DEPARTMENT OF THE NAVY
OFFICE OF NAVAL RESEARCH
ARLINGTON, VIRGINIA 22217

IN REPLY REFER TO
442PT:SW:sw
Ser: 83-131
29 Mar 83

Dr. Patricia Baggett
University of Colorado, Boulder
Department of Psychology
Muenzinger Psychology Building
Campus Box 345
Boulder, Colorado 80309

Dear Dr. Baggett:

The title and abstract of your technical report " Four Principles for Designing Instructions" have been reviewed.

I am enclosing an updated distribution list for the report, together with two DTIC Form 50 cards. You should refer to the enclosed Research Reporting Requirements and Procedures package for detailed guidance regarding preparation and distribution. Please read this document carefully before you issue any report. Your attention is called particularly to the requirement involving the DTIC Accession Notice. Special plans on your part to comply with this requirement would be particularly appreciated.

Please note that, with respect to the enclosed distribution list, the number immediately preceding each name indicates how many copies should be sent to that addressee.

Sincerely,

Shirley M. Wilson

Shirley M. Wilson
Secretary for
HENRY M. HALFF
Leader, Personnel and Training
Research Group (Acting)

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(2) DTIC Form 50 Cards
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August 1980

RESEARCH REPORTING REQUIREMENTS AND PROCEDURES

PERSONNEL AND TRAINING RESEARCH PROGRAMS

OFFICE OF NAVAL RESEARCH

A. REPORTS REQUIRED

1. Status Reports

Please submit status reports, quarterly, as follows: four copies to this office, one copy to the appropriate ONR Branch Office, and one copy to the ONR Resident Representative or other field contract-administration office. Also submit one copy to each of the persons designated to receive them in the letter you received at the inception of your contract. The status report should contain a brief account of progress during the prior three months; information about your research schedule for the next quarter; any change in your overall plans; and any problems encountered. There is no special format for the status report. It may take the form of a letter, identifying the contract and time period being discussed, addressed to this office.

2. Technical Reports

Technical reports are the most important of the report series. They are prepared at the completion of a meaningful unit of the research, and are of journal-article quality. Technical reports are distributed to a mailing list supplied by this office, and the list always includes 12 copies to the Defense Technical Information Center (DTIC). Rules which apply to distribution of these reports are described herein and in your contract.

You are urged to write up your research first in the form of technical reports; you are free, subsequently, to submit them to journals for publication. This insures that at least our audience receives information about the research without the usual publication delays associated with journal publication. When you submit your article to a journal, you MUST send us a copy of the manuscript. The journal article should acknowledge support of this office, and cite the contract number and contract authorization identification number (NR number).

Reprints of journal articles which have not previously been distributed in the form of technical reports should be distributed to our mailing list. These reprints should be bound in such a way as to include the required "Document Control Data -- R&D" form (DD Form 1473) and the distribution list. The front cover page of the bound reprint should identify the contract and bear an acknowledgment statement of ONR support in the manner described below for technical and final reports.

3. Final Report

Upon completion of a contract, a final report is required which should summarize all work accomplished during the life of the contract, and refer the reader for details to cited technical reports and other publicactions which have been produced under the contract. The rules applying to technical report preparation also apply to final reports.

B. SPECIAL REQUIREMENTS PRIOR TO PREPARATION OF TECHNICAL, ANNUAL, AND FINAL REPORTS

1. Submittal Requirements

(a) We wish to insure prompt report distribution and ease of report retrieval by interested scientists, research managers, and users of research results on a report-by-report basis. Therefore, we ask each of our Principal Investigators to furnish the following information to this office during the early planning stage of the preparation of each technical report.

(1) The exact title of the report. This should reflect the essential information of the report so that interested parties will recognize the pertinence of the report to their needs.
(2) A brief substantive abstract. This can be the same as the one to be used on the DD Form 1473. The purpose of the abstract is to aid the scientific officer in determining the appropriate distribution list for each technical and final report.
(3) Proposed security classification, if any.
(4) Proposed distribution statement (see section C below)

C. PROCEDURES FOR PREPARING AND DISTRIBUTING TECHNICAL AND FINAL REPORTS

1. Preparation of Report

(a) In preparing your technical and final reports (NOT periodic status reports) please include in each report:

(1) The Report Distribution List. This is to be bound as the final item in each report distributed.
(2) A DD Form 1473 (Rev. 1 Jan 73). The Form 1473 should be bound in the report as the FIRST page. Duplimats of this form may be obtained from your Resident Representative or your appropriate ONR Branch Office. Instructions for completing it accompany the duplimat form. The following should clarify a number of points that have proved confusing to some investigators.

Items 2 and 3 should remain blank, while Items 4, 7, 9, 12, 13, 18, 19, and 20 are adequately explained in the instructions accompanying the blank. Items 1 and 6 are apt to be a bit confusing. Item 1 should contain any report number which uniquely identifies the report within the sequence of reports prepared under this contract, while Item 6 should contain any report number which pertains to a larger sequence of reports. Items 8 should be your contract number. Item 10 should contain the program element number, the project number, the task area number, and the work unit number (your NR number). Item 11 should be "Personnel and Training Research Programs, Office of Naval Research (Code 458), Arlington, VA 22217." In most cases, item 15 will be "unclassified" and item 15a will be left blank. If you feel that another security classification is appropriate, please notify us early in the preparation of the report. Likewise, the distribution statement that will typically apply in item 16 is "Approved for public release; distribution unlimited;"

in that case, item 17 may be left blank. As with security classification, if another distribution statement is appropriate, initiate discussions on this point early. Finally, note that the security classification should be typed on the appropriate lines on the top and bottom of both pages of the form. See attached sample.

(b) Near the lower margin on the cover of the report, as well as on the title page, there MUST appear an appropriate DISTRIBUTION STATEMENT relating to dissemination of the report.

(1) This statement will be identical to the entry you have made in item 16 of your DD Form 1473 (Rev. 1 Jan 73).

(2) The latest approved statement which is likely to apply in most instances is "Approved for public release; distribution unlimited." If you have any reason to believe this distribution statement is not appropriate for your use, please consult your Scientific Officer, Branch Office Representative, or Resident Representative.

(c) The front cover page of each report should bear the following information:

(1) The statement: "Reproduction in whole or part is permitted for any purpose of the United States Government."

(2) A statement to the effect that this research was sponsored by the Personnel and Training Research Programs, Psychologicla Sciences Division, Office of Naval Research, under Contract No.____________ , Contract Authority Identification Number, NR________________.

(3) An appropriate Distribution Statement (see C.1(b) above).

2. DTIC Form 50 (Accession Notice) and Report Distribution

(a) The DTIC Form 50, Accession Notice, is the vehicle by which the author of a technical report and this office are informed of the Defense Technical Information Center (DTIC) file number of your report.

(1) Along with the up-to-date distribution list that will be furnished to you, this office will provide you with two cards, DTIC Form 50. On one card you should type your address; on the other card, the address of this office:

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For both cards, complete items 1 (ALL FOUR PARTS) and 2. For item 1.B, show both the title and number. For item 1.C, fill in your NR number, and show the date of the technical or final report, even though this is not called for on the card.

(2) The Distribution Statement on these cards should be identical to the one on the report and on the Form 1473.

(3) Please mail the two cards, DTIC Form 50, together with 12 copies of your report to the Defense Technical Information Center at the address shown on the distribution list.

(4) When your copy of the DTIC Form 50 is returned to you by DTIC, it will bear an Accession Document (AD) identifying number. Please notify this office promptly of the number assignment. (This can probably be done most readily by taping the card to your letterhead and xeroxing a copy to send to ONR Code 458.

3. Summary of Reports

This office is maintaining a summary/abstract of all reports distributed by our contractors. To aid us in this task, please send us two unbound copies of DD Form 1473 no later than the time you make your report distribution. (Since compliance with this requirement has been spotty, you are urged to take special pains to see that it is not overlooked. One solution is to send us the required two copies at the time you first complete the DD Form 1473, or when you order the report duplicated.)

4. Oral Presentations

Whenever you present any of your ONR-supported research orally, e.g., at a professional society meeting, please precede the talk by acknowledging your support from this Office.

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SAMPLE REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER Technical Report No. 1	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) The Effects of Augmented Feedback on the Performance of Electronic Maintenance Technicians		5. TYPE OF REPORT & PERIOD COVERED Semi-Annual Technical Report (1 Jan 77-30 Jun 77) 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Aubrey Q. Arnold Robin S. James		8. CONTRACT OR GRANT NUMBER(s) N00014-77-C-0000
9. PERFORMING ORGANIZATION NAME AND ADDRESS Department of Psychology University of Bigcity Bigcity, NY 10001		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 61153N; RR 042-04; RR 042-04-01; NR 154-000
11. CONTROLLING OFFICE NAME AND ADDRESS Personnel and Training Research Programs Office of Naval Research (Code 458) Arlington, VA 22217		12. REPORT DATE 30 Jun 77 13. NUMBER OF PAGES 185
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

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

18. SUPPLEMENTARY NOTES

In press, Journal of Educational Psychology

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

performance assessment, electronic maintenance, electronic troubleshooting, etc.

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

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1. REPORT NUMBER 121-ONR	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Four Principles for Designing Instructions		5. TYPE OF REPORT & PERIOD COVERED
		6. PERFORMING ORG. REPORT NUMBER ONR
7. AUTHOR(s) Patricia Baggett		8. CONTRACT OR GRANT NUMBER(s) N00014-78-C-0433
9. PERFORMING ORGANIZATION NAME AND ADDRESS Institute of Cognitive Science University of Colorado - Campus Box 345 Boulder, CO 80309		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS NR 157-422
11. CONTROLLING OFFICE NAME AND ADDRESS Personnel & Training Research Programs Office of Naval Research (Code 458)		12. REPORT DATE April, 1983
		13. NUMBER OF PAGES 42
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
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16. DISTRIBUTION STATEMENT (of this Report)

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

18. SUPPLEMENTARY NOTES

This report is also to appear in IEEE Transactions on Professional Communication.

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

Designing instructions, naming, naming schema, categorization, classification of unfamiliar items, recognition, recall, visual-verbal associations, dual media, multimedia, conceptualization of a procedure, comparing conceptualizations, cluster analysis, learning a procedure, audio-visual training, hands-on practice, retaining a procedure.

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

This paper gives four principles for preparing multimedia instructional sequences, and, where necessary, the experimental methods for applying the principles successfully. It also describes the empirical experiments on which the principles are based. Principle One is a criterion for good terminology for unfamiliar objects, actions, and situations, with methods for deriving such terminology. Principle Two tells how to overlap visual and spoken elements in time (as in

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) a movie or lecture with slides) in order for good associations to be formed. Principle Three states that division of instructions into conceptual units should be in agreement with people's natural conceptualization. Here, a method is presented for finding the natural conceptualization. Finally, Principle Four regards mixing audiovisual instruction with hands-on practice in learning a procedure. These principles should be useful in a variety of situations.

Four Principles for Designing Instructions

ABSTRACT

This paper gives four principles for preparing multimedia instructional sequences, and, where necessary, the experimental methods for applying the principles successfully. It also describes the empirical experiments on which the principles are based. Principle One is a criterion for good terminology for unfamiliar objects, actions, and situations, with methods for deriving such terminology. Principle Two tells how to overlap visual and spoken elements in time (as in a movie or lecture with slides) in order for good associations to be formed. Principle Three states that division of instructions into conceptual units should be in agreement with people's natural conceptualization. Here, a method is presented for finding the natural conceptualization. Finally, Principle Four regards mixing audiovisual instruction with hands-on practice in learning a procedure. These principles should be useful in a variety of situations.

Four Principles for Designing Instructions

Introduction

This article contains four principles for designing multimedia instructions. By multimedia is meant visual and verbal material (such as a film or a text with illustrations) and actual practice. The instructions we have focussed on are for assembly of physical objects, but the principles are not restricted to application only in assembly.

The first principle deals with how to construct terminology for use with unfamiliar objects, actions, or situations. The second principle is how to overlap visual and spoken material in time, in order for good associations to be made. The third principle tells how to divide instructional material into conceptual units. And the fourth deals with mixing audiovisual instruction with hands-on practice.

Principles one through four are in general both task- and subject-dependent. For example, the right terminology depends on the task or the material presented, and on the verbal abilities of the subjects. The amount of hands-on practice could depend on subjects' manual dexterity and experience with similar kinds of tasks.

For the principles which are subject- or task-dependent, we present here the experimental methods which one can use to determine subject and task parameters. For example, in Part I we present an experimental method of how to develop terminology which is adequate for a task and for subjects who will perform the task. In Part III we present an experimental method for the division of material into conceptual units. It is again task- and subject-dependent.

In some cases we can suggest <u>general</u> principles, namely, specific do's and don't's that should apply to any task and any group of subjects. For example, in Part II, a visual presentation should precede or be in synchrony with the related spoken presentation, and not follow it. The general principles which we present have been derived from empirical experiments, or are consistent with what we know from the experiments.

Part I: Developing Terminology

The Principle: The criteria for good terminology to use with unfamiliar objects, actions, or situations are that the terminology:

(a) be natural, so people with no experience can use it;

(b) be short, so that in a verbal communication, only a few words of description are needed;

(c) be well remembered; and

(d) form a classification system. That is, names of objects should contain generic terms and, when necessary, one or more modifiers.

We give here the experimental method for deriving terminology which meets the above criteria. Part of the method is described in detail in [1]. It is extended and improved here.

The method for creating good names for unfamiliar objects is an iterative procedure with three steps:

Step 1. Names are generated for each of the objects by a group of subjects.

Step 2. From the names generated by subjects, the experimenter chooses a subset of the names, according to the following criteria: (1) the modal name is chosen, namely, if a particular name is generated more often than others, it is chosen; (b) shorter names are preferred; and (c) the names chosen stay within the classification system provided by the subjects.

Step 3. How good the names are is tested by measuring, first, how well people can match the names with the objects they describe, and second, how well they can recall the names, given the objects.

Steps 2 and 3 can be iterated: If a given name is poorly matched or recalled, it can be replaced by another generated name and tested again.

In our experiment, the items to be named were the 48 different pieces from the Fischer-Technik 50 assembly kit. One such piece is shown in Figure 1. It is red plastic, with an actual size of 15 x 15 x 7.5mm (.6 x .6 x .3 in). We show here how it was named.

Insert Figure 1 about here

In Step 1, fourteen people[1] named it as follows: red H block, all purpose joint, universal connector, X-joint, H piece, universal connector, H joint, holder, universal frame connection, large block connector, flat grooved connector (female), red ____, flat bracket with grooves, block 2.

These names were formed into a graph, as shown in the upper panel of Figure 2. The graph has nodes containing the different words.

Insert Figure 2 about here

It also has directed links, from A to B, for all cases when two words, A and B, were given consecutively in a name, with A preceding B. There are also start and end nodes. The number of times a particular word was used is given in parentheses under its node, for all words used twice or more.

One has options in forming the graph. For example, one can decide to form grammatical categories, so that "block" can occur on the graph as both adjective and noun. (We did.) One can decide to collapse the nodes "grooved" and "with" and "grooves" into one node, "grooved". (We did.)

From this graph, a <u>composite naming diagram</u> was formed, as shown in the lower panel of Figure 2. It is a subgraph consisting of all nodes with words mentioned at least twice. (How many times a word must be mentioned in order for it to appear on the composite naming diagram is determined by the experimenter, depending on the number of subjects run and the variety of words. We chose two.)

From the composite diagram, a name was chosen, using the guidelines of (a), (b), (c), and (d) above. Names suggested as candidates from the diagram were: block, red H block, red H joint, H block, H joint, flat grooved connector, and universal connector. These were only suggestions; the experimenter could choose as a name any shortened name (e.g., red block, grooved connector) or any name formed from unlinked combinations of modifiers and noun (e.g., universal block, flat H joint). We chose the name red H joint for iteration 1.

In a similar manner, a name was selected for each of the other 48 pieces. These are called iteration one names. The 48 iteration one names were used to begin the iterative procedure. That is, they were tested (using new subjects) for matching and recall. In scoring the matching and recall tasks, the errors clearly indicated misleading names. These names were changed for the next iteration. Usually a new name from the composite naming diagram was selected. Sometimes, when the composite naming diagram did not suggest a new name, more subjects generated names for the piece(s), and a new name was chosen from the new composite naming diagram.

If a new name involved a change in category for a piece (as "strip" to "rail" or "plate" to "platform"), names of all other pieces in that category were changed to the new one.

The names for the piece in Figure 1 were red H joint, grooved H joint, and H joint for iterations 1, 2, and 3 respectively. (The manufacturer's name for it is building block 7.5.)

Percentage correct for the 48 names on matching and recall, and the average number of words per name, are given in Table 1 for each of the three iterations, and for the names appearing in the manufacturer's instruction booklet. Table 1 shows that in general, as iterations progressed, names became shorter and were better matched with their physical referents and better recalled. All groups with subject-derived names (iterations 1, 2, and 3) substantially outperformed the group with the manufacturer's names.

The number of iterations needed to derive the names will probably vary with the items to be named. In our study, only three iterations were used because the score on the matching task on iteration three was nearly 100% and therefore could not be significantly increased.

This technique to derive good names has two nice properties:

(1) It gets around the problem of having to specify what should (always) and should not (ever) be included in a name. For example, it does not specify if color, size, or shape should be included.

(2) It is subject-driven. The names elected will probably reflect subjects' linguistic abilities and preferences.

A feature of a piece is a part of the piece which needs a name in instructions for assembly. Examples are knob, groove, teeth, and slot. These names were derived as follows.

The same methodology used for the naming schema (but without the iterations) was used. That is:

(1) Subjects generated names for the features.

(2) New subjects were given the feature names and ranked them according to their preference.

(3) The feature was given the name which was most preferred.

Here is an important finding: In most cases, the most frequently generated feature name got the most first place votes (or the highest mean rank ordering). But in a few cases, a less frequently generated name won. This means that, although people cannot necessarily generate the most preferred name, they can nevertheless recognize it.

To derive descriptions of actions required to join pieces, a similar methodology was used:

1. Subjects learned the names derived above for pieces and their features.

2. They studied diagrams and actual pieces in each of two states, unassembled and assembled.

3. They went through the action with the actual pieces, from unassembled to assembled, five times.

4. They wrote down what they did in the form of instructions.

These data showed that of the three parts necessary for a full description, that is, (1) initial condition; (2) action; (3) final condition, about 1/4 of the subjects described (1) and (2), leaving (3) unspecified, and about 3/4 of the subjects described (2) and (3), leaving (1) unspecified. We do not know at the present time which elements of the action descriptions will give the best learning results. We also do not know if the most frequently generated verbs used to describe the actions are the most preferred.

We have given the methodology to derive names for pieces, feature names, and action descriptions that ought to be easily matched with their visual counterparts. This methodology has already been successfully applied in other situations ([2] and [3]) where naming schemas are needed, and it ought to be useful in new situations as well.

The first principle, then, states the criteria for a good system of terminology. And the methodology to derive such terminology is given.

Part II: The Correct Temporal Overlap of Visual and Spoken Elements in a Presentation

The Principle: In order for good associations between the visual and spoken elements in a presentation to occur, the visual part should precede, or be in synchrony with, the spoken part, and not follow it.

This general principle does not require additional experiments for its implementation. It can simply be used as stated.

We describe briefly the experiment we performed, from which we derived the principle. A full version of the experiment is given in [4]. A related experiment, using educational material, is in [5].

Fourteen groups of subjects were shown a thirty minute film which introduced the Fischer-Technik 50 assembly kit, its pieces, their names (the iteration three names derived above), and some of their uses. The film's visuals and narration could be presented in synchrony, or one could be shifted relative to the other up to 21 sec.

Subjects saw the film in one of seven versions: visuals moved relative to narration by -21, -14, -7, 0 (synchrony), 7, 14, or 21 sec. They were tested immediately or after seven days for recall of the names, given the pieces. The hypothesis was, the higher the recall, the better the associations.

The results are illustrated in Figure 3. Scores were highest immediately

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Insert Figure 3 about here

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and after seven days for two groups: synchrony and visuals 7 sec before narration. On the immediate test, each of the other five groups scored about 80% of the highest groups. On the test after seven days, the other five groups scored differently: the three narration-first groups performed about 30% less well than the two visuals-first groups. (The statistical analyses, and a theoretical interpretation of the results, are given in [4].)

The temporal order in which visual and auditory elements were presented differentially influenced the formation of visual-verbal associations. When visuals precede narration by up to 7 sec, recall is as good as when visuals and narration are in synchrony. When narration precedes visuals by 7 sec or more, much of the narration is lost, especially after a delay.

To repeat, then, the principle of how to overlap visual and spoken material in time, in order for good associations to be formed, is: The spoken material should follow, or be in synchrony with, the visual image, and not precede it. The correct temporal overlap of visuals and narration should not be restricted only to films. It should hold as well for illustrated lectures, slide shows, written text with pictures, etc. One should present the visual part early, or simultaneously with the text. Show first and tell second, or show and tell in synchrony, but do not tell first and show second.

Part III: Dividing Instructional Material into Conceptual Units.

The Principle: Decomposition of instructional material into conceptual units should be in agreement with people's natural conceptualization of the task.

In order to implement this principle, three steps are required:

1. Find what the natural conceptualization of a person is.
2. Find if different people conceptualize uniformly (If they do not, probably different conceptualizations of the material are required for different people.)
3. Arrange the material to be presented according to the subjects' conceptualization.

Below, we present the experimental methods for steps (1) and (2). Namely, we present first the technique for finding an individual subject's conceptualization. We then present the technique for determining if subjects conceptualize uniformly, and for constructing a composite conceptualization for a population of subjects. (Step two requires extensive programming.)

Step 1: Finding the natural conceptualization of an individual.

We outline here a methodological schema to find how people divide an object into subassemblies, that is, how they conceptualize it, from the order in which they use the parts in the construction of the object. The assumption we are making can be illustrated by a simple example. If, in joining four pieces, A, B, C, and D, a person consistently joins A and B, and then C and D, and then joins the two subassemblies, it is expected that in a division into two parts, the person has the concepts (AB) and (CD).

The method used is to have a person ask for pieces one at a time for assembly, and to record the order of request. It has the following underlying hypothesis: In assembling an object from a model or other input, the person conceptualizes the object to be built, and then asks for parts, grouped together according to the conceptual division.

These data are easy to gather, even for complex objects. We will show data from an object (the toy helicopter shown in Figure 4) consisting of 54 pieces, but we estimate that substantially more pieces do not create

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Insert Figure 4 about here

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a problem. The data analysis is also straightforward. It consists of three parts:

1. An assembly object is drawn as an abstract graph whose nodes represent pieces and whose edges (links) represent connections. (This representation can be used on <u>any</u> assembled object, not just Fischer Technik.) The abstract graph of the helicopter shown in Figure 4 is given in Figure 5.[2] Nodes in Figure 5 are numbered 1 through 54, to correspond to specific pieces in the helicopter.

Insert Figure 5 about here

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2. A <u>distance</u> between nodes on the graph is introduced, based on how closely the requests for the different pieces are. (For example, if a person requests piece 10 fifth and piece 11 ninth, the distance between pieces 10 and 11 is | 5 -

9 | = 4.)

3. A cluster analysis is performed, and the clusters are used as hypothetical conceptual units of the person building. Each node is put in a cluster with its closest connected neighbor. An example is given in Figure 6 by the thin solid lines on the figure. Then each cluster is put in a

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Insert Figure 6 about here

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higher-order cluster with its closest connected neighbor. These are the dotted lines on the figure. Each of these is put in an even higher-order cluster (the heavy solid lines on the figure). The process is continued until all clusters fall into the same higher order cluster.

This analysis yields a hierarchical tree, which is the hypothetical natural conceptualization of the object by an individual.

Step 2: Finding if different people conceptualize uniformly.

Below we give a method to determine how different conceptualizations from different people, and from one person on different trials, are. That is, are they minor variants of the same conceptualization, or do they form different categories? We demonstrate the method in the context of the experiment we conducted.

Sixteen people built the helicopter five times, once every other day. A physical model was used as a guide on each trial. Each time, the subject was required to request each piece separately, and the order of request was recorded. A person's conceptualization of the helicopter was derived from the order of requests, as described above, using a computer package ([6]).

Among the 80 trials (16 subjects x 5 trials each), all conceptualizations were different. The questions we were able to answer were:

1) Can different conceptualizations be treated as variants of one

conceptualization, or do they form different categories?

2) How does the conceptualization presented in an instructional film we are using compare with subjects' conceptualizations?

The method used was a cluster analysis of the 81 trials, including the conceptualization from the film. The distance between trials is described in the Appendix.

The main result is that the population of trials divided into one large cluster of 66 cases, and three others, having 11, 2, and 2 cases respectively. The conceptualization presented in the instructional film went into the largest cluster.

For a composite graph, the average distance between nodes is computed. The composite conceptualization from the 66 cases is shown in Figure 6.

Our major finding is that over 80% of the trials (66 of 81) fall into the same cluster. This finding is important for individualized instruction. When a collection of trials splits into many different clusters, it means that different people conceptualize differently, and that one person conceptualizes differently at different times. That indicates that in order to improve performance, instructions need to be tailored specifically for a person in a given situation. The fact that 80% of the trials fall in one cluster indicates that, at least for the subject population tested and the object built here, one set of instructions can cover a majority of people. (We have obtained a similar result using a different, more complex, object in another study. There, the majority cluster contains 70% of the trials.)

The fact that the conceptualization from our film (used in Part IV) falls into the largest cluster means that it follows Principle 3. Its conceptualization is the same as that of the majority of the people who will be instructed by it.

In Part III we have given the principle (to be tested in future work) that the conceptual units given in instructions should conform to people's natural conceptualization. And we have given the methodology to find if people conceptualize uniformly, and the technique for constructing a composite conceptualization for a group of subjects.

Part IV: Learning a Procedure from Multimedia Instructions: The Effects of Film and Practice.

The Principle. For good retention of a procedure to be performed from memory, the arrangement of an instructional sequence consisting of film and practice should be practice first and film second. This is a rule of thumb, to be used when no information is known about the person being trained. When variables such as manual dexterity and experience with similar tasks have been assessed, a training sequence differing from practice first, film second may be better for a particular individual.

We present here a summary of the experiment on which we base the principle. The details are in [7]. A related study, using only pictures and text for instructions, is in [8].

Different modalities of instruction (film versus practice), different amounts of the two, and different orders (film first or practice first) were given to people in the experiment. By practice we mean that people built the object with a physical model sitting before them as a guide. The object to be assembled was the 54 piece helicopter shown in Figure 4. The 12 groups, their instructional sequences, and their time of test, are given in Table 2.

Insert Table 2 about here

The instructional film, shot by James Otis, was 15 min long, in color, and narrated. The conceptual units presented in the film were the same as those of the majority of the people who built the helicopter from a model, in the work presented in Part III.

After the instructions, including practice where appropriate, each person was required to build the helicopter from memory, either immediately or after a one week delay. Note that the four groups instructed by film alone did not have hands-on practice during training. They built the helicopter only once, from memory. All other groups built the helicopter at least once during training, using a model as a guide. They built it again, this time from memory, during the test trial.

Performance on the memory trial was assessed as follows: The abstract graph of each helicopter built from memory was drawn. The number of correct connections it contained was the dependent measure. (This assesses the similarity in structure of the helicopter built from memory and the correctly built helicopter.) There are 58 connections in the correctly built helicopter (as can be seen in Figure 5), so the range was 0 to 58.

The results are given in Table 3. For convenience in talking about the

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Insert Table 3 about here

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groups, we abbreviate film by F and model by M. For example, the groups who, during training, saw the film first and built the model second, are abbreviated FM.

A Newman-Keuls procedure was used to test differences between pairs of means at zero delay. (See [9].) A separate procedure was used for 7-day delay. The groups who built the helicopter immediately after their instruction line up statistically as follows with respect to their performance from memory:

$$MM = MF = FM > FF = M > F.$$

This result means that some practice is good during instruction, either building twice or building once and seeing a film. (Order of practice and film does not matter when performance is tested immediately.)

After a seven day delay, the lineup of the groups is different:

MF > MM = FM = M = FF > F.

All groups are depressed to about 50% of their scores when tested immediately, except for one, the group that builds first and sees the film second. Its performance after a week is 30.3/46.7 = 65% of its performance at zero delay. Retention of a procedure to be performed from memory is clearly highest in this group. In general, when a person builds first and then sees a film displaying conceptual units, with names, second, his or her performance is best.[3]

However, individual differences in performance within a group were very great. For example, scores could range from 0 to 58, and an actual range in a single group of 2 to 56 was common. The average standard deviation in a group was over 20%.

This finding leads us to conclude that the right training sequence for a procedure that is to be performed from memory varies, depending on the individual. And this brings up the question of individualized instruction. A goal of our future research is to discover what individualized instruction should contain. Specifically, should instruction be individualized simply by varying the amount given to different people, depending on their experience or skill? Or should it be individualized by giving different modalities, or modalities in different orders, or different conceptualizations, etc.? A second goal of our future work is to develop a small number of brief tests which can be easily given to subjects. Performance on these tests would be used to (a) predict performance as a function of instructions; and (b) assign a person to an appropriate instructional sequence.

Until such tests are available, we recommend that a person's performance be tested after practice, after film instruction, and after various amounts and combinations, to see which gives optimum results. If such testing is not possible, the instructional sequence should be practice first and film second.

Final Remarks

The four principles presented in this paper were derived from and tested on primarily assembly tasks. Their generalizability to other types of tasks, for example, repair tasks, programming, use of new equipment, etc., should be tested experimentally. The methodologies given here can be easily modified for studying the tasks mentioned above.

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Footnotes

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1. In this and all other experiments reported, the subjects were students enrolled in introductory psychology at the University of Colorado who participated as part of a class requirement.

2. The connections to be considered can be set for each analysis. Here we consider only physical connections. There are 58 in the helicopter. We could have considered as many as $\binom{54}{2} = 1431$.

3. In our experiment, we put a limit on the type and amount of instruction. The theoretical rationale for this is given in [7]. When there is no such limit, longer sequences, such as practice first, film second, practice third, might prove even better than the arrangement suggested here.

Figure Captions

Figure 1. A piece from the assembly kit. Its actual size is 15 x 15 x 7.5mm (.6 x .6 x .3in).

Figure 2. Upper panel: A graph of the 14 names generated for the piece shown in Figure 1. The nodes contain the different words. The links are directed from A to B, for all cases when two words, A and B, were given consecutively in a name, with A preceding B. The number of time a particular word was used is given in parentheses under its node, for all words used twice or more.

Lower panel: A composite naming diagram. It is a subgraph consisting of all nodes with words mentioned at least twice. Names for the piece in Figure 1 suggested as candidates from the diagram are: block, red H block, red H joint, H block, H joint, flat grooved connector, and universal connector.

Figure 3. Percentage correct on recall of names, given the pieces, as a function of degree of asynchrony between the visual and spoken material in the film, and delay between the film and the test (zero- or 7-day).

Figure 4. A toy helicopter built from 54 pieces of the Fischer-Technik 50 assembly kit.

Figure 5. An abstract graph of the toy helicopter shown in Figure 4. The nodes represent pieces in the helicopter, and the links represent physical connections.

Figure 6. The composite conceptualization of the helicopter from the majority group (66 of 81 trials). The method for obtaining this division into conceptual units is given in the text.

Figure 7. Pieces p_1 and p_2 occur in conceptualizations T_i and T_j as shown. In T_i, p_1 and p_2 are in the same first order cluster, so that their height equals one. In T_j, they are in the same second order cluster, so that their height equals two.

Appendix

There are two steps in doing the cluster analysis on a group of conceptualizations. Both are done using the computer package in [6].

1. Find the distance between all pairs of conceptualizations;
2. Do a cluster analysis on the space of all pairs of conceptualizations, with distances defined from step 1.

The details required for each step are given below:

1. The distance between conceptualization on two trials T_i and T_j is defined as follows:

It is the sum (over all 58 connected pairs of pieces in the helicopter) of the difference in height in a conceptualization necessary to put a connected pair in the same cluster.

Here is an example. Consider a pair of connected pieces p_1 and p_2. Suppose they are placed in the conceptualizations of T_i and T_j as shown in Figure 7. In conceptualization T_i, p_1 and p_2 are in the same first order cluster. Their height = 1. In conceptualization T_j, p_1 and p_2 are in the

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Insert Figure 7 about here

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same second order cluster (dotted). Their height = 2.

The distance between the pair of pieces (p_1, p_2) in conceptualizations T_i and T_j is the difference in their heights, 2-1 =1.

The distance between T_i and T_j is the sum (over all 58 pairs) of these distances.

2. A cluster analysis is done on the conceptualizations, with each one put in a cluster with its closest connected neighbor (as described in Part 3).

Table 1: Percentage Correct on Matching and Recall, and Average Number of Words per Name, for Each of Four Groups

	percentage correct: matching	percentage correct: surprise recall*	average number of words per name
group given names from manufacturer	59.89	27.25	2.94
group given iteration 1 names	89.20	48.64	2.75
group given iteration 2 names	93.92	48.60	2.81
group given iteration 3 names	96.23	50.72	2.60

*No variation was scored as correct. For example, for the triangle joint, the name triangular joint was scored as wrong.

Table 2: Experimental Groups for Mixing Modalities in Instruction

stimulus 1	see film	build from model	see film	build from model	-----	-----
stimulus 2	build from model	see film	see film again	build from model again	see film	build from model
test	(immediately, for 6 groups) build helicopter from memory					
test	(after 1 week, for 6 groups) build helicopter from memory					

Table 3: Mean Number of Correct Connections in Helicopter Built From Memory (a score of 58 is possible)

stimulus 1	see film	build from model	see film	build from model	-----	-----
stimulus 2	build from model	see film	see film again	build from model again	see film	build from model
zero delay	46.6	46.7	40.0	49.2	21.3	39.6
7-day delay	23.8	30.3	18.5	24.2	11.4	22.6

Note: Data are from 360 subjects, 15 males and 15 females per group. They asserted on a questionnaire that they had neither seen the film nor built the helicopter before the experiment.

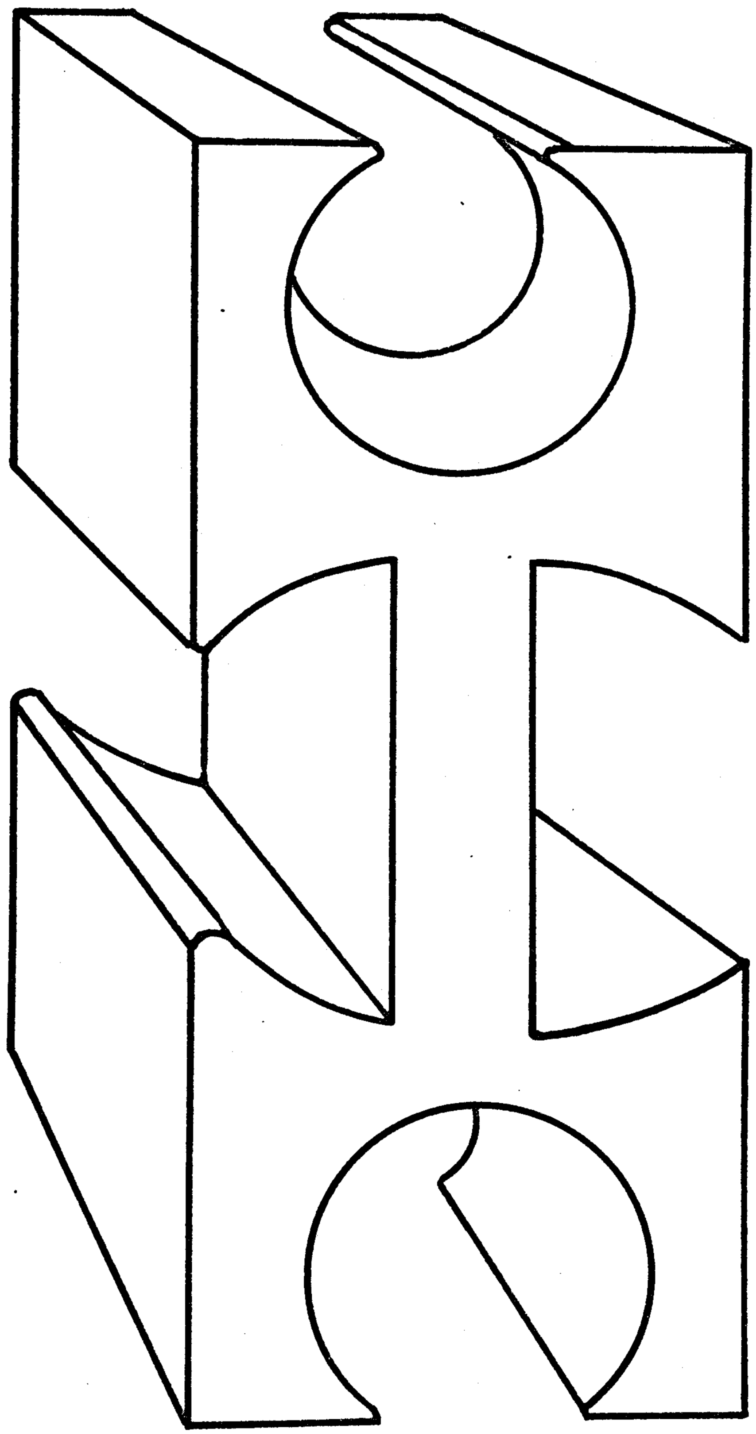

Figure 1

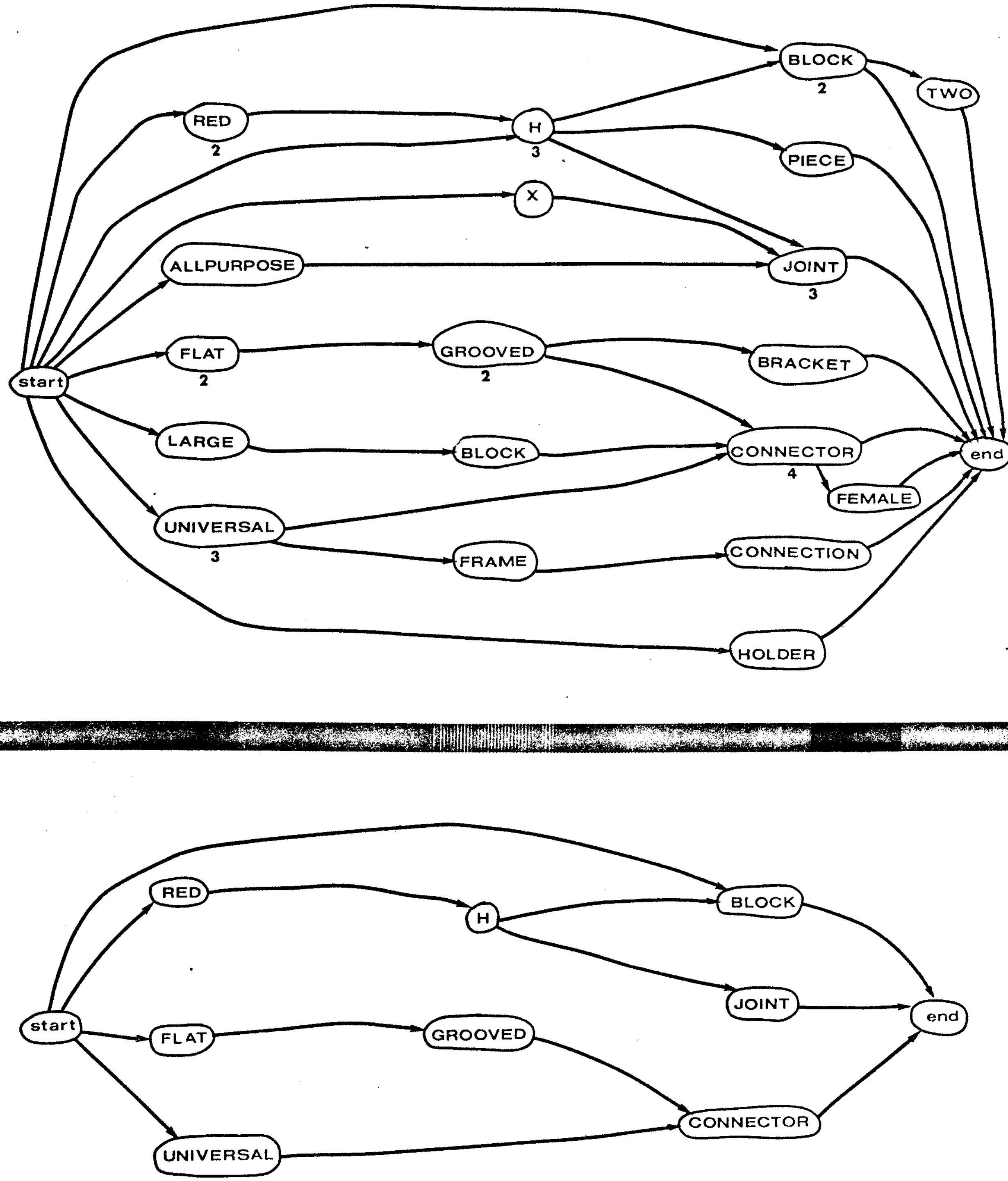
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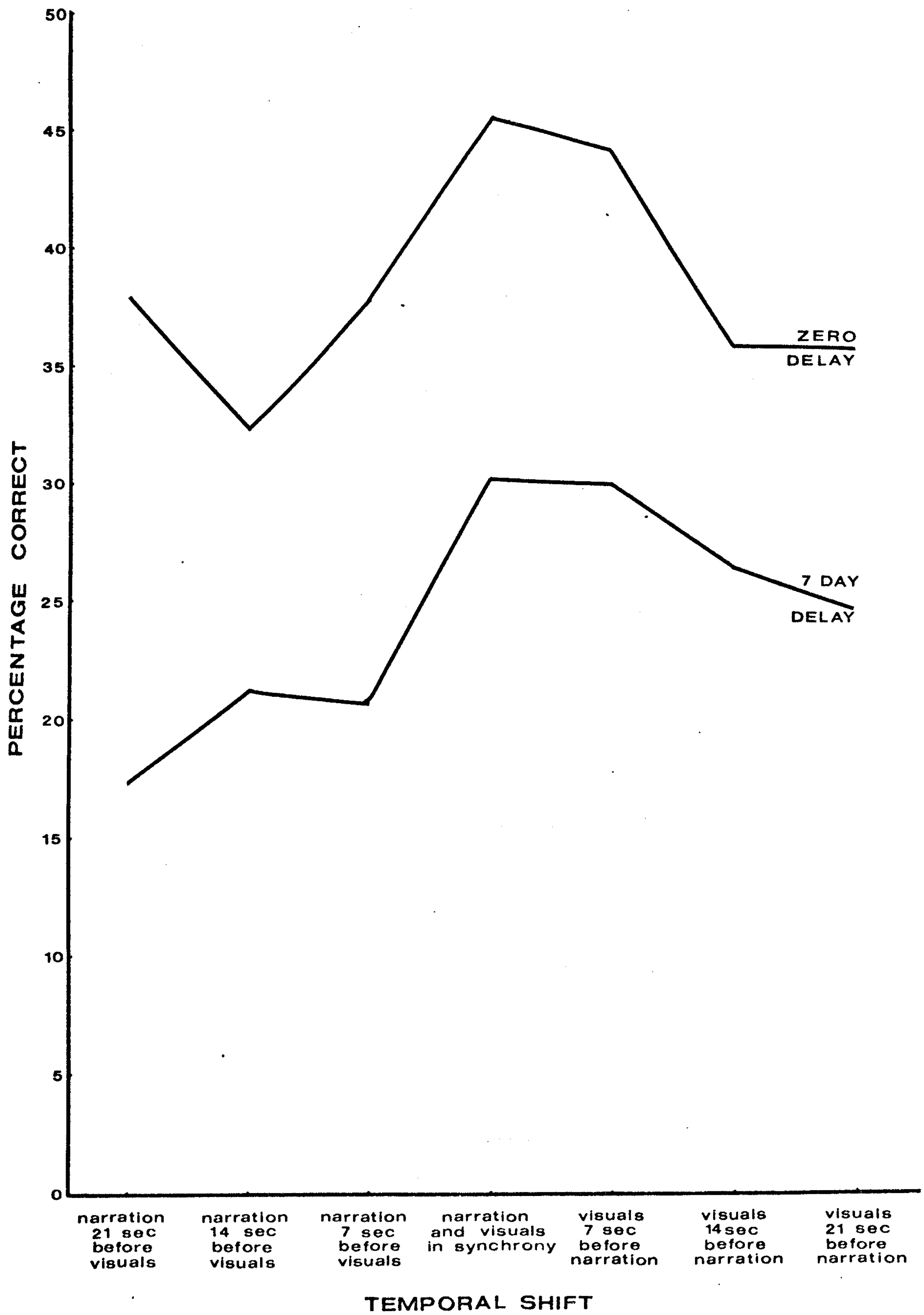
Figure 2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ZERO DELAY
7 DAY DELAY
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narration 14 sec before visuals
narration 7 sec before visuals
narration and visuals in synchrony
visuals 7 sec before narration
visuals 14sec before narration
visuals 21 sec before narration
TEMPORAL SHIFT

Figure 3

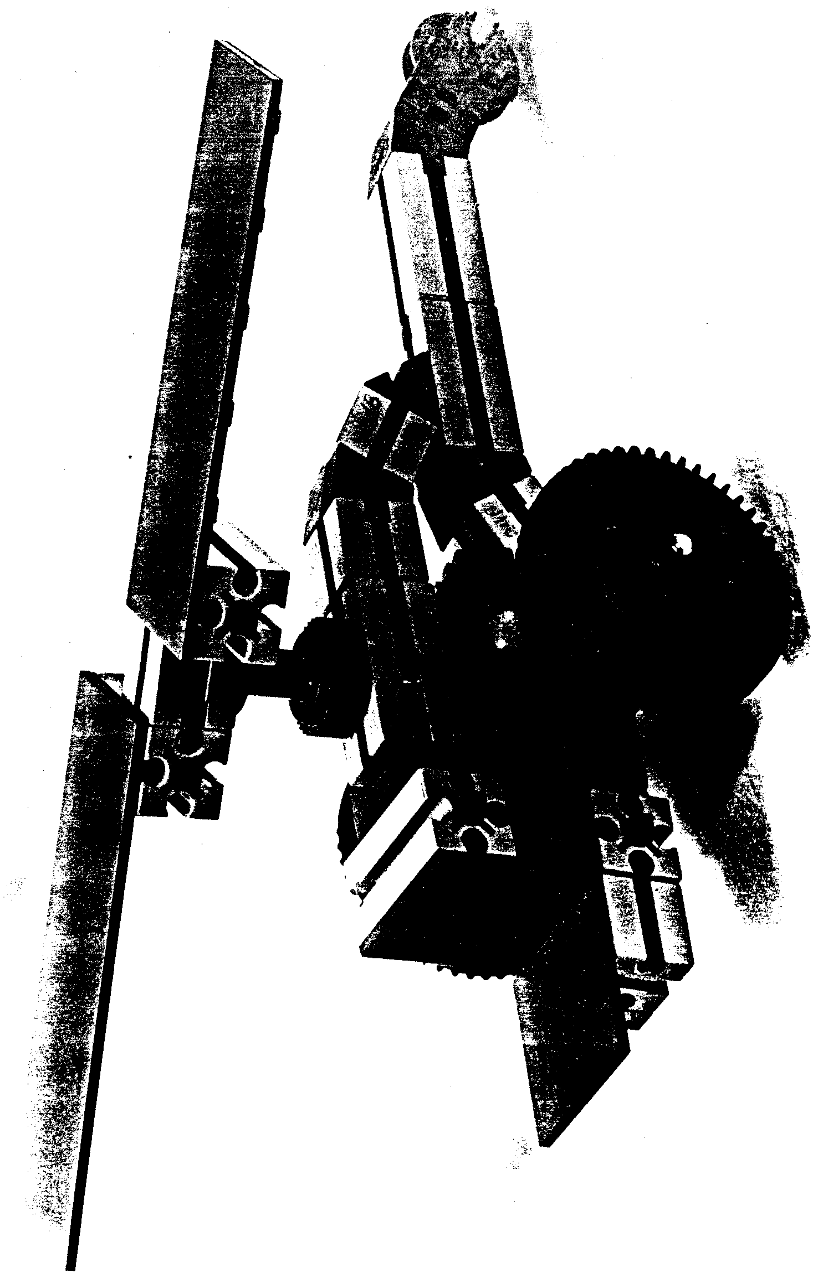

Figure 4

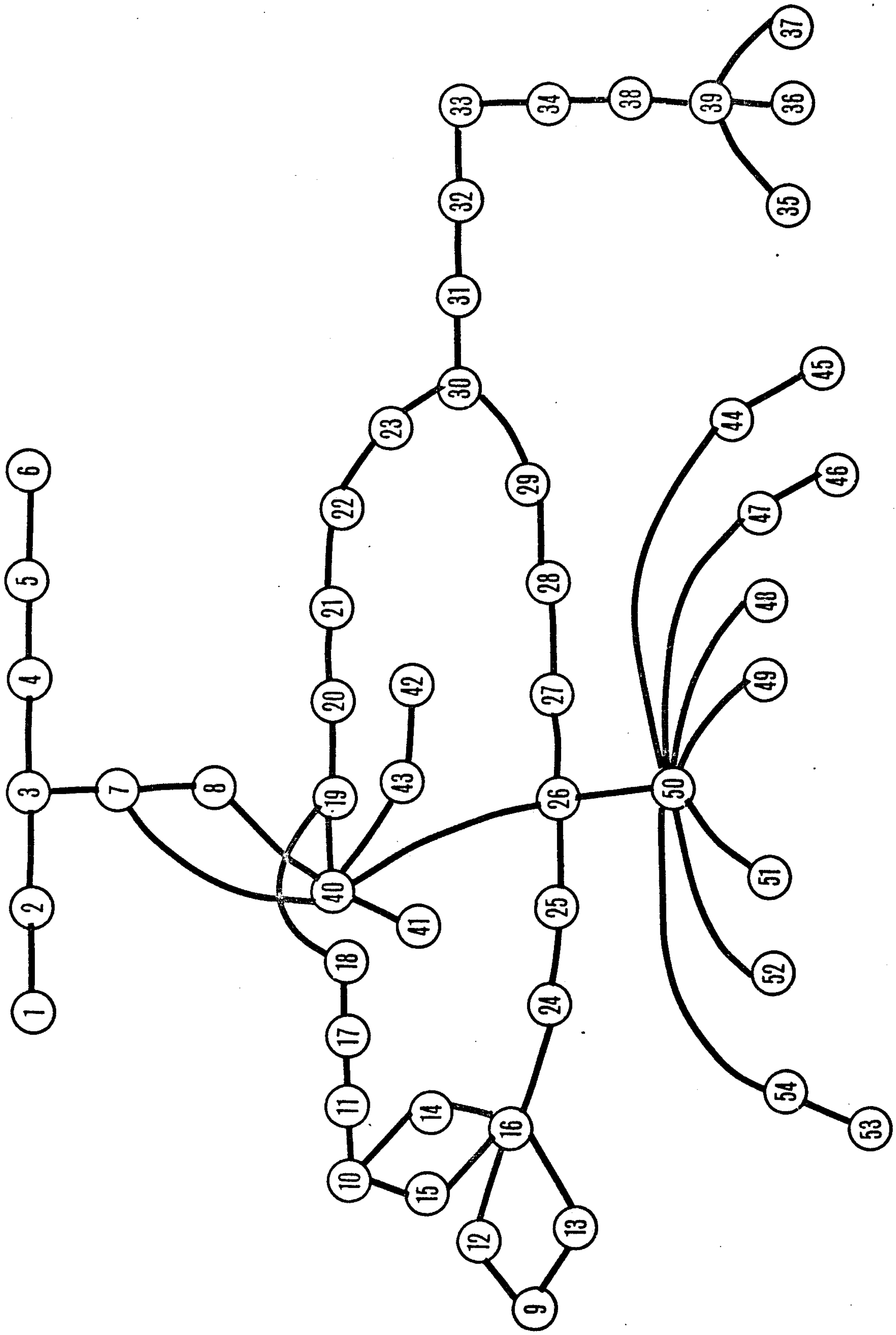
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Figure 5

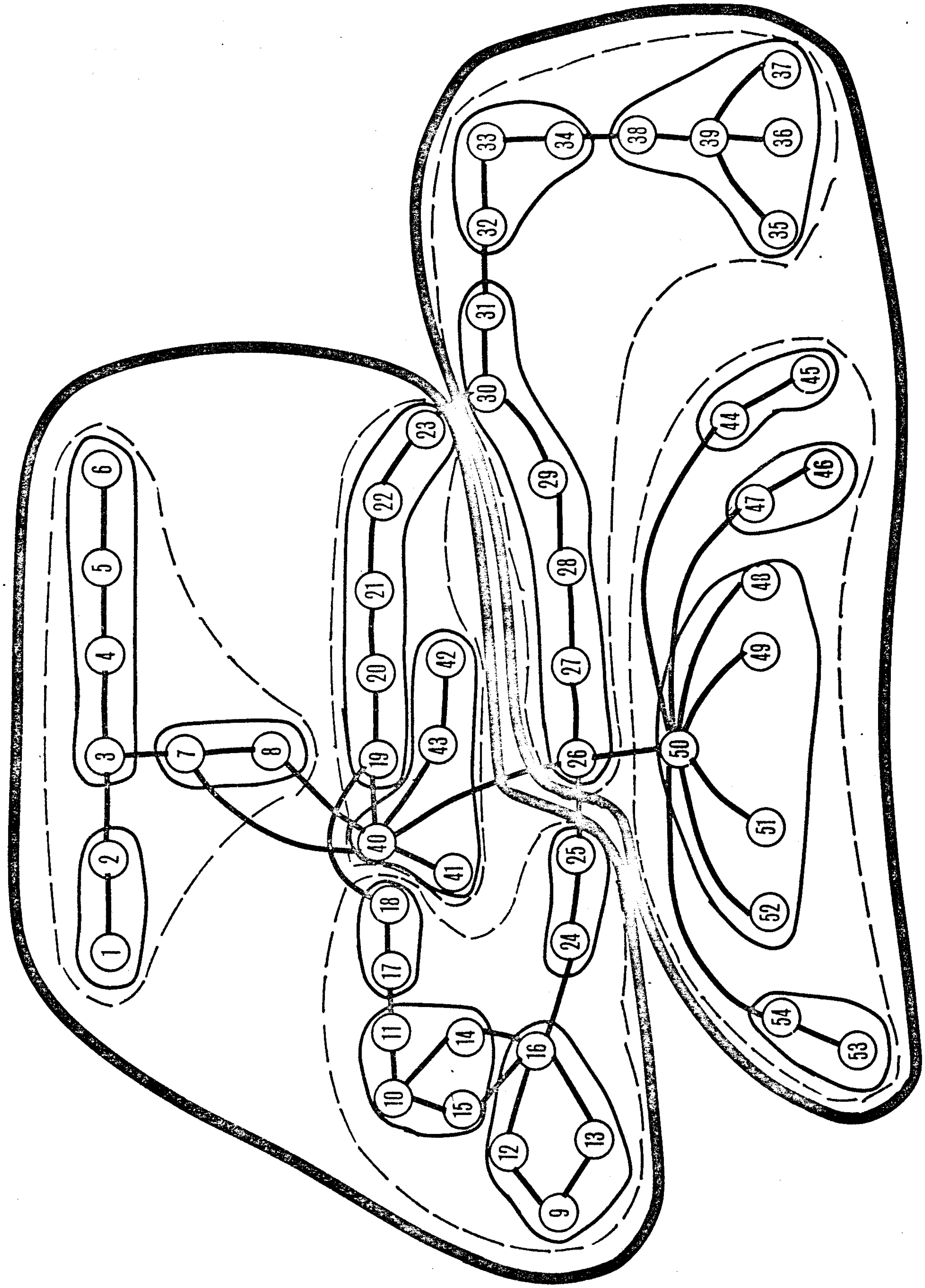
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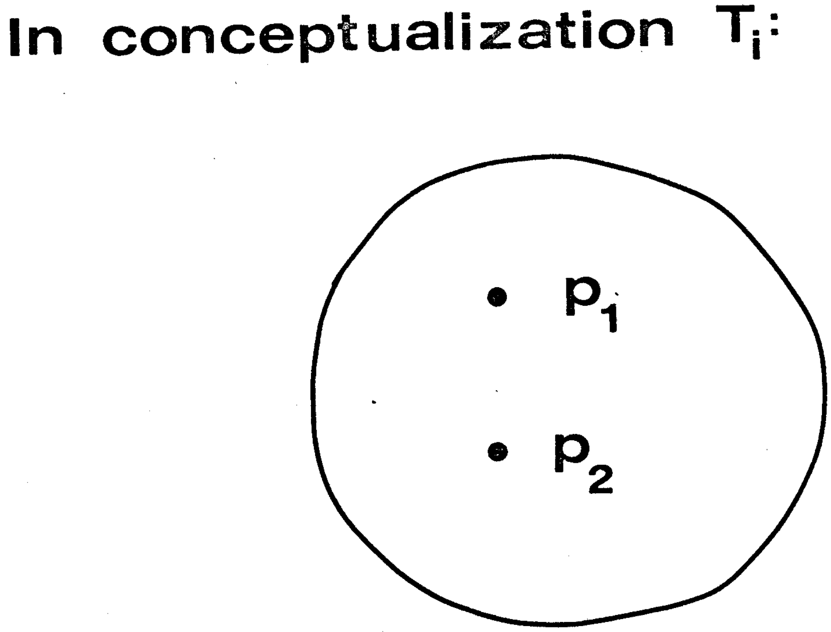
Figure 6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p_2

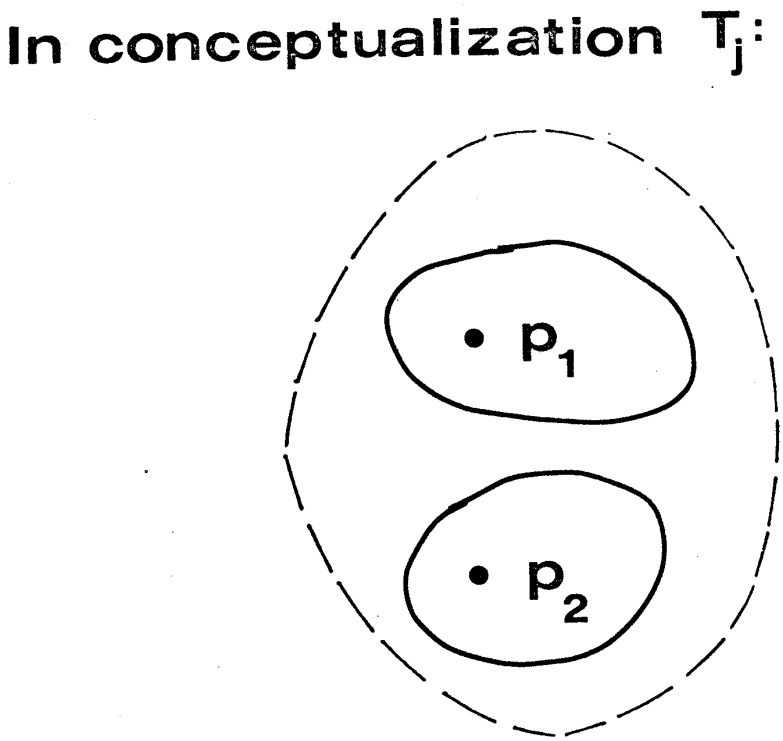
In conceptualization T_j:
p_1
p_2

Figure 7

Navy

1 Mr. Ernest Abel
Naval Education & Training Command
Code N-913
NAS
Pensacola, FL 32508

1 Mr. Fred Abell
Training Specialist
Naval Oceanographic Command Facility
Bldg. 800
NSTL Station, MS 39529

1 Robert Ahlers
Code N711
Human Factors Laboratory
NAVTRAEQUIPCEN
Orlando, FL 32813

1 Dr. Meryl S. Baker
Navy Personnel R&D Center
San Diego, CA 92152

1 CDR Robert J. Biersner
Naval Medical R&D Command
National Naval Medical Center
Bethesda, MD 20814

1 Code N711
Attn: Arthur S. Blaiwes
Naval Training Equipment Center
Orlando, FL 32813

1 Liaison Scientist
Office of Naval Research
Branch Office, London
Box 39
FPO New York, NY 09510

1 Lt. Alexander Bory
Applied Psychology
Measurement Division
NAMRL
NAS Pensacola, FL 32508

1 Dr. Richard Cantone
Navy Research Laboratory
Code 7510
Washington, DC 20375

1 Dr. Robert Carroll
NAVOP 115
Washington , DC 20370

Navy

1 Chief of Naval Education and Training
Liason Office
Air Force Human Resource Laboratory
Operations Training Division
WILLIAMS AFB, AZ 85224

1 Dr. Stanley Collyer
Office of Naval Technology
800 N. Quincy Street
Arlington, VA 22217

1 CDR Mike Curran
Office of Naval Research
800 N. Quincy St.
Code 270
Arlington, VA 22217

1 Dr. Tom Duffy
Navy Personnel R&D Center
San Diego, CA 92152

1 Edward E. Eddowes
Educational Advisor, Code N-3
HQ Chief of Naval Air Training
Corpus Christi, TX 78419

1 DR. PAT FEDERICO
Code P13
NPRDC
San Diego, CA 92152

1 Dr. John Ford
Navy Personnel R&D Center
San Diego, CA 92152

1 Dr. Mike Gaynor
Navy Research Laboratory
Code 7510
Washington, DC 20375

1 Dr. Jim Hollan
Code 304
Navy Personnel R & D Center
San Diego, CA 92152

1 Dr. Ed Hutchins
Navy Personnel R&D Center
San Diego, CA 92152

1 Dr. Norman J. Kerr
Chief of Naval Technical Training
Naval Air Station Memphis (75)
Millington, TN 38054

Navy

1 Dr. Peter Kincaid
Training Analysis & Evaluation Group
Dept. of the Navy
Orlando, FL 32813

1 Dr. Ray Main
Code 14
Navy Personnel R&D Center
San Diego, CA 92152

1 Dr. William L. Maloy
Principal Civilian Advisor for
Education and Training
Naval Training Command, Code 00A
Pensacola, FL 32508

1 CAPT Richard L. Martin, USN
Commanding Officer
USS Carl Vinson (CVN-70)
FPO New York, NY 09558

1 Dr William Montague
NPRDC Code 13
San Diego, CA 92152

1 Bill Nordbrock
1032 Fairlawn Ave.
Libertyville, IL 60048

1 Library, Code P201L
Navy Personnel R&D Center
San Diego, CA 92152

1 Technical Director
Navy Personnel R&D Center
San Diego, CA 92152

6 Commanding Officer
Naval Research Laboratory
Code 2627
Washington, DC 20390

1 Office of Naval Research
Code 433
800 N. Quincy SStreet
Arlington, VA 22217

6 Personnel & Training Research Group
Code 442PT
Office of Naval Research
Arlington, VA 22217

Navy

1 Psychologist
ONR Branch Office
1030 East Green Street
Pasadena, CA 91101

1 Special Asst. for Education and
Training (OP-01E)
Rm. 2705 Arlington Annex
Washington, DC 20370

1 Office of the Chief of Naval Operations
Research Development & Studies Branch
OP 115
Washington, DC 20350

1 Dr. Gary Poock
Operations Research Department
Code 55PK
Naval Postgraduate School
Monterey, CA 93940

1 Dr. Gil Ricard
Code N711
NTEC
Orlando, FL 32813

1 Dr. Carl Ross
CNET-PDCD
Building 90
Great Lakes NTC, IL 60088

1 Dr. Worth Scanland
CNET (N-5)
NAS, Pensacola, FL 32508

1 Mr. Irving Schiff
Dept. of the Navy
Chief of Naval Operations
OP 113
Washington, DC 20350

1 Dr. Robert G. Smith
Office of Chief of Naval Operations
OP-987H
Washington, DC 20350

1 Dr. Alfred F. Smode, Director
Training Analysis & Evaluation Group
Dept. of the Navy
Orlando, FL 32813

1 Dr. Richard Sorensen
Navy Personnel R&D Center
San Diego, CA 92152

Navy

1 Dr. Frederick Steinheiser
CNO - OP115
Navy Annex
Arlington, VA 20370

1 Code 14
Navy Personnel R&D Center
San Diego, CA 92152

1 Roger Weissinger-Baylon
Department of Administrative Sciences
Naval Postgraduate School
Monterey, CA 93940

1 Mr John H. Wolfe
Navy Personnel R&D Center
San Diego, CA 92152

Marine Corps

1 H. William Greenup
Education Advisor (E031)
Education Center, MCDEC
Quantico, VA 22134

1 Special Assistant for Marine Corps Matters
Code 100M
Office of Naval Research
800 N. Quincy St.
Arlington, VA 22217

1 DR. A.L. SLAFKOSKY
SCIENTIFIC ADVISOR (CODE RD-1)
HQ, U.S. MARINE CORPS
WASHINGTON, DC 20380

Army

1 Technical Director
U. S. Army Research Institute for the
Behavioral and Social Sciences
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Mr. James Baker
Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Dr. Beatrice J. Farr
U. S. Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Dr. Milton S. Katz
Training Technical Area
U.S. Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Dr. Harold F. O'Neil, Jr.
Director, Training Research Lab
Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Joseph Psotka, Ph.D.
ATTN: PERI-1C
Army Research Institute
5001 Eisenhower Ave.
Alexandria, VA 22333

1 Dr. Robert Sasmor
U. S. Army Research Institute for the
Behavioral and Social Sciences
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Dr. Robert Wisher
Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

Air Force

1 AFHRL/LRS
Attn: Susan Ewing
WPAFB
WPAFB, OH 45433

1 U.S. Air Force Office of Scientific
Research
Life Sciences Directorate, NL
Bolling Air Force Base
Washington, DC 20332

1 Air University Library
AUL/LSE 76/443
Maxwell AFB, AL 36112

1 Dr. Earl A. Alluisi
HQ, AFHRL (AFSC)
Brooks AFB, TX 78235

1 Bryan Dallman
AFHRL/LRT
Lowry AFB, CO 80230

1 Dr. Alfred R. Fregly
AFOSR/NL
Bolling AFB, DC 20332

1 Dr. Genevieve Haddad
Program Manager
Life Sciences Directorate
AFOSR
Bolling AFB, DC 20332

1 Dr. T. M. Longridge
AFHRL/OTGT
Williams AFB, AZ 85224

1 Dr. Joseph Yasatuke
AFHRL/LRT
Lowry AFB, CO 80230

Department of Defense

12 Defense Technical Information Center
Cameron Station, Bldg 5
Alexandria, VA 22314
Attn: TC

1 Military Assistant for Training and
Personnel Technology
Office of the Under Secretary of Defens
for Research & Engineering
Room 3D129, The Pentagon
Washington, DC 20301

1 Major Jack Thorpe
DARPA
1400 Wilson Blvd.
Arlington, VA 22209

Civilian Agencies

1 Dr. Patricia A. Butler
NIE-BRN Bldg, Stop # 7
1200 19th St., NW
Washington, DC 20208

1 Dr. Susan Chipman
Learning and Development
National Institute of Education
1200 19th Street NW
Washington, DC 20208

1 Edward Esty
Department of Education, OERI
MS 40
1200 19th St., NW
Washington, DC 20208

1 Dr. John Mays
National Institute of Education
1200 19th Street NW
Washington, DC 20208

1 Dr. Arthur Melmed
OERI
1200 19th Street NW
Washington, DC 20208

1 Dr. Andrew R. Molnar
Office of Scientific and Engineering
Personnel and Education
National Science Foundation
Washington, DC 20550

1 Dr. Judith Orasanu
National Institute of Education
1200 19th St., N.W.
Washington, DC 20208

1 Dr. Ramsay W. Selden
National Institute of Education
1200 19th St., NW
Washington, DC 20208

1 Chief, Psychological Reserch Branch
U. S. Coast Guard (G-P-1/2/TP42)
Washington, DC 20593

1 Dr. Frank Withrow
U. S. Office of Education
400 Maryland Ave. SW
Washington, DC 20202

Civilian Agencies

1 Dr. Joseph L. Young, Director
Memory & Cognitive Processes
National Science Foundation
Washington, DC 20550

Private Sector

1 Dr. Erling B. Andersen
Department of Statistics
Studiestraede 6
1455 Copenhagen
DENMARK

1 Dr. John R. Anderson
Department of Psychology
Carnegie-Mellon University
Pittsburgh, PA 15213

1 Dr. John Annett
Department of Psychology
University of Warwick
Coventry CV4 7AJ
ENGLAND

1 Dr. Michael Atwood
Bell Laboratories
11900 North Pecos St.
Denver, CO 80234

1 Psychological Research Unit
Dept. of Defense (Army Office)
Campbell Park Offices
Canberra ACT 2600
AUSTRALIA

1 Dr. Alan Baddeley
Medical Research Council
Applied Psychology Unit
15 Chaucer Road
Cambridge CB2 2EF
ENGLAND

1 Ms. Carole A. Bagley
Minnesota Educational Computing Consortium
2354 Hidden Valley Lane
Stillwater, MN 55082

1 Mr. Avron Barr
Department of Computer Science
Stanford University
Stanford, CA 94305

1 Dr. George R. Bieger
B-110 Coleman Hall
Bucknell University
Lewisburg, PA 17837

Private Sector

1 Dr. John Black
Yale University
Box 11A, Yale Station
New Haven, CT 06520

1 Dr. John S. Brown
XEROX Palo Alto Research Center
3333 Coyote Road
Palo Alto, CA 94304

1 Bundministerium der Verteidigung
-Referat P II 4-
Psychological Service
Postfach 1328
D-5300 Bonn 1
F. R. of Germany

1 Dr. C. Victor Bunderson
WICAT Inc.
University Plaza, Suite 10
1160 So. State St.
Orem, UT 84057

1 Dr. Jaime Carbonell
Carnegie-Mellon University
Department of Psychology
Pittsburgh, PA 15213

1 Dr. Pat Carpenter
Department of Psychology
Carnegie-Mellon University
Pittsburgh, PA 15213

1 Dr. William Chase
Department of Psychology
Carnegie Mellon University
Pittsburgh, PA 15213

1 Dr. Micheline Chi
Learning R & D Center
University of Pittsburgh
3939 O'Hara Street
Pittsburgh, PA 15213

1 Dr. William Clancey
Department of Computer Science
Stanford University
Stanford, CA 94306

Private Sector

1 Dr. Michael Cole
University of California
at San Diego
Laboratory of Comparative
Human Cognition - D003A
La Jolla, CA 92093

1 Dr. Allan M. Collins
Bolt Beranek & Newman, Inc.
50 Moulton Street
Cambridge, MA 02138

1 Dr. Kenneth B. Cross
Anacapa Sciences, Inc.
P.O. Drawer Q
Santa Barbara, CA 93102

1 ERIC Facility-Acquisitions
4833 Rugby Avenue
Bethesda, MD 20014

1 Dr. Paul Feltovich
Department of Medical Education
Southern Illinois University
School of Medicine
P.O. Box 3926
Springfield, IL 62708

1 Professor Reuven Feuerstein
HWCRI Rehov Karmon 6
Bet Hakerem
Jerusalem
Israel

1 Mr. Wallace Feurzeig
Department of Educational Technology
Bolt Beranek & Newman
10 Moulton St.
Cambridge, MA 02238

1 Dr. Victor Fields
Dept. of Psychology
Montgomery College
Rockville, MD 20850

1 Dr. Dexter Fletcher
WICAT Research Institute
1875 S. State St.
Orem, UT 22333

1 Dr. John D. Folley, Jr.
Applied Science Associates, Inc.
P. O. Box 158
Valencia, PA 16059

Private Sector

1 Dr. John R. Frederiksen
Bolt Beranek & Newman
50 Moulton Street
Cambridge, MA 02138

1 Dr. Michael Genesereth
Department of Computer Science
Stanford University
Stanford, CA 94305

1 Dr. Dedre Gentner
Bolt Beranek & Newman
10 Moulton St.
Cambridge, MA 02138

1 Dr. Robert Glaser
Learning Research & Development Center
University of Pittsburgh
3939 O'Hara Street
PITTSBURGH, PA 15260

1 Dr. Marvin D. Glock
217 Stone Hall
Cornell University
Ithaca, NY 14853

1 Dr. Josph Goguen
SRI International
333 Ravenswood Avenue
Menlo Park, CA 94025

1 Dr. Bert Green
Johns Hopkins University
Department of Psychology
Charles & 34th Street
Baltimore, MD 21218

1 DR. JAMES G. GREENO
LRDC
UNIVERSITY OF PITTSBURGH
3939 O'HARA STREET
PITTSBURGH, PA 15213

1 Dr. Barbara Hayes-Roth
Department of Computer Science
Stanford University
Stanford, CA 95305

1 Dr. Frederick Hayes-Roth
Teknowledge
525 University Ave.
Palo Alto, CA 94301

Private Sector

1 Dr. Lloyd Humphreys
Department of Psychology
University of Illinois
Champaign, IL 61820

1 Dr. Earl Hunt
Dept. of Psychology
University of Washington
Seattle, WA 98105

1 Mr. R. P. Joyce
Applied Science Associates
P. O. Box 158
Valencia, PA 16059

1 Dr. Steven W. Keele
Dept. of Psychology
University of Oregon
Eugene, OR 97403

1 Dr. David Kieras
Department of Psychology
University of Arizona
Tuscon, AZ 85721

1 Dr. Walter Kintsch
Department of Psychology
University of Colorado
Boulder, CO 80302

1 Dr. Stephen Kosslyn
Department of Psychology
Brandeis University
Waltham, MA 02254

1 Dr. Pat Langley
Carnegie-Mellon University
Pittsburgh, PA 15213

1 Dr. Marcy Lansman
The L. L. Thurstone Psychometric Laboratory
University of North Carolina
Davie Hall 013A
Chapel Hill, NC 27514

1 Dr. Jill Larkin
Department of Psychology
Carnegie Mellon University
Pittsburgh, PA 15213

Private Sector

1 Dr. Alan Lesgold
Learning R&D Center
University of Pittsburgh
3939 O'Hara Street
Pittsburgh, PA 15260

1 Dr. Jim Levin
University of California
at San Diego
Laboratory fof Comparative
Human Cognition - D003A
La Jolla, CA 92093

1 Dr. Michael Levine
Department of Educational Psychology
210 Education Bldg.
University of Illinois
Champaign, IL 61801

1 Dr. Marcia C. Linn
University of California
Director, Adolescent Reasoning Project
Berkeley, CA 94720

1 Dr. Robert Linn
College of Education
University of Illinois
Urbana, IL 61801

1 Dr. Erik McWilliams
13216 Ridge Drive
Rockville, MD
Washington, DC 20550

1 Dr. James R. Miller
Texas Instruments, Inc.
Central Research Laboratory
P. O. Box 226015, MS238
Dallas, TX 75266

1 Dr. Mark Miller
Computer Thought Corporation
1721 West Plane Parkway
Plano, TX 75075

1 Dr. Tom Moran
Xerox PARC
3333 Coyote Hill Road
Palo Alto, CA 94304

1 Dr. Allen Munro
Behavioral Technology Laboratories
1845 Elena Ave., Fourth Floor
Redondo Beach, CA 90277

Private Sector

1 Dr. Donald A Norman
Cognitive Science, C-015
Univ. of California, San Diego
La Jolla, CA 92093

1 Dr. Jesse Orlansky
Institute for Defense Analyses
1801 N. Beauregard St.
Alexandria, VA 22311

1 Dr. Seymour A. Papert
Massachusetts Institute of Technology
Artificial Intelligence Lab
545 Technology Square
Cambridge, MA 02139

1 Dr. James A. Paulson
Portland State University
P.O. Box 751
Portland, OR 97207

1 Dr. Nancy Pennington
University of Chicago
5801 S. Ellis Avenue
Chicago, IL 60637

1 Mr. L. Petrullo
2431 N. Edgewood Street
ARLINGTON, VA 22207

1 Dr. Richard A. Pollak
Director, Special Projects
Minnesota Educational Computing Consort
2520 Broadway Drive
St. Paul,MN

1 Dr. Martha Polson
Department of Psychology
Campus Box 346
University of Colorado
Boulder, CO 80309

1 DR. PETER POLSON
DEPT. OF PSYCHOLOGY
UNIVERSITY OF COLORADO
BOULDER, CO 80309

1 Dr. Fred Reif
Physics Department
University of California
Berkeley, CA 94720

Private Sector

1 Dr. Lauren Resnick
LRDC
University of Pittsburgh
3939 O'Hara Street
Pittsburgh, PA 1521

1 Dr. Jeff Richardson
Denver Research Institute
University of Denver
Denver, CO 80208

1 Mary S. Riley
Program in Cognitive Science
Center for Human Information Processing
University of California, San Diego
La Jolla, CA 92093

1 Dr. Andrew M. Rose
American Institutes for Research
1055 Thomas Jefferson St. NW
Washington, DC 20007

1 Dr. Ernst Z. Rothkopf
Bell Laboratories
Murray Hill, NJ 07974

1 Dr. William B. Rouse
Georgia Institute of Technology
School of Industrial & Systems Engineering
Atlanta, GA 30332

1 Dr. David Rumelhart
Center for Human Information Processing
Univ. of California, San Diego
La Jolla, CA 92093

1 Dr. Michael J. Samet
Perceptronics, Inc
6271 Variel Avenue
Woodland Hills, CA 91364

1 Dr. Roger Schank
Yale University
Department of Computer Science
P.O. Box 2158
New Haven, CT 06520

1 Dr. Walter Schneider
Psychology Department
603 E. Daniel
Champaign, IL 61820

Private Sector

1 Dr. Alan Schoenfeld
Mathematics and Education
The University of Rochester
Rochester, NY 14627

1 DR. ROBERT J. SEIDEL
INSTRUCTIONAL TECHNOLOGY GROUP
HUMRRO
300 N. WASHINGTON ST.
ALEXANDRIA, VA 22314

1 Mr. Colin Sheppard
Applied Psychology Unit
Admiralty Marine Technology Est.
Teddington, Middlesex
United Kingdom

1 Dr. H. Wallace Sinaiko
Program Director
Manpower Research and Advisory Services
Smithsonian Institution
801 North Pitt Street
Alexandria, VA 22314

1 Dr. Edward E. Smith
Bolt Beranek & Newman, Inc.
50 Moulton Street
Cambridge, MA 02138

1 Dr. Richard Snow
School of Education
Stanford University
Stanford, CA 94305

1 Dr. Eliott Soloway
Yale University
Department of Computer Science
P.O. Box 2158
New Haven, CT 06520

1 Dr. Kathryn T. Spoehr
Psychology Department
Brown University
Providence, RI 02912

1 Dr. Robert Sternberg
Dept. of Psychology
Yale University
Box 11A, Yale Station
New Haven, CT 06520

Private Sector

1 Dr. Albert Stevens
Bolt Beranek & Newman, Inc.
10 Moulton St.
Cambridge, MA 02238

1 David E. Stone, Ph.D.
Hazeltine Corporation
7680 Old Springhouse Road
McLean, VA 22102

1 DR. PATRICK SUPPES
INSTITUTE FOR MATHEMATICAL STUDIES IN
THE SOCIAL SCIENCES
STANFORD UNIVERSITY
STANFORD, CA 94305

1 Dr. Kikumi Tatsuoka
Computer Based Education Research Lab
252 Engineering Research Laboratory
Urbana, IL 61801

1 Dr. Maurice Tatsuoka
Department of Educational Psychology
University of Illinois
Urbana, IL 61801

1 Dr. Perry W. Thorndyke
Perceptronics, Inc.
545 Middlefield Road, Suite 140
Menlo Park, CA 94025

1 Dr. Douglas Towne
Univ. of So. California
Behavioral Technology Labs
1845 S. Elena Ave.
Redondo Beach, CA 90277

1 Dr. Kurt Van Lehn
Zerox PARC
3333 Coyote Hill Road
Palo Alto, CA 94304

1 Dr. Keith T. Wescourt
Perceptronics, Inc.
545 Middlefield Road, Suite 140
Menlo Park, CA 94025

1 Dr. Mike Williams
Zerox PARC
3333 Coyote Hill Road
Palo Alto, CA 94304