓
M C N P H	

Notice that only the groups containing an "L" or "K" are checked.

You are to continue working down the column until you are told to "STOP". When you hear the word "STOP" draw a line under the last group of letters you looked at, not the last item you checked. At the bottom of the page on the right, write the letters you were searching for.

Some of the pages are blurred and hard to read. This is for the purposes of the experiment.

Any questions?

We shall begin by giving you some practice on the task.

STOP.

PLEASE DO NOT TURN THE PAGE

UNTIL INSTRUCTED TO DO SO.

AGBDT	XJDQE	AJMPO	XUMFC
YZMFU	AHPRO	EHQCY	OTDMB
UPCJX	UBMDY	AFDMX	AGMQY
YQMDA	AFDOG	RBAET	OZPDU
VPROX	VFCYK	LQMDG	JBMDN
OHFDA	EQMZU	XBDMY	AHPXU
BMDKL	AMDBN	EFDVO	URVFX
KQMYL	PMTNA	EOUZP	UYDQE
YVQCX	KQDZL	NBMDA	AUMFZ
OBDME	VPRUX	KYFMH	LNDQG
AEFMZ	OTMFU	GPDXY	KLJDP
NAPDG	PDGEO	UXBMR	YKTMF
LBMJN	BMDKL	JCQOU	XVDBY
YQDTU	NFCHA	NAFDT	ERMPU
KMDPL	BDMAE	EPMZO	UHQCX
KHFRY	NLMQJ	AEQDV	OXMDB

AUMFZ	NBMDA	YVOCX	KOCZL
LNDQG	KYFMH	OBDME	VFRUX
KLJDP	GPDXY	AEFMZ	OTMFU
YKTMF	UXBMR	NAPDG	PDGEO
XVDBY	JCQOU	LBMJN	BMDKL
ERMPU	NAFDT	YQDTU	NFCRA
UHOCX	EPMZO	KMDPL	BDMAE
JXMDB	AEQUV	KHFRY	NLMDJ
XJMFC	AGBOT	XJDQE	AJMPG
OTDMB	YZMFU	AHPRO	EHQCY
AGMQY	UPCJX	UBMDY	AFDMX
OZPGU	YQMDA	AFDOG	RBAET
JBMDN	VPROX	VFCYK	LQMDG
AHPXU	OHFDA	EQMZU	XBDMY
URVFX	BMDKL	AMDBN	EFDVC
GYDQE	KQMYL	PMTNA	EQUZP

INSTRUCTIONS FOR THE SENTENCE RECOGNITION TASK

In this task we are interested in your ability to recognize sentences you have heard before. We shall read a series of sentences for you to study and remember. At the end of the series of sentences you will be given a recognition test in which we shall again read sentences to you. Each sentence in the test will either be a sentence from the series you were asked to study or it will be a new sentence. You are to decide if each test sentence was in the series you studied earlier. The new sentences will be very similar to the sentences from the earlier series, so you must study these sentences very closely. We are asking for recognition of exact wording as well as events. If the test sentence is exactly as you saw it in the series you studied earlier cross out the "YES" on the response sheet; if the test sentence is new and was not in the earlier series then cross out "NO" on your response sheet. In the blank space beside your answer, you are to write a number from one to five indicating how confident you are that your answer is correct. Write 5 for very high confidence, 4 for high confidence, 3 for moderate confidence, 2 for low confidence and 1 for very low confidence. Respond to every sentence that you hear on the test and do not leave any sentences blank.

To repeat, you will hear some sentences which you will study and try to remember exactly as they are presented. Following the study sentences you will be given a test and have to decide whether or not each sentence on the test was one of the study sentences. Cross out the "YES" if it was, and the "NO" if it was not. Beside your answer indicate how confident you are in your answer, with 5 meaning very high confidence and 1 meaning very low confidence.

Any questions?

We shall now give you some practice trials.

STOP.

DAY 2 ________ NAME ____________________

RESPONSE SHEET: SENTENCE RECOGNITION, PART A

RATINGS: 1 very low, 2, 3 moderate, 4, 5 very high

	RESPONSE		RATING		RESPONSE		RATING
1.	YES	NO	_____	8.	YES	NO	_____
2.	YES	NO	_____	9.	YES	NO	_____
3.	YES	NO	_____	10.	YES	NO	_____
4.	YES	NO	_____	11.	YES	NO	_____
5.	YES	NO	_____	12.	YES	NO	_____
6.	YES	NO	_____	13.	YES	NO	_____
7.	YES	NO	_____	14.	YES	NO	_____

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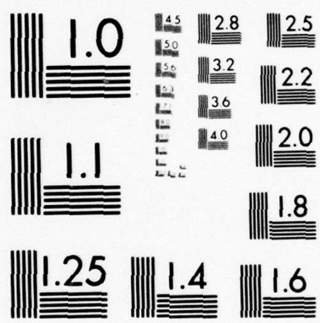

MICROCOPY RESOLUTION TEST CHART

INSTRUCTIONS FOR THE SET MEMBERSHIP TASK

In this task we are interested in how quickly you can recognize items you have heard before. At the start of each trial you will memorize a set of letters. You will then work down a column of letters indicating whether or not each letter was in the set you memorized. If a particular letter was in the memorized set put a check to the left of the letter. If a letter was not in the memorized set then put a check to the right of the letter. For example, if the memorized set was "L T R S W" then your responses to the following letters should be as illustrated:

YES		NO
___	D	✓
___	G	✓
✓	R	___
✓	W	___
___	K	✓
✓	R	___

You are to work as accurately and as quickly as possible until you hear the word "STOP" at which time you should stop making the checks. At the bottom right of the page we then want you to write down the letters you memorized.

Any questions?

We shall now give you some practice.

STOP.

PLEASE DO NOT TURN THE PAGE.

RESPONSE SHEET: SET MEMBERSHIP TASK 67

YES		NO	YES		NO	YES		NO	YES		NO	YES		NO	YES		NO
	T			N			S			R			V			D	
	T			L			H			D			N			M	
	H			T			P			T			T			T	
	L			T			T			T			T			T	
	T			P			T			B			T			T	
	P			T			T			N			S			T	
	R			S			T			T			T			Z	
	L			H			T			C			C			T	
	M			T			G			T			T			L	
	H			T			F			N			T			B	
	L			T			R			T			N			L	
	N			P			T			T			T			T	
	H			T			N			R			D			S	
	S			T			T			T			L			T	
	G			T			T			L			T			T	
	T			T			S			B			N			T	
	H			R			T			R			T			T	
	T			R			T			T			S			J	
	F			T			T			T			H			T	
	T			D			T			D			T			S	
	G			F			H			T			T			T	
	T			R			P			T			F			P	
	T			T			T			P			S			T	
	D			T			B			T			T			T	
	T			T			C			N			T			H	
	T			T			T			C			T			B	
	T			M			K			B			T			T	
	H			T			T			T			B			T	
	T			T			S			N			T			N	
	T			D			H			S			T			T	

APPENDIX B

ANALYSIS OF VARIANCE SUMMARY TABLES

TABLE OF CONTENTS

B-1

ANOVA OF LETTER RECALL: ORDER RECALL

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F
Mean	60762.55	1	60762.55	4353.11*
Subjects	935.22	67	13.96	
D (Day)	164.71	1	164.71	60.33*
De[1]	182.90	67	2.73	
S (Administration)	47.85	1	47.85	25.65*
Se	124.99	67	1.87	
DS	23.89	1	23.89	16.31*
DSe	98.11	67	1.46	
C (No. of Letters)	897.35	5	179.47	80.32*
Ce	748.54	335	2.23	
DC	38.05	5	7.61	4.46*
DCe	571.68	335	1.71	
SC	49.87	5	9.97	6.21*
SCe	537.63	335	1.60	
DSC	23.16	5	4.63	3.17*
DSCe	490.18	335	1.46	
R (Repetition)	19.42	2	9.71	8.02*
Re	162.14	134	1.21	
DR	23.74	2	11.87	6.29*
DRe	252.82	134	1.89	

* $p < 0.01$

[1] In each case, e represents the error term of the treatment above it and is treatment by subject interaction.

ANOVA OF LETTER RECALL: ORDER RECALL (Cont'd.)

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F
SRe[1]	175.76	134	1.31	
SR	36.57	2	18.29	13.94*
DSR	19.16	2	9.53	6.67*
DSRe	192.50	134	1.44	
CR	76.46	10	7.65	5.10*
CRe	1005.32	670	1.50	
DCR	56.21	10	5.62	4.13*
DCRe	911.90	670	1.36	
SCR	98.22	10	9.82	6.80*
SCRe	98.22	670	1.44	
DSCR	49.48	10	4.95	3.23*
DSCRe	1025.53	670	1.53	

* $p < 0.01$

[1] In each case, e represents the error term of the treatment above it and is treatment by subject interaction.

B-2

ANOVA OF LETTER RECALL: DERIVED-FREE RECALL

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F
Mean	84650.39	1	84650.39	12476.41*
Subjects	454.58	67	6.78	
D (Day)	27.36	1	27.36	23.71*
De[1]	77.31	67	1.15	
S (Administration)	2.21	1	2.21	2.56
Se	57.74	67	0.86	
DS	3.78	1	3.78	4.80
DSe	52.78	67	0.78	
C (No. of Letters)	390.36	5	78.07	89.82*
Ce	291.19	335	0.87	
DC	16.33	5	3.27	5.03*
DCe	217.51	335	0.65	
SC	11.71	5	2.34	4.06*
SCe	193.18	335	0.58	
DSC	8.21	5	1.64	2.86
DSCe	192.73	335	0.58	
R (Repetition)	13.88	2	6.94	13.21*
Re	70.42	134	0.53	
DR	17.25	2	8.63	11.88*
DRe	97.33	134	0.73	

* $p < 0.01$

[1] In each case, e represents the error term of the treatment above it and is treatment by subject interaction.

ANOVA OF LETTER RECALL: DERIVED-FREE RECALL (Cont'd.)

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F
SR	17.97	2	8.98	16.91*
SRe[1]	71.17	134	0.53	
DSR	3.41	2	1.71	2.34
DSRe	97.78	134	0.73	
CR	40.15	10	4.01	6.68*
CRe	402.55	670	0.60	
DCR	50.30	10	5.03	8.08*
DCRe	417.11	670	0.62	
SCR	60.17	10	6.02	10.97*
SCRe	367.36	670	0.55	

* $p < 0.01$

[1] In each case, e represents the error term of the treatment above it and is treatment by subject interaction.

B-3

ANOVA OF LETTER ROTATION: CORRECT

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F
Mean	2875.80	1	2875.80	505.40*
Subjects	369.86	65	5.69	
D (Day)	46.29	1	46.29	78.07*
De[1]	38.54	65	0.59	
C (Condition)	341.37	3	113.79	62.16*
Ce	356.97	195	1.83	
DC	4.01	3	1.34	3.07
DCe	85.00	195	0.44	

*$p < 0.01$

[1]In each case, e represents the error term of the treatment above it and is treatment by subject interaction.

B-4

ANOVA OF LETTER ROTATION: COMPLETED

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F
Mean	2026.83	1	2026.83	866.85*
Subjects	151.98	65	2.34	
D (Day)	20.14	1	20.14	77.10*
De[1]	16.98	65	0.26	
C (Condition)	199.83	3	66.61	133.63*
Ce	97.20	195	0.50	
DC	0.89	3	0.30	2.01
DCe	26.10	195	0.15	

*p < 0.01

[1]In each case, e represents the error term of the treatment above it and is treatment by subject interaction.

B-5

ANOVA OF SET MEMBERSHIP: COMPLETED

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F
Mean	602.32	1	602.32	3500.66*
Subjects	11.53	67	0.17	
D (Day)	2.55	1	2.55	197.42*
De[1]	0.86	67	0.01	
C (Condition)	7.42	3	2.47	371.68*
Ce	1.34	201	0.01	
DC	0.03	3	0.01	3.08**
DCe	0.68	201	0.003	
R (Repetition)	0.06	2	0.03	7.38*
Re	0.51	134	0.004	
DR	0.07	2	0.03	7.13*
DRe	0.63	134	0.005	
CR	0.16	6	0.03	7.35*
CRe	1.44	402	0.004	
DCR	0.20	6	0.03	8.26*
DCRe	1.65	402	0.004	

* $p < 0.01$
** $p < 0.05$

[1] In each case, e represents the error term of the treatment above it and is treatment by subject interaction.

B-6

ANOVA OF SET MEMBERSHIP: CORRECT

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F
Mean	626.26	1	626.26	2538.56*
Subjects	16.53	67	0.25	
D (Day)	1.82	1	1.82	26.90*
De[1]	4.54	67	0.07	
C (Condition)	9.24	3	3.08	50.31*
Ce	12.31	201	0.06	
DC	0.28	3	0.09	1.60
DCe	11.82	201	0.06	
R (Repetition)	0.27	2	0.13	2.29
Re	7.82	134	0.06	
DR	0.06	2	0.03	0.53
DRe	7.46	134	0.06	
CR	0.55	6	0.09	1.59
CRe	22.97	402	0.06	
DCR	0.54	6	0.09	1.53
DCRe	23.54	402	0.06	

* $p < 0.01$

[1] In each case, e represents the error term of the treatment above it and is treatment by subject interaction.

B-7

ANOVA OF SENTENCE RECALL: CLUSTER

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F
Mean	806.81	1	806.81	1906.00*
Subjects	28.36	67	0.42	
D (Day)	0.02	1	0.02	0.23
De[1]	4.78	67	0.07	
S (Sentence)	6.85	11	0.62	2.21*
A (Attribute)	1.20	2	0.60	10.04*
R (Remainder)	5.65	9	0.63	12.66*
Se	37.61	737	0.05	
Ae	8.00	134	0.06	
Re	29.61	603	0.05	
DS	4.51	11	0.41	7.64*
DA	0.18	2	0.09	1.39*
DR	4.33	9	0.48	9.33*
DSe	39.60	737	0.05	
DAe	8.53	134	0.06	
DRe	31.07	603	0.05	

* $p < 0.01$

[1] In each case, e represents the error term and is the treatment by subject interaction.

ANOVA OF SENTENCE RECALL: ITEM

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F
Mean	941.37	1	941.37	3452.03*
Subjects	18.27	67	0.27	
D (Day)	0.00	1	0.00	0.00
De[1]	4.78	67	0.07	
S (Sentence)	6.17	11	0.56	14.60*
A (Attribute)	0.85	2	0.42	10.27*
R (Remainder)	5.32	9	0.59	15.74*
Se	28.17	737	0.04	
Ae	5.53	134	0.04	
Re	22.64	603	0.04	
DS	4.52	11	0.41	10.66*
DA	0.55	2	0.27	6.16*
DR	3.97	9	0.44	11.83*
DSe	28.43	737	0.04	
DAe	5.94	134	0.04	
DRe	22.49	603	0.34	

* $p < 0.01$

[1]In each case, e represents the error term of the treatment above it and is treatment by subject interaction.

B-9

ANOVA OF SCAN AND SEARCH: COMPLETED

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F
Mean	1245.82	1	1245.82	2585.14*
Subjects	32.29	67	0.48	
D (Day)	2.57	1	2.57	68.00*
De[1]	2.54	67	0.04	
S (Administration)	0.44	1	0.44	18.85*
Se	1.56	67	0.02	
DS	0.34	1	0.34	15.25*
DSe	1.48	67	0.02	
G (Degraded)	2.31	1	2.31	83.71*
Ge	1.85	67	0.03	
DG	0.003	1	0.003	0.26
DGe	0.90	67	0.01	
SG	0.003	1	0.003	0.03
SGe	0.77	67	0.01	
DSG	0.01	1	0.01	0.43
DSGe	1.43	67	0.02	
C (Condition)	188.74	2	94.37	634.87*
Ce	19.92	134	0.15	
DC	0.87	2	0.44	20.70*
DCe	2.82	134	0.02	
SC	0.10	2	0.05	3.06**
SCe	2.26	134	0.02	
DSC	0.03	2	0.01	0.84
DSCe	2.34	134	0.02	

*$p < 0.01$

**$p < 0.05$

[1]In each case, e represents the error term of the treatment above it and is treatment by subject interaction.

B-9

ANOVA OF SCAN AND SEARCH: COMPLETED (Cont'd.)

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F
GC	0.12	2	0.06	3.36**
GCe[1]	2.36	134	0.02	
DGC	0.01	2	0.005	0.32
DGCe	1.33	134	0.01	
SGC	0.02	2	0.01	0.97
SGCe	1.60	134	0.01	
DSGC	3.16	2	1.58	67.18*
DSGCe	3.15	134	0.02	
Pooled Error	14.60	804	0.02	

* $p < 0.01$
** $p < 0.05$

[1] In each case, e represents the error term of the treatment above it and is treatment by subject interaction.

B-10
ANOVA OF SCAN AND SEARCH: CORRECT

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F
Mean	1552.65	1	1552.65	2414.65*
Subjects	43.08	67	0.64	
D (Day)	4.37	1	4.37	67.28*
De[1]	4.35	67	0.06	
S (Administration)	0.87	1	0.87	21.28*
Se	2.72	67	0.04	
DS	0.47	1	0.47	11.38*
DSe	2.75	67	0.04	
G (Degraded)	8.21	1	8.21	150.79*
Ge	3.65	67	0.05	
DG	0.16	1	0.16	4.05**
DGe	2.62	67	0.04	
SG	0.04	1	0.04	1.77
SGe	1.46	67	0.02	
DSG	0.002	1	0.002	0.06
DSGe	2.77	67	0.04	
C (Condition)	318.52	2	159.76	741.77*
Ce	28,86	134	0.22	
DC	2.17	2	1.09	25.75*
DCe	5.66	134	0.04	
SC	0.30	2	0.15	4.50**
SCe	4.43	134	0.03	
DSC	0.01	2	0.005	0.08
DSCe	4.62	134	0.03	

* $p < 0.01$

** $p < 0.05$

[1]In each case, e represents the error term of the treatment above it and is treatment by subject interaction.

B-10

ANOVA OF SCAN AND SEARCH: CORRECT (Cont'd.)

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F
GC	0.82	2	0.41	8.86*
GCe[1]	6.23	134	0.05	
DGC	0.15	2	0.08	2.34
DGCe	4.38	134	0.03	
SGC	0.04	2	0.02	0.74
SGCe	3.45	134	0.03	
DSGC	4.00	2	2.00	44.44*
DSGCe	6.03	134	0.05	
Pooled Error	28.23	804	0.04	

* $p < 0.01$
** $p < 0.05$

[1] In each case, e represents the error term of the treatment above it and is treatment by subject interaction.

B-11

ANOVA OF SENTENCE RECOGNITION: WITHOUT LEVEL FOUR

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F
Mean	283.53	1	283.53	11.31*
Subjects	1679.18	67	25.06	
D (Day)	389.82	1	389.82	34.69*
De[1]	752.88	67	11.24	
L (Complexity)	18.63	2	9.32	0.72
Le	1734.78	134	12.95	
DL	206.30	2	103.15	11.46*
DLe	1206.11	134	9.00	
N (New-Old)	2527.08	1	2527.08	191.63*
Ne	883.55	67	13.19	
DN	875.03	1	875.03	84.71*
DNe	692.09	67	10.33	
LN	339.56	2	169.78	18.63*
LNe	1221.44	134	9.12	
DLN	586.30	2	293.15	36.13*
DLNe	1087.20	134	8.11	
I (Inconsistency)	4626.53	1	4626.53	348.81*
Ie	888.68	67	13.26	
DI	517.77	1	517.77	68.36*
DIe	507.44	67	7.57	
LI	656.68	2	328.34	37.82*
LIe	1163.49	134	8.68	

* $p < 0.01$

[1] In each case, e represents the error term of the treatment above it and is treatment by subject interaction.

B-11

ANOVA OF SENTENCE RECOGNITION: WITHOUT LEVEL FOUR (Cont'd.)

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F
DLI	72.38	2	36.19	3.62**
DLIe[1]	1340.28	134	10.00	
NI	32.96	1	32.96	3.54
NIe	623.83	67	9.31	
DNI	48.53	1	48.53	6.10**
DNIe	533.09	67	7.96	
LNI	237.54	2	118.77	11.44*
LNIe	1391.04	134	10.38	
DLNI	447.81	2	223.91	22.25*
DLNIe	1348.44	134	10.06	
V (Administration)	240.50	1	240.50	33.42*
Ve	482.12	67	7.20	
DV	671.08	1	671.08	80.59*
DVe	557.88	67	8.33	
LV	34.72	2	17.36	1.87
LVe	1241.28	134	9.26	
DLV	126.22	2	63.11	7.52*
DLVe	1124.44	134	8.39	
NV	21.35	1	21.35	2.45
NVe	583.52	67	8.71	
DNV	247.06	1	247.06	30.58*
DNVe	541.32	67	8.08	

* $p < 0.01$
** $p < 0.05$

[1] In each case, e represents the error term of the treatment above it and is treatment by subject interaction.

B-11

ANOVA OF SENTENCE RECOGNITION: WITHOUT LEVEL FOUR (Cont'd.)

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F
LNV	446.56	2	223.28	27.88*
LNVe[1]	1073.19	134	8.01	
DLNV	207.06	2	103.53	11.25*
DLNVe	1233.19	134	9.20	
IV	782.35	1	782.35	72.27*
IVe	725.27	67	10.82	
DIV	979.46	1	979.46	136.01*
DIVe	482.50	67	7.20	
LIV	217.34	2	108.67	11.29*
LIVe	1289.91	134	9.63	
DLIV	145.86	2	77.43	7.07*
DLIVe	1468.56	134	10.96	
NIV	29.82	1	29.82	2.68
NIVe	744.72	67	11.16	
DNIV	519.36	1	519.36	57.01*
DNIVe	610.34	67	9.11	
LNIV	347.45	2	173.72	17.62*
LNIVe	1321.39	134	9.86	
DLNIV	151.26	2	75.63	7.86*
DLNIVe	1289.90	134	9.63	

* $p < 0.01$
** $p < 0.05$

[1]In each case, e represents the error term of the treatment above it and is treatment by subject interaction.

B-12

ANOVA OF MENTAL ADDITION: CORRECT

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F
Mean	8090.82	1	8090.82	5243.08*
Subjects	111.11	72	1.54	
D (Day)	0.49	1	0.49	1.81
De[1]	19.40	72	0.27	
S (Administration)	3.85	1	3.85	28.65*
Se	9.67	72	0.13	
DS	0.37	1	0.37	3.54
DSe	7.59	72	0.11	
L (Long-Short)	28.18	1	28.18	213.50*
Le	9.50	72	0.13	
DL	0.52	1	0.52	6.40**
DLe	5.83	72	0.08	
SL	0.02	1	0.02	0.14
SLe	8.22	72	0.11	
DSL	0.25	1	0.25	3.19
DSLe	5.61	72	0.08	
C (Condition)	64.26	3	21.42	153.33*
Ce	30.18	216	0.14	
DC	1.54	3	0.51	6.57*
DCe	16.83	216	0.08	
SC	0.98	3	0.33	3.74**
SCe	18.89	216	0.09	
DSC	3.00	3	1.00	13.10*
DSCe	16.47	216	0.08	

* $p < 0.01$
** $p < 0.05$

[1]In each case, e represents the error term of the treatment above it and is treatment by subject interaction.

ANOVA OF MENTAL ADDITION: CORRECT (Cont'd.)

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F
LC	6.58	3	2.19	24.87*
LCe[1]	19.03	216	0.09	
DLC	2.65	3	0.88	10.11*
DLCe	18.87	216	0.09	
SLC	0.35	3	0.12	1.37
SLCe	18.57	216	0.09	
DSLC	3.39	3	1.13	13.34*
DSLCe	18.29	216	0.08	
R (Repetitions)	7.25	2	3.62	37.72*
Re	13.83	144	0.10	
DR	3.39	2	1.69	17.13*
DRe	14.25	144	0.10	
SR	0.55	2	0.27	3.06**
SRe	12.63	144	0.09	
DSR	1.32	2	0.66	7.90*
DSRe	12.03	144	0.08	
LR	2.34	2	1.17	14.23*
LRe	11.82	144	0.08	
DLR	0.69	2	0.35	3.66**
DLRe	13.60	144	0.09	

* $p < 0.01$
** $p < 0.05$

[1] In each case, e represents the error term of the treatment above it and is treatment by subject interaction.

B-12

ANOVA OF MENTAL ADDITION: CORRECT (Cont'd.)

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F
CR	5.16	6	0.86	9.98*
CRe[1]	37.22	432	0.09	
DCR	10.15	6	1.69	19.57*
DCRe	37.35	432	0.09	
SCR	3.56	6	0.59	7.23*
SCRe	35.39	432	0.08	
DSCR	4.92	6	0.82	8.92*
DSCRe	39.69	432	0.09	
LCR	2.64	6	0.44	5.18*
LCRe	36.73	432	0.09	
DLCR	7.09	6	1.18	13.54*
DLCRe	37.69	432	0.09	
SLCR	1.53	6	0.25	3.35*
SLCRe	32.87	432	0.08	
DSLCR	9.99	6	1.66	18.25*
DSLCRe	39.40	432	0.09	
SLR	0.64	2	0.32	3.55**
SLRe	12.98	144	0.09	
DSLR	1.19	2	0.60	5.90*
DSLRe	14.53	144	0.10	

* $p < 0.01$
** $p < 0.05$

[1] In each case, e represents the error term of the treatment above it and is treatment by subject interaction.

B-13

ANOVA OF MENTAL ADDITION: BLANKS

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F
Mean	814.88	1	814.88	488.28*
Subjects	120.16	72	1.67	
D (Day)	0.98	1	0.98	8.23*
De[1]	8.60	72	0.12	
S (Administration)	1.13	1	1.13	12.91*
Se	6.29	72	0.09	
DS	1.40	1	1.40	15.75*
DSe	6.39	72	0.09	
L (Short-Long)	21.45	1	21.45	144.10*
Le	10.72	72	0.15	
C (Condition)	39.84	3	13.28	119.36*
Ce	24.03	216	0.11	
DC	1.42	3	0.47	7.09*
DCe	14.44	216	0.07	
DSC	1.37	3	0.46	7.98*
DSCe	12.35	216	0.06	
LC	0.63	3	0.21	3.66**
LCe	12.45	216	0.06	
DLC	0.66	3	0.22	3.27**
DLCe	14.50	216	0.07	
DSLC	1.80	3	0.60	10.03*
DSLCe	12.92	216	0.06	
R (Repetition)	1.51	2	0.76	10.82*
Re	10.05	144	0.07	

* $p < 0.01$
** $p < 0.05$

[1] In each case, e represents the error term of the treatment above it and is treatment by subject interaction.

B-13

ANOVA OF MENTAL ADDITION: BLANKS

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F
Mean	814.88	1	814.88	488.28*
Subjects	120.16	72	1.67	
D (Day)	0.98	1	0.98	8.23*
De[1]	8.60	72	0.12	
S (Administration)	1.13	1	1.13	12.91*
Se	6.29	72	0.09	
DS	1.40	1	1.40	15.75*
DSe	6.39	72	0.09	
L (Short-Long)	21.45	1	21.45	144.10*
Le	10.72	72	0.15	
C (Condition)	39.84	3	13.28	119.36*
Ce	24.03	216	0.11	
DC	1.42	3	0.47	7.09*
DCe	14.44	216	0.07	
DSC	1.37	3	0.46	7.98*
DSCe	12.35	216	0.06	
LC	0.63	3	0.21	3.66**
LCe	12.45	216	0.06	
DLC	0.66	3	0.22	3.27**
DLCe	14.50	216	0.07	
DSLC	1.80	3	0.60	10.03*
DSLCe	12.92	216	0.06	
R (Repetition)	1.51	2	0.76	10.82*
Re	10.05	144	0.07	

* $p < 0.01$
** $p < 0.05$

[1] In each case, e represents the error term of the treatment above it and is treatment by subject interaction.

B-13

ANOVA OF MENTAL ADDITION: BLANKS (Cont'd.)

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F
SLR	2.75	2	1.38	20.96*
SLRe[1]	9.44	144	0.07	
CR	2.07	6	0.34	5.42*
CRe	27.46	432	0.06	
DCR	3.35	6	0.56	8.47*
DCRe	28.44	432	0.07	
SCR	1.17	6	0.20	3.16*
SCRe	26.68	432	0.06	
DSCR	2.29	6	0.38	6.64*
DSCRe	24.76	432	0.06	
LCR	3.00	6	0.50	8.09*
LCRe	26.75	432	0.06	
DLCR	2.63	6	0.44	6.50*
DLCRe	29.12	432	0.07	
SLCR	0.98	6	0.16	3.05*
SLCRe	23.20	432	0.05	
DSLCR	2.53	6	0.42	6.69*
DSLCRe	26.21	432	0.06	

* $p < 0.01$

[1] In each case, e represents the error term of the treatment above it and is treatment by subject interaction.

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