REPORT ON THE ANNUAL CARNEGIE COGNITION SYMPOSIUM (10TH): COGNITION AND INSTRUCTION

David Klahr

Carnegie-Mellon University

Prepared for:

Advanced Research Projects Agency
Office of Naval Research

15 November 1974

REPORT ON THE TENTH ANNUAL CARNEGIE COGNITION SYMPOSIUM: COGNITION AND INSTRUCTION

Final Report

David Klahr

Carnegie-Mellon University

December 1974

Short Title: Cognition and Instruction

sponsored by

Personnel & Training Research Programs

Psychological Sciences Division

Office of Naval Research

Arlington, Virginia

Project No. NR 154-363

Advanced Research Projects Agency
ARPA Order No. 2284
Program Code No. 5 W 1 0
Name of Contractor: Carnegie-Mellon University
Effective Date: 1 May, 1973
Expiration Date: 31 Oct., 1974
Amount of Contract: $30,698
Principal Investigator: Dr. David Klahr
(412) 621-2600
Scientific Officer: Dr. Joseph Young
(202) 642-4504

Contract No: N00014-73-C-0405

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Final Technical Report	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) REPORT ON THE TENTH ANNUAL CARNEGIE COGNITION SYMPOSIUM: COGNITION AND INSTRUCTION		5. TYPE OF REPORT & PERIOD COVERED Final Technical Report 1 May 73 - 31 Oct. 74 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) David Klahr		8. CONTRACT OR GRANT NUMBER(s) N00014-73-C-0405
9. PERFORMING ORGANIZATION NAME AND ADDRESS Department of Psychology Carnegie-Mellon University Pittsburgh, Pa. 15213		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 61153N; RR 042-06; RR 042-06-01 NR 154-363
11. CONTROLLING OFFICE NAME AND ADDRESS Personnel and Training Research Programs, Office of Naval Research (Code 458) Arlington, VA 22217		12. REPORT DATE 15 November, 1974 13. NUMBER OF PAGES 14
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

To be followed by conference proceedings in a later distribution

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

Instruction, cognition, information processing, learning, memory, cognitive development, understanding, comprehension, education, problem solving

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

Summary of the activities at the 10th Annual Carnegie Cognition Symposium, held June 2-8, 1974 at Vail, Colorado. Includes abstracts of 10 formal papers, brief summaries of six workshops, formal comments by 9 discussants.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

This report contains a brief description of the purpose, substance and form of the 10th Annual Carnegie Cognition Symposium, sponsored jointly by the Advanced Projects Research Agency and by the Personnel and Training Research Programs, Office of Naval Research. A supplementary report, containing revised and edited versions of the papers presented at the symposium, will be distributed at a later date.

Background and Purpose

The broad outlines for this conference were jointly sketched by Dr. David Klahr of CMU and Dr. Joseph L. Young, of Personnel and Training Research Programs, ONR. We sought a mechanism whereby researchers in the forefront of instructional design and cognitive psychology could productively explain, evaluate and influence one others research. One way to pose the substantive issue is to ask what it would take to create a detailed model of a human learner in an instructional environment. This question has two important properties. First, if we really could construct such a model, it would be of great value in evaluating alternative instructional methodologies through simulation studies. Second, attempting to answer the question will help reveal the nature of what we still need to discover about human cognition in this complex area.

Conceptual Organization

The Symposium activities were divided into three main parts. (See Appendix I). Part I was "Strategies for Instructional Research." The intent was to emphasize some of the variety of strategic approaches to a common problem. These strategic variations differ in methodology, data collection and analysis, modelling, and level of aggregation. The broad spread of this variety, emphasizes the fact that the "appropriateness" of an approach can only be decided with respect to the nature of the questions being asked.

The second part, "Process and Structure in Learning" is an attempt to focus a bit more upon one particular line of research in cognition and instruction. The emphasis is upon a cumulative effort to precisely and explicitly represent the details of what is learned, how it is utilized and how it is modified. The third part is once again a "magnification" of the previous section. Here the focus is upon instructions - which are central to the instructional process - and upon a fine grained information processing analysis.

Format

There were three kinds of sessions:

1) Paper sessions, in which a participant presented a formal written paper. Brief abstracts of all of these papers are presented in Appendix II.

2) Workshops in which a participant described, informally, an ongoing piece of instructional practice, progress reports, and demonstrations. The purpose of the workshops was to provide some extensive concrete instances of interesting instructional problems.

3) Discussion sessions, in which assigned participants presented their responses to specific papers and workshops.

The schedule for the week is shown in Figure 1.

Participants

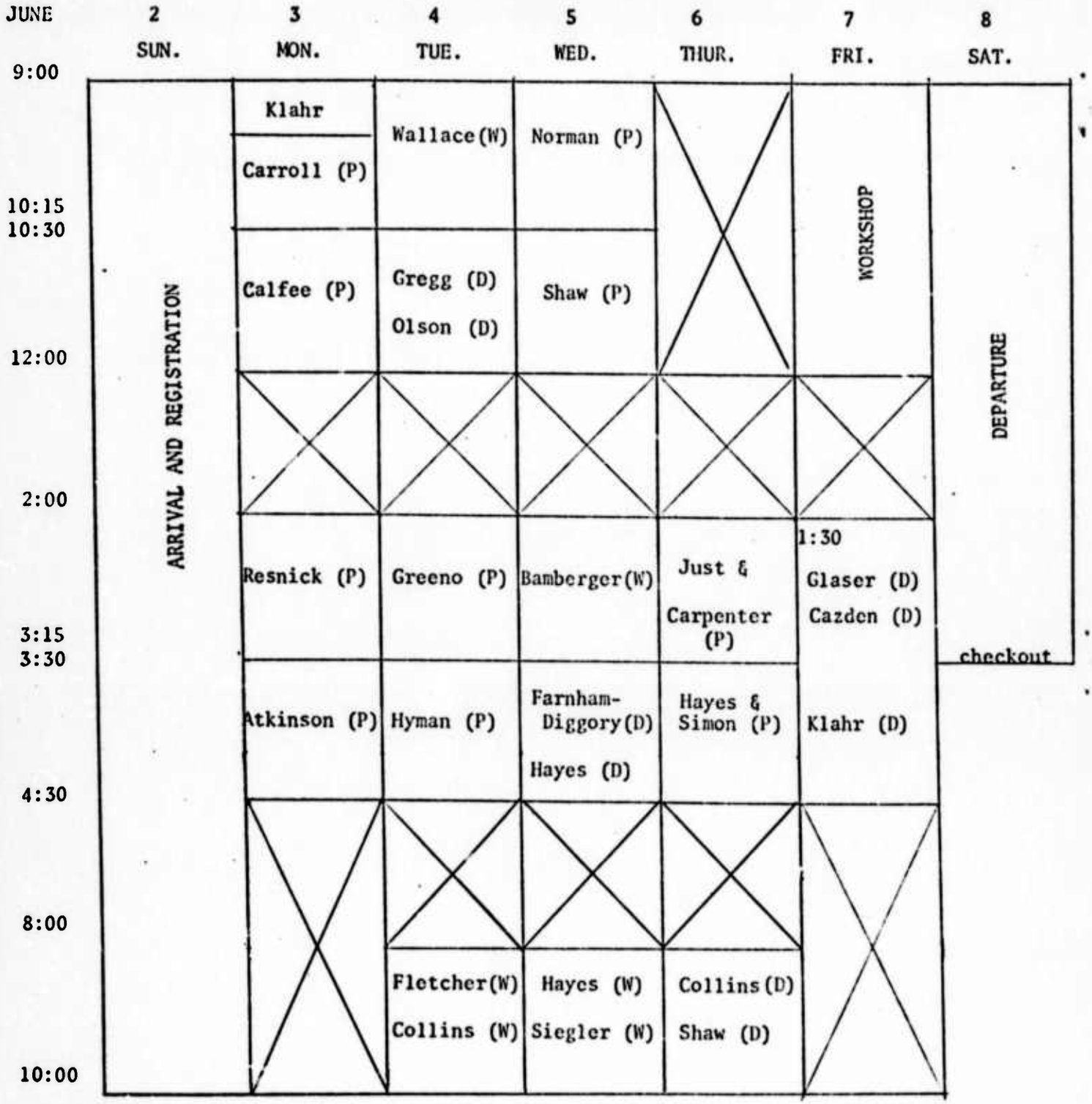
A list of all participants who presented Papers, Workshops or Discussions is in Appendix IV. In addition, a small staff of 4 people from Carnegie-Mellon University assisted in the symposium arrangements. Representatives from the Office of Naval Research, the Naval Personnel Research and Development

Center, the Army Research Center and the Air Force Human Resources Laboratory, also participated in some or all of the sessions.

Location and Time

The Symposium was held from June 3 to June 7, 1974 at Manor Vail Lodge, Vail, Colorado.

Figure 1
Revised Schedule
10th Annual Carnegie Cognition Symposium



General Schedule:

mornings: 9:00-12:00, coffee ~10:15-10:30
afternoons: 2:00-4:30, coffee ~ 3:15-3:30
evenings: 8:00-10:00

codes:

P - paper
D - discussion
W - workshop

Appendix I: Schedule of Papers Workshops and Discussions

Monday June 3

morning

Opening Comments — David Klahr, Carnegie-Mellon Univ.

I. STRATEGIES FOR INSTRUCTIONAL RESEARCH

(P1) Promoting Language Skills: The Role of Instruction
John Carroll, Educational Testing Service

(P2) Fisher in the Mind and the Classroom
Robert Calfee, Stanford University

afternoon

(P3) Information Processing Analysis in Instructional Design: Some Cases from Mathematics
Lauren Resnick, University of Pittsburgh

(P4) Some Attempts to optimize the learning process.
Richard Atkinson, Stanford University

Tuesday June 4

morning

(W1) The adaptation of instruction to individual differences: an information processing approach
Iain Wallace, University of Warwick

(D1) Discussion of papers by Carroll, Calfee, Resnick and Atkinson
Lee Gregg, Carnegie-Mellon University
David Olson, Ontario Institute for Studies in Education

afternoon

II. PROCESS AND STRUCTURE IN LEARNING

(P5) Issues for the new cognitive theory of learning
Jim Greeno, University of Michigan

(P6) Coherence, comprehension and the reorganization of semantic memory
Ray Hyman, University of Oregon

evening

(W2) On some cognitive processes presumed to be operating in computer assisted instruction
Dexter Fletcher, University of Illinois

(W3) Memory structures (human and non-human) in computer based tutorial systems
Allan Collins, Bolt, Beranek & Newman

Wednesday June 5

morning

(P7) Teaching and Learning as a Communication Process
Don Norman*, University of California, San Diego

*coauthored with Gentner and Stevens

II. (continued)

(P8) Acquisition of Conceptual Systems
Robert Shaw*, University of Minnesota

afternoon

(W4) Intuitive and formal modes of representing music
Jean Bamberger, MIT
(D2) Discussion of presentations by Greeno, Hyman, Norman and Shaw
Sylvia Farnham-Diggory, Carnegie-Mellon University
John Richard Hayes, Carnegie-Mellon University

evening

(W5) Teaching problem solving
Dick Hayes, Carnegie-Mellon University
(W6) Teaching formal operations
Bob Siegler, SUNY

Thursday June 6

afternoon

III. FUNDAMENTAL PROCESSES IN THE UNDERSTANDING OF INSTRUCTIONS

(P9) Linguistic control of information processing
Marcel Just and Patricia Carpenter, Carnegie-Mellon University
(P10) Understanding complex instructions
Herbert Simon and John Richard Hayes, Carnegie-Mellon University

evening

(D3) Discussion of papers by Just, Carpenter and Simon
Allan Collins
Robert Shaw

Friday June 7

morning

IV. WHAT TO DO TILL THE DOCTOR COMES: IMPROVING INSTRUCTION WITH CURRENT KNOWLEDGE

Discussion about how the instructional practice, as represented by the workshop sessions, might be made more effective using findings coming from ongoing research.

afternoon

Summary discussion
Robert Glaser, University of Pittsburgh
Courtney Cazden, Harvard University
David Klahr, Carnegie-Mellon University

*coauthored with Wilson

Appendix II
Abstracts of Paper Sessions

I. STRATEGIES FOR INSTRUCTIONAL RESEARCH

P1 Promoting language skills: The role of instruction

John B. Carroll
Educational Testing Service

Educators usually talk about the development of language skills, whereas at least some psycholinguists prefer to talk in terms of competence and performance.

(1) Is there a theoretical bridge between the two systems of terminology, and if so, what is it?

(2) What (if any) models of the language learner are assumed by teachers?

(3) What (if any) models of the language learner have been proposed in psycholinguistic theory (or in psychology in general)?

(4) What (if anything) do these models imply regarding the role of "instruction" or even the possibility of such a role? (For example, what would be the implications of an extreme form of nativism? Of an extreme form of behaviorism? Of a "cognitive psychology"?) Are presently available models of the language learner adequate? If not, where do they fail?

P2 Fisher in the mind and the classroom

Robert Calfee
Stanford University

Progress on the mapping between experimental and applied investigations of reading processes requires considerably greater efficiency in conducting research than that which is currently obtained. Correctly designed factorial investigations can help to improve this efficiency. Anderson (1970) has proposed that the general linear model on which analysis of variance is based provides a foundation for functional measurement of cognitive processes, as well as for statistical evaluation of experimental data. This research, serves as a useful model for research in education, both basic and applied. For example, the Sternberg additive-factor model can be extended to examination of independent stages in complex tasks such as reading and arithmetic. What is required is (a) the postulation of a set of specific processing stages needed in performing the task, (b) identification of factors that affect each stage and (c) development of one or more reasonably independent measures of the operation of each stage. Assessing the independence of the processing stages requires a factorial design allowing a test of interstage interactions. If two stages are independent in Sternberg's sense, then interactions between factors associated with different stages should be negligible. An example of this application is an examination of the independence of decoding and word-interpretation stages in the reading of isolated words. The general research paradigm can be extended to the experimental evaluation of new curricula or other complex instructional programs. Of particular relevance to such applications is the use of fractional factorial experiments, in which critical sources of variance are identified, and the design reduced in size commensurate with those critical sources.

Another useful tool from Fisherian design and analysis is the specific linear contrast. If an experiment is planned so that multiple observations fit into a factorial structure, then it is natural to analyze performance according to specific linear contrasts. In addition to isolating significant components of variance in the set of observations, this procedure provides a ready method for determining specific sources of significant individual differences.

We now have examples of research using these procedures in a number of different instructional areas - effects of story structure on recall of prose, effects of social studies content on impressions about a country, and effect of variation in geometry figures on perception of critical figural features. Analysis of these complex data sets by linear contrasts suggests that a small number of sources of variance typically account for performance quite adequately.

P3 Information processing analysis in instructional design: Some cases from mathematics

Lauren Resnick
University of Pittsburgh

Mathematics tasks have been analyzed over the past fifty or so years by psychologists of varying theoretical persuasions. Their analyses have, on the one hand, reflected basic assumptions concerning psychological processes, and on the other suggested instructional practices in keeping with these assumptions. This paper will review older psychological task analysis approaches in the domain of mathematics and then consider the actual and potential contributions of information processing analyses. Among the questions that will be addressed are: the nature of "problem-solving" behavior in mathematics; the relationship between teaching algorithms and performance algorithms in computational skills; accounting for individual differences in learning and performance in mathematics; and changes in performance at different levels of "expertness" and the implications of such changes for instruction.

P4 Some attempts to optimize the learning process

R. C. Atkinson
Stanford University

This paper reviews three projects whose principal focus is the development of computer-controlled teaching programs. One project is aimed at developing a course called BIP (BASIC Instructional Program) to teach computer programming at the college and junior-college levels; the course gives the student practice and instruction in developing interactive programs. The core of BIP is an information network that embodies the interrelations of concepts, skills, problems, and remedial lessions making up the course. This network, in conjunction with a student response history, is used to control the sequence of programming problems, the frequency and types of assistance given during programming, and the identification of problem areas. A second project is concerned with a computer-controlled course for teaching reading to students in the primary grades. This course is designed around the concept of a series of instructional strands. Each strand is devoted to developing particular reading skills; at any moment in time a student will be working in one of

these strands. The path of each student through the curriculum is determined by a set of programs that allocate instructional time to strands, and control the branching sequence within a strand. The time allocations and branching sequences are based on simple learning models, and have proven to be highly effective. The third project is concerned with developing second-language vocabulary learning programs: programs have been written for Russian, Spanish and German and are used as a supplement to the standard language-learning curriculum.

The three projects have one theme in common; namely, developing procedures that make instruction more effective. These procedures are based on models of how the learner represents, stores, modifies and retrieves information from memory. For several of the instructional problems considered here, precise mathematical models of the learning process can be formulated thereby permitting us to use formal methods to derive optimal policies. In other cases the "optimal schemes" are not optimal in a well-defined sense; rather they are based on our intuitions about learning and appropriate experiments. The examples discussed in this paper illustrate problems in developing effective instructional methods and have implications for a theory of instruction.

II. PROCESS AND STRUCTURE IN LEARNING

P5 Some issues for the new cognitive theory of learning

James Greeno
University of Michigan

1) How should we incorporate generative processes in the representation of conceptual and propostional knowledge?

2) Is there more than one representation of a conceptual structure in memory, and if so, how are they related?

3) What is the interplay between conceptual/propositional knowledge, and procedural/algorithmic knowledge?

4) How does a person's conceptual and propositional knowledge apply when a problem is to be solved?

Examples from both elementary school and college level instruction will be utilized.

P6 Coherence, comprehension and the reorganization of semantic memory

Ray Hyman
University of Oregon

A number of studies from widely different areas of psychology suggest that how information is dealt with when it is originally encoded determines its later availability and utility in new situations and tasks. Other studies suggest that the attempt to bring information from memory to bear upon a new task may result in an alteration of the structure and content of the older memory. This research attempts to bring findings and issues from these varying sources together in terms of current models of semantic memory. The paradigm is based upon the underlying processes that take place when an individual attempts to match a character sketch to what he knows about the individual being described or a prediction to an actual event. The subject "stores" a

data base such as a number of propositions about a hypothetical individual. He is then presented a character sketch allegedly describing the individual in his data base. Depending upon the experimental condition, the subject is required to compare the character sketch with the information in his data base. In some conditions he is merely requested to evaluate how well the sketch matches the stored description. In other conditions he is required to list as many "matches" or hits as he can find between the sketch and the data base. In still other conditions his task is to list as many misses or deviations between the sketch and the data base that he can. The sketches will vary, as an additional independent variable, in terms of how coherent (in terms of prior research) the sketch is with the data base. A sketch which is very coherent and one which is very discrepant from the original data base should have much less effect upon S's memory for the data base than will one that is moderately discrepant. The interest here is in both how the task of "making sense" of the sketch in terms of the original data base will affect the memory for the stored data base as well as the memory for the character sketch. The instructional implications are obvious.

P7 Teaching and learning as a communication process
Donald A. Norman, Donald Gentner, Albert Stevens
The University of California, San Diego

The teacher has the task of conveying a particular knowledge structure to the student. The learner has the task of deducing just what structure is intended by the teacher, as well as the additional task of adding the new information to the old in such a way that it can be referred to and used at a later time. Many of the problems of learning and teaching can be understood as problems with this communication process. Learning, however, is unlike most simple communications in that the structures that are to be acquired are complex, and it is not always clear how they are to fit together. Moreover, the differences in the knowledge shared among the participants in a learning situation is often considerably greater than in a simple discourse.

This paper examines the process of learning by examining in detail the manner by which information is represented within human memory. Then, the problem of presenting new information so that it can make appropriate contact with previously known information is discussed. This causes us to analyze the overall structure of knowledge, including a quasi-hierarchical representational system in which the representation of a topic matter can be successively expanded into more and more detailed and elaborated structures. To teach, it is necessary to understand the student, and the paper concludes with an analysis of the processes invoked by the student in attempting to understand the material presented. We discuss just how one might go about modeling the student and we show from examples in the learning of a programming language how the model of the student might incorporate newly acquired schemata about the nature of the task before him. Often an initial schema is incorrect. Much of learning turns out to involve the effort of the student to discover and eliminate the errors in each of his conceptual schemata.

III. FUNDAMENTAL PROCESSES IN THE UNDERSTANDING OF INSTRUCTIONS

P9 Linguistic control of information processing
Marcel Just and Patricia Carpenter
Carnegie-Mellon University

The first step in carrying out instructions in tests, work situations, or elsewhere in everyday life, is reading (or hearing) and understanding sentences. This research is concerned with very basic and general processes that are common to almost every act of language comprehension: quantification, presupposition, predication and matching visual and linguistic codes.

We will examine several linguistic structures that are used frequently in written or spoken instructions, with the following research questions in mind.

1) How is the instruction represented internally?

2) What operators are used to process the information?

3) What is the nature of the working memory used to execute the instruction?

4) How is the result of this processing translated into overt performance?

P10 Understanding complex instructions
Herbert A. Simon and John Richard Hayes
Carnegie-Mellon University

How does a subject organize his information processing system to perform a task, given the task instructions? What are the processes that operate between the first presentation of task instructions and the end of the "practice trials" in a typical experiment or intelligence test. What are some promising methods for approaching these questions?