REPORT OF 1973 WORKSHOPS ON INFORMATION PROCESSING PSYCHOLOGY

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ABSTRACT

A series of seven workshops on information processing psychology were held at CMU in the summer of 1973 under the sponsorship of the Mathematical Social Science Board (MSSB). They followed on a similar workshop held in 1972. The topics were: (1) automatic protocol analysis; (2) concept attainment and rule induction; (3), (4), (5) semantic representation; (6) developmental psychology; (7) short term memory and the immediate processor (production systems). They all involved the interactive exploration of programs that embodied theories in the respective areas. One purpose of the workshops was to discover how intense interactive use of computers can aid in scientific communication. Participants were scientists in cognitive psychology and artificial intelligence.

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A. General Description

1. Introduction

From June 17 until July 29 a series of seven workshops on various problems of information processing psychology was held at CMU under the auspices of the Mathematical Social Science Board. Approximately 50 invited participants took part on a regular basis in one or more of the workshops. In addition several people came by as guests and a number of scholars from CMU sat in on a more casual basis. The workshops spanned a wide range of topics and also differed widely with respect to the degree of structure which was imposed, the extent to which they were built around particular computer systems, the degree of technical sophistication of the participants, the degree of committment to specific substantive problems, and the particular expectations which the participants brought to the workshops. As a consequence of this plurality the series represents, to some extent, an experiment in the design of workshops and in the efficacy of various modes of communication among scholars engaged in information processing psychology and computational studies of cognition. This report attempts not only to describe the activities of the workshops but also to compare various aspects of the way in which workshops functioned. Even though these somewhat subjective impressions are not well substantiated they may still prove useful to planning such enterprises in the future.

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2. Background

A perspective on the goal of these workshops may be obtained from earlier attempts at coming to grips with the problem of communicating research results and techniques in information processing psychology. Some of these are documented in Reitman (1965, chapter 21),in the historical appendix in Newell & Simon (1972) and in Newell, Simon, Hayes, & Gregg (1972). The latter is a report of an intensive 20 participant nine-day workshop held at CMU in June 1972 which was the direct predecessor to the present series of shorter and smaller workshops. Because the purpose of this year's workshops is very closely related to that of the 1972 workshop the following paragraphs from the Newell et. al. (1972) report may serve as an introduction to the present report as well.

> "Two concerns provided the impetus for the present workshop. One is the continued growth, in complexity and sophistication, of the computer programs used for the study of information processing. This includes direct simulations of cognitive behavior, basic studies in artificial intelligence, and programs that aid the analysis of cognitive data. The characteristics of these current programs appear to be that: (1) each is an embodiment of some specific psychological content; (2) each permits substantial variation and modification; (3) each has a language of interaction, which gives it some of the flavor of a programming language, but a language that speaks directly in psychological terms; (4) each is interactive, so that the user modifies and explores an existing system, rather than creating something from scratch; and (5) each is a large program.
>
> The second concern is the continued ineffectiveness of scientific communication of the content of these various programs via the standard means of papers, hour-long lectures and even the half-day long sessions that characterize the small invitational working conference. One difficulty is that the underlying technical systems of computer science are not fully assimilated by the psychological community. This was the underlying motive for the intensive summer sessions in the fifties and sixties (both for mathematics and for computer science). But the difficulties lie also in the nature of the systems--their size, complexity and the detailed knowledge necessary for understanding and evaluation. These latter difficulties can be seen at work even in sessions of experts."

These two concerns were also behind the plans for the 1973 workshop.

The experience with 1972 workshop suggested a number of different

design decisions, in response to difficulties encountered last year when a relatively large group of people (i.e., 20) were exposed during a short intense period (i.e., 9 days) to a large number (i.e. 7) of major computer systems plus a large overseer and tutor system called ZOG. (ZOG was especially designed for the workshop as the primary medium of interaction between users and programs; it is described in the Newell et. al. (1972) report). The information-overload problem as well as frustrations felt by some participants in not having enough time to explore particular systems in depth or in not having enough substantive focus on psychological issues were discussed on several occasions during the 1972 workshop. In addition there was the additional problem that the CMU PDP-10 system became overloaded, causing further frustrations for both participants as well as for the regular CMU computer users. As a result it seemed appropriate to attempt a follow-up project designed to minimize these problems. It seemed that several smaller and more focussed workshops might allow more opportunity for participants to explore selected systems in greater depth and to focus more sharply on relevant psychological issues. Accordingly plans were drawn up for a series of workshops, each bringing together 5 to 10 scientists with common interests to explore and discuss psychologically relevant computer-based technologies and particular computer systems.

3. Personnel

A steering committee was formed consisting of A. Newell, H. A. Simon, J. R. Hayes, and Z. Pylyshyn; The latter served as director for the workshops.

In early winter a meeting was held at CMU to discuss possible topics, systems, and formats. People closely associated with the proposed systems were contacted, and their help solicited in generating further potential participants. This process was repeated until a set of topics, systems, and interested participants emerged consistent with the original goals. As in the 1972 workshop the intention was not to introduce psychologists to the information processing

approach but to provide scientists already familiar with this general approach with an opportunity to explore techniques and discuss both technical and substantive issues in a more intensive manner.

Participation was by invitation, as proposed by the steering committee, those associated with the systems to be used, and by already-invited people. The workshop on cognitive development elected to publicize that particular workshop somewhat more widely among scholars in the field and subsequently selected a number of participants from among those expressing an interest. Participants were members of the faculty of a university or professional staff at a research institution, except that several people came as staff because of their special expertise in a computer system, and some participants came with a senior graduate student. Although not part of our original plan the latter turned out to be a useful feature. There was a feeling (not yet substantiated by evidence) that the effect of the workshop would be longer lasting if more than one member of a research team attended.

4. Computer systems

Because we wished to encourage participants to actively explore computer programs, those supplying the systems were required to human-engineer and document these systems so that they could be easily explored in an interactive manner. Considerable effort was put into polishing up existing programs. A list and brief description of the systems involved is given in appendix A. Several of the larger programs which we wished to explore (notably TOPLE, SCHOLAR, AND MEMOD) were either written on a different machine, or on a machine running under a different monitor and so could not easily be brought up on the CMU PDP-10 computer. In these cases we decided to use the programs through the ARPA network (all were on computers on the network, i.e., MIT, BBN, and UCSD). To ensure that all systems would be ready for the workshop as well as to reveal potential problems, the developers of the systems were invited to demonstrate them at a two day rehearsal

held at CMU in mid-May. CMU faculty and graduate students were invited to sit in on this rehearsal. No major technical problems were uncovered, but the rehearsal did provide a valuable early deadline for completion of systems. It gave demonstrators an opportunity to try out their systems before an audience and to obtain some feedback on pedagogical features.

5. Additional local arrangements

(a) Physical arrangements

The physical arrangements were the same as for the 1972 workshop. Participants were housed in a dormatory on campus, given meal tickets, and had offices assigned to them for the duration of the workshop. Sessions were held in a room which contained a high speed (120 characters/second) terminal connected to 2 large and 4 small TV monitors located around a central table. This arrangement was very convenient for lecture-demonstrations. We rented six 30 character/second hard-copy terminals (Datanet 300). Five of these were located in the computer science terminal room which also housed a high-speed line printer, and one was located in the seminar room.

(b) Software and computer access arrangements

It was decided to use programs directly through the PDP-10 monitor in the conventional manner. ZOG was available for participants to explore the systems which were used in last year's workshop, but was not the main medium of interaction between users and the computer. There were three reasons for the decision, in spite of positive experience with ZOG in the 1972 workshop:

(i) ZOG seems most useful when a variety of programs need to be made easily accessible since it provides a buffer stage with simple and uniform conventions. In the present case there were never more than 2 programming systems in use in any one workshop.

(ii) For technical reasons having to do with the PDP-10 monitor,

ZOG cannot intervene properly between the user and the ARPA network. Thus network programs would have to be handled outside of ZOG.

(iii) To use ZOG requires writing appropriate tutorial text in an appropriate hierarchical format. While not very difficult, the benefits (in view of point (i) above) did not warrant the added effort.

In place of ZOG we relied on tutorials, personal contact with PDP-10 users, and a very elementary guide to the PDP-10 facilities known affectionately by its file name as MONIT.MAN. This light introduction was handed out to participants on the evening of their arrival and served to introduce them to the monitor, the text editor, the network handler (IMP commands) and several utility programs such as the file transfer program (PIP) and the MAIL forwarding facility. All textual material written for the workshop (including MONIT.MAN, the workshop schedule, names and addresses of participants, and outlines of several manuals, reports, and theses) were kept on a common "communication area" of the disc and could be printed out at any time by participants.

A separate account number was set up for the workshop as a whole with subaccounts (man-numbers) for each participant, and an entire disc pack was set aside for the exclusive use of the workshops. By the end of the workshop a total of 26,250 blocks (of 128 words per block in 654 files)were in use by the workshop.

B. Individual Workshops

In this section we will present a brief resume of the activities of individual workshops. The background reading recommended to participants is appended as a bibliography to this report. In addition to the director, each workshop had designated coordinators who were the people who demonstrated major systems or who organized a particular workshop. Several workshops invited guests from the Pittsburgh area to talk about their work.

Towards the end of each workshop participants discussed strengths and weaknesses of their workshop, what they had learned from it, and the effect of on-line computer facilities. Each participant was also asked to comment in writing on the workshop before they left. The reactions elicited by these two methods, as well as by more informal discussions, form the basis of this section.

1. Workshop on Protocol Analysis (Workshop 1: June 17 - June 23)

Participants: Don Waterman (CMU) *
Dick Hayes (CMU) *
J. Peter Denny (U. Western Ontario)
Steve Reed (Case-Western Reserve)
Dennis Egan (U. Michigan)
Gordon Wilcox (Cornell)

Guest participants:
Samiha Mourad (Fordham)

Staff assistants:
Michael Rychener
Barbara Bessie

Systems: Protocol Analysis System II (PAS II)
- Example of application in Cryptarithmetic

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* Names of those acting as coordinators for each workshop are asterisked.

- Example of application to the Liar-Truthteller problem (A. Newell)
- Example of application to analyse the instructions for the "Tea Ceremony" problem (J.R. Hayes)

Description

This was a one-system workshop. The goal was to explore the PAS II system in depth in order to understand it both as a tool for the analysis of verbal problem-solving protocols and as a set of theoretical ideas relevant to a range of phenomena -- from the comprehension of natural language to problem solving heuristics. Since participants in this workship had had very little experience (in some cases none at all) with interactive programming a considerable part of the total time was spent mastering the technical tools -- which included such things as the monitor facilities, the text editor (although this was minimized by the editing facilities within PAS II which most people relied on exclusively), and the technical aspects of communicating with PAS II (*e.g.*, the syntax and semantics of the command language). PAS II is a large and complex system. Participants mastered a significant portion of PAS II -- a tribute both to their perseverence and to the constant availability of expert help. In fact there was one PAS II expert for each invited participant and the experts were available during the entire workshop. Comments received from participants indicated that this aspect of the workshop was its most valuable asset.

After the first day of this workshop, mornings and most evenings were devoted to working at computer terminals while the afternoons were reserved largely for talks and seminars. Participants had several days of lectures on PAS II itself (by Don Waterman), one on its use to analyse protocols of a subject solving the "liars and truthteller problem" (by Allen Newell), and one by Dick Hayes on a rather unconventional use of the system to analyse instructions to subjects for a problem isomorphic to the classic "Towers of Hanoi" problem called the "Tea Ceremony Problem". The latter work is described in Hayes and Simon (1973).

Three of the participants brought their own protocols and proceeded to develop a system to analyse them. One of these protocols consisted of a narrator's description of the ongoing interactions between a parent and child -- a piece of text rather different from that anticipated in the design of PAS II. Discussion of this unorthodox application served to bring up some interesting points about the generality of PAS II and of Problem Behavior Graphs (one of the products of an almost complete PAS II analysis).

2. Workshop on Concept Attainment and Rule Induction (Workshop 2: June 20 - June 26)

Participants: H. A. Simon (CMU) *

L. Gregg (CMU) *

Peter Polson (U. Colorado)

James Chumley (U. Mass.)

James Greeno (U. Michigan)

Thomas Wickens (UCLA)

John Cotton (UCSB)

Guest participants:

Dennis Egan (U. Michigan)

Peter Denny (U. Western Ontario)

Systems: Several SNOBOL programs for concept learning and rule induction, described in Simon & Lea (1973).

(a) a grammar induction program GRAIND

(b) a concept attainment program CONATT

(c) a sequence extrapolation program NEWTRA

(d) two programs for running concept attainment and sequence extrapolation experiments on the DDP-116 computer

This workshop was heavily oriented towards writing actual simulation programs. After the first day only about two hours per day were spent in formal session. This consisted of such things as a lecture on SNOBOL, demonstrations of SNOBOL programs, a demonstration of the computer controlled psychology laboratory, a lecture and demonstration of the Hayes and Simon program for the Tea Ceremony Problem mentioned earlier, and discussions by participants of their work. The bulk of the time was spent in small groups planning or writing programs. Although the participants had little previous interaction programming experience, all had mathematical training. In fact one of the themes running through the workshop was the comparison of mathematical and procedural ways of expressing concept learning theories. The participants' intense

and generally productive involvement in actual program-writing may be traced to the following characteristics of this workshop: (a) the strong direction given by the coordinators of this workshop who placed heavy emphasis on programming; (b) the use of a common and relatively easily learned language, SNOBOL; (c) the strong common interest is a specific theme -- viz, the integration of ideas on problem solving, concept attainment and rule induction; (d) the availability of small, easily understood SNOBOL programs which captured theoretical ideas about the main substantive theme. Most of participants worked in groups of 2 or 3 to modify and generalize CONATT. There was also some more ambitious exploration of SNOBOL programs to solve the Tower of Hanoi problem by building on concept attainment and sequence extrapolation notions.

Because of the rewarding involvement of participants in substantive tasks many (i.e., 3) indicated that they had been "permanently" influenced by this experience and would likely continue this work. The major complaint was that unnecessarily long time was spent learning SNOBOL, which could have been saved had they known in advance that this was to be the operating language.

3. Workshop on Short-term Memory and the Immediate Processor (Workshop 7: July 22 - July 29)

Participants: W. Chase (CMU) *
A. Newell (CMU) *
Jim Juola (U. Kansas)
Roberta Klatzky (UCSB)
Nancy Frost (Princeton)
Patricia Carpenter (CMU)
Marcel Just (CMU)

Guest participants:
Micheline Chase (CMU)
John Payne (CMU)

Staff assistant:
Tom Moran (CMU)

Systems: PSG2 (Production System) and sample programs

We discuss this workshop next because of its similarities and contrasts with the concept learning and rule induction workshop. Both workshops were intended to be highly content-oriented. Participants were experts in a well defined substantive problem area of psychology. In both cases there were simple and clear sample programs embodying a theoretical position relevant to the substantive problem area and in both cases there was a single programming language. In the STM workshop participants had received a greater number of descriptive publications (including a description of the PSG language) in advance than did participants of the concept learning workshop. In spite of the similarities, however, there were some significant differences in the directions which the two workshops took.

As in the concept learning workshop there was considerable emphasis placed on programming by the coordinators. The agenda developed by the group on the first day called for a minimal amount of group discussion to be held in the afternoons with mornings and evenings devoted to exploring and writing programs.

Among the topics covered in the formal afternoon sessions were lectures on the PSG2 system and on the production system model for the Sternberg search task, general disucssions of production systems and their relevance to psychology, a demonstration of Tom Moran's production system for simulating a visualization task, and several discussions of substantive research in short-term memory. During the mornings and evenings participants typically worked in pairs on gaining experience in PSG2 and on designing programs to account for a number of known empirical regularities not captured in the sample programs.

In spite of the parallels with the progress of the concept learning workshop however, a certain frustration became apparent by the end of the third day -- both in the formal sessions where participation tended to decrease and in the programming. Disucssion with some of participants suggested that there was a tension between the constraints imposed by the PSG2 system and the theoretical ideas which some of the participants held. Many of the participants had been used to constructing models of a descriptive, continuous, or stochastic nature and tried to implement these notions in PSG2. As a result there were a number of requests for additional features to be added to the PSG2 system (some of which were indeed added the next day!).

Because one of the staff was due to depart on the fifth day a special seminar was held that morning, instead of on the last day, to discuss the progress of the workshop. It became apparent then that about half of the participants had made significant progress towards implementing a model in PSG2. The other half had reached a point where, according to their own judgment, they could understand what the sample programs did and what PSG2 represented but felt that either the PSG2 system was too deficient in areas they wished to pursue or else it would take more time than available to go the next step and write a PSG2 system capable of performing in the areas they had chosen to explore. Apparently then for these several participants the happy situation which obtained in the concept learning workshop did not occur:

there appeared to be too large a gap between the theoretical ideas these people had tried to come to grips with and the ease with which such ideas could be implemented in a short time in PSG2. The point was raised that with certain systems one gains enough experience in a reasonably short time to see what the system is capable of doing and beyond this it may take a much greater investment in time and effort to go the next step and produce an interesting and original variant on the system. One of the participants remarked, in contrast, that while he had felt exactly this way during an earlier exposure to PSG2, by persisting at the problem he was now deeply into a reasonably large PSG2 program and had found his original pessimism unfounded.

In spite of the difficulties encountered, however, several large systems were written in PSG2 and participants indicated that they had learned from their experience of trying to work with the production system approach.

4. Workshops on semantic representation (Workshops 3,4,5; June 25 - July 14)

(a) Semantic representation I: Models of long-term memory

(Workshop 3: June 25 - July 1)

Participants: Don Norman (UCSD) *

Allen Collins (BBN) *

Robert Abelson (Yale)

John Anderson (Yale)

Jim Levin (UCSD)

Guest participants:

Lynne Reder (Yale)

Allen Newell (CMU)

Staff assistant:

Joseph Passafiume (BBN)

Systems: Scholar

Memod

Story-gen

(b) Semantic representation II: Language comprehension

(Workshop 4: June 30 - July 9)

Participants: Terry Winograd (Stanford) *

David Rumelhart (UCSD) *

Zenon Pylyshyn (UWO) *

Wallace Chafe (Berkeley)

Neil Stillings (Hampshire)

Steve Isard (Edinburgh)

Anthony Davey (Edinburgh)

Jim Levin (UCSD)

Guest participants:

John Payne (CMU)

Lee Gregg (CMU)

Herbert Simon (CMU)

Systems: Memod

SHRDLU

Whatif

Spout

(c) Semantic representation III: Procedural semantics

(Workshop 5: July 7 - July 14)

Participants: Zenon Pylyshyn (UWO) *

Bertram Bruce (Rutgers)

Eugene Charniak (MIT)

Anthony Davey (Edinburgh)

Michael Fehling (Rutgers)

Steve Isard (Edinburgh)

Drew McDermott (MIT)

Guest participants:

Stuart Card (CMU)

Thomas Moran (CMU)

Allen Newell (CMU)

Herbert Simon (CMU)

Steve Rosenberg (CMU)

Richmond Thomason (U. Pitt)

Systems: Tople

Whatif

Spout

Chronos

These three workshops share much in common so they will be described together. In fact partitioning the 18 people into three workshops was done mainly to keep the group size down and to prevent the simultaneous exploration of too many large systems. The attempt to group people with similar interests worked out well in one case, but probably resulted in excessive homogeneity in the other two cases.

The main goal of all three workshops was to understand contemporary approaches to the difficult problem of representation of meaning in computer systems. This includes the general problem of language comprehension and representation as well as issues arising from the alternative approaches to representation of knowledge in memory--semantic networks, procedures, alternative worlds (contexts), production systems, modal logic, and images. This is a very broad area with considerable activity and diversity, and a general lack of consensus. In consequence, the workshops were less focused and the direction less clearly laid out in advance than was true in the other four workshops. Additional factors gave these workshops a rather different flavor from the other workshops. Almost all participants were experienced computer types who had worked on computer simulation systems themselves--most were in fact professionals in the area of artificial intelligence. The major systems were different from those which played a part in the other workshops, being very large and complex whose internal operation could not easily be examined (there were a few exceptions). The amount of psychological theory represented in the system was often small in comparison with the sheer technical complexity. Nevertheless, these systems represent the state of the art in an area which is central to cognitive psychology. It is perhaps not surprising that these workshops did not proceed in the same manner as the others.

All three of the semantics workshops began with the enumeration of a set

of topics and issues which the participants wished to explore. Not all the topics listed were eventually covered and others not listed were introduced. Tight discipline over the agenda was not adhered to--agendas were constructed anew for each day. This loose format had some disadvantages, and several people later commented that they wished that the week had been more structured.

(a) Semantics I.

This workshop was rather slow in getting started. Part of the problem was technical and represented the only serious technical difficulty of the series. The IMPCOM satelite computer which connected the UCSD computer with the ARPA TELNET experienced frequent failures on the first day and finally went down for the rest of the week. As a result oneof the main systems of this workshop, MEMOD, was not available at all. Since the extent of the trouble was not known until late in the week there were attempts to prepare a task to incorporate into MEMOD in order to illustrate its operation. Enthusiasm for this proposal flagged as each day brought a new message of delay. We did hear about one of the modules of MEMOD (called Verbworld) even in the absence of an operating system. There were also sessions devoted to an exposition and demonstration of SCHOLAR and of a story generating program based on Abelson's belief system notions. Many of the topics occurred in groups--the first leading spontaneously to others. Thus after a description of the story generator a system was written up (in about half an hour) to demonstrate how this task might be done in Micro-planner. This led to a discussion of the advantages and inadequacies of that approach. Similarly after a discussion of the "features" vs. "prototypes" approach to representation of concepts, Al Newell was invited to talk about MERLIN which has a strong committment to the approach of representing new concepts in terms of mapping from old ones--i.e., a prototype-plus-further-specification representation. After the question of visual versus semantic representation was raised there was a long

session on the possibility of analogical representations and after the question of the empirical significance of MEMOD was raised there was a discussion in which the more experimentally-based system HAM (described in Anderson & Bower, 1973) was described and compared with other approaches.

There were also discussions of such problems as the problem of representation of nouns and of adjectives, the problem of reference (in language), the problem of bringing appropriate knowledge to bear in understanding statements or answering questions. On this latter, what kind of knowledge is relevant to answering such questions as "Where is the Empire State Building?" ...Do you say "In New York?" "In the U.S.?" "On X street?"..., and what is involved in understanding a sentence such as "I went to three drug stores this afternoon.".

By the end of the week all participants had had an opportunity to discuss their work. There was, however, a minimal amount of individual exploration of systems (i.e., other than in the form of group demonstrations). The individual work was done in the evenings: almost all the days were devoted to presentations and discussion. This mode of operation (which was repeated, with some variation, in all three semantics workshops) is, if nothing else, exhausting. While most participants felt that important issues had been raised and they had learned something there is no doubt that we were beginning to saturate.

(b) Semantics II.

The second of the three semantics workshops covered similar topics to the first, but was somewhat more structured with more direct contact with specific systems--perhaps because there were more comparable working systems available. To this extent there appeared to be more concrete foci for discussion. The UCSD computer was back on the network so we had access to MEMOD. We were able to see it in action and interact with it as well as hear a talk on its operation. After the session on MEMOD Winograd volunteered to attempt to

modify his SHRDLU system to handle the type of discourse we had seen with MEMOD (actually with the "Verbworld" data base of MEMOD). This attempt, while not carried through to completion, pointed out some important differences between the two systems. SHRDLU, with its relatively closed data base, needs to find a referent in its world for each definite noun phrase, while MEMOD simply constructs a new node. This apparently minor difference has deeper implications which were discussed. The differences between SHRDLU and MEMOD provided a focus for several fundamental issues of representation--such as the limitations and strengths of an approach based on semantic primitives, ways of handling problems of scope, representations of time, of facts vs. procedures, of generic vs. particular items, of context frames for supersentential references, and questions of the psychological content of these systems. These questions recurred in all three semantic workshops but the approach to them was always colored by the systems being used as a point of reference.

Again all participants had an opportunity to discuss their work. We heard about Chafe's empirical studies of the process of describing scenes and events and Stilling's studies of transfer verbs and got into the perennial question of analogical (imagerial) representation and what that could mean.

The somewhat smaller systems represented by Whatif and Spout proved to be of considerable interest since each was dedicated to doing the best possible job on a smaller problem than that to which MEMOD and SHRDLU were directed. As a consequence it was easier to understand how they operated. These systems were also explored in the subsequent workshop where they were given a rather more thorough examination.

There was a somewhat higher level of actual program exploration in this workshop than in the other two semantics workshops. Most of the interaction was

done through the people who wrote the systems rather than by individual work or original programming. The lack of individual exploration was no doubt due to the complexity of the systems involved. Even to explore a system as elaborately human-engineered as the currentversion of SHRDLU (which had had several man-months of work done on it in connection with last year's workshop) was extremely difficult for anyone not intimately familiar with its facilities. In any case even if a person could interact with the program it still remains unclear how much he could learn about its fundamental limitations without studying the program code or without having an expert present who can help him to separate programming bugs from limitations in principal. The latter point was made by one of the participants in the final overview discussion.

One active project undertaken by participants was to modify the Verbworld data base of MEMOD to incorporate some ideas which had come up earlier regarding how questions of the form "where is X?" should be answered. A first-approximation by Rumelhart's, known as the "room theory", suggested an answer in terms of the unit of size immediately below the smallest unit which contains both the questioner and the object referred to. The modifications required of Verbworld were accomplished one evening by several people working with Rumelhart and Levin. In the course of the modification several limitations of the current MEMOD were uncovered which had not been apparent to the passive observers (e.g., it was not possible, without major changes, to make MEMOD answer "Where is Don?" differently from "Where was Don?" or "Where has Don been?" because the parser throws away tense information). Similar limitations were also uncovered in the course of interactions with SCHOLAR. While the game is not to stump a system, nevertheless it seems easier to separate the good ideas embodied in a system from the "kludges" by interactive exploration--especially in the company of the system's designers.

Though there was more active exploration of programs in this workshop, most of the days were still spent in demonstrations and seminars. Consequently the saturation effect mentioned earlier was still present in the latter part of the week (before the "end effect" revitalized us).

(c) Semantics III.

This workshop contained perhaps the largest proportion of computer programmers. Also at least four of the participants had a special interest in the question of the relationship between modal logic (especially "possible world" semantics) and recent work in artificial intelligence which appeared to be at least superficially related. There was some interest expressed prior to the workshop in such general issues as appropriate language systems(theory-laden languages?) for describing cognition, ways of representing belief systems, counter-factual conditionals, representation of time, and psychological evidence for constructive processes or processes of elaboration occurring during language comprehension. In view of this it was expected that this workshop would involve more discussions of a technical and formal nature than the others. This did indeed turn out to be the case--although not without some tension since some of the participants would have preferred more emphasis on detailed substative questions.

The following were among the topics discussed during the week. A day was spent on McDermott's TOPLE system--observing a trace of its operation and learning how the multiple-contexts facility of the underlying CONNIVER language was used. A session was devoted to Isard's Whatif system for understanding conditionals. This included getting into some detail regarding how the "partial application" facility of the POP2 language was used to advantage for context-sensitive procedural parsing. Another session was devoted to Davey's Spout system which describes the way in which a Tic-tac-toe game was played. The session on Davey's system was another good example of how one can learn things by interactive

exploration which would be difficult to find out from reading about the program. By a series of iterations through the running program we formed hypotheses about how it operated and then asked Tony Davey to make it do certain things in a particular order to verify the conjectures. By so doing we uncovered some of the weaknesses of the system and came to a much better understanding of the problems involved in its design.

A long session was devoted to the representation of time. The CHRONOS system (by Bruce) was demonstrated and its underlying philosophy critically examined. The discussion bore some resemblance to a similar discussion in the previous workshop. The disadvantages of representing time as a measure on either an interval or even an ordinal scale were discussed and the parallels with the problem of representing space noted.

A session was devoted to some of the questions which Charniak considered in his thesis; e.g., the distinction between "hear-time" and "inquire time" processes (paralleling the distinction in computer science between compilation-time and interpretation-time) and the question of what knowledge must be brought to bear in understanding apparently simple sentences in children's stories. Considerable time was spent considering how a listener can give the correct reading to the phrase "take back" in an story segment such as that in which Mary says she will buy Dick a top for his birthday and Janet replies "Don't do that Mary. Dick already has a top. He will make you take <u>it</u> back." (How does the listener know what the referent of "it" is?). This discussion also led to a comparison of Charniak's "demons" approach with McDermott's "alternative world's" approach. Here the discussion was aided by a working paper on the subject prepared in advance for participants by Charniak.

This workshop also heard presentations from a number of guests. Richmond Thomason, a logician and formal semanticist from the University of Pittsburgh,

spent a day with us discussing the formal semantic system of Richard Montegue as well as his own linguistic work and examining the similarity between problems encountered in his field and those encountered in artificial intelligence. Allen Newell and several people working with production systems (Tom Moran, Stu Card, Don Waterman and Mike Rychener) joined a session at which we examined the merits of using production systems as a language for describing cognition. Steve Rosenberg and Herb Simon described Rosenberg's empirical studies of sentence recognition using the Bransford and Franks paradigm as well as a simulation model of the process which he developed.

The only interaction with computer systems which this group engaged in was done as a group during seminar sessions. There was considerable small-group discussion during the evenings, however, on topics of speical interest to some of the participants. There was again the satiation effect of prolonged and intensive seminars so one afternoon was left free for recovery. In the final overview session some people expressed the wish that the sessions had been shorter with more time for small group work. The general feeling was, however, that there had been about the right amount of contact with the computer, that the presence of the terminals had served as a pedagogical tool, a stimulant, and a change of pace. Two of the participants did not feel that the computer's presence was critical to the learning process but this point was hotly disputed by others.

5. Workshop on Developmental Psychology (Workshop 6: July 15 - July 22)

Participants: David Klahr (CMU) *

George Baylor (U. Montreal) *

Jean Gascon (U. Montreal) *

Loren Resnick (Pitt)

Lynn Lyons Morris (Pitt)

Juan Pascual-Leone (York)

Jud Burtis (York)

Klaus Witz (Illinois)

R. Hart (Illinois)

Christine Riley (Princeton)

Paul Weener (Penn. State)

Guest participants:

Sylvia Farnham-Diggory (CMU)

Lee Gregg (CMU)

Allen Newell (CMU)

J. G. Wallace (Warwick)

Micheline Chase (CMU)

John Payne (CMU)

Staff assistant:

Marshall Atlas (CMU)

Systems: BG

- sample programs for seriation

PSG2

- sample programs

- subitizing & quantification programs (PSQC1)

This workshop had some of the flavor of the concept learning and immediate processor workshops described above: it was highly content-oriented, emphasized programming, and involved psychologists with little computer experience. It was the most structured of the workshops, although participants still had most of their time free to work at the computer terminals or in small groups.

The agenda was approximately as follows. The first day was spent introducing participants to productions systems as models of children's cognition. This was done by a detailed description of Baylor and Gascon's models of seriation, written in a very simple production system language called BG. The development of the models was traced, beginning with videotape recordings of children of various ages doing a weight seriation task, through how this data was abstracted and summarized, to its simulation as a process model in BG. The simplicity of BG proved a good vehicle for introducing issues of data analysis, simulation, and the nature of production systems. The following day one of participants demonstrated a somewhat unorthodox use of BG concocted overnight to illustrate the arbitrary nature of some of the particular things that had been done with it on the first day. This was followed by a half day lecture on PSG by Al Newell. Subsequent afternoons were spent discussing the work of several of the other participants, including an illustration of alternative ways of analysing videotape protocols by Klaus Witz and a detailed analysis of a production system of David Klahr's written in PSG. As was the pattern in most workshops, discussion gradually shifted to more abstract topics of methodology and philosophy of science.

After participants had had more experience with programming production systems and more tutorial background on a number of specific production systems, some productive substantive group discussions took place. Towards the end of the week there was a discussion on how production systems for weight seriation, representing children at several different levels of development, reflected such classical processes as differentiation-generalization. Participants also analyzed the differences between production systems for simulating older and younger subjects and reasons why the production system for older children appeared to be simplier.

As with the previously discussed workshops a major part of participants' time was spent interacting with programs and writing new programs. Comments received from participants in the final resume seminar indicated that they had benefited from this opportunity for personal involvement with the computer technology. Several people commented that they had come to appreciate how difficult it was to write reasonable simulations (see, however, the comments on the STM workshop concerning the constraints embodied in PSG2). Nearly half of the participants in this workshop had never programmed before, so much effort went into learning the basic skills of working with a computer. The participants comment indicated the workshop succeeded in giving a clear enough idea of production systems so their theoretical utility could be seriously discussed. The on-line experience provided by the workshop appeared to be an important component of this.

C. Conclusions

We have described seven quite different workshops and discussed several issues arising from them. No firm conclusion can be drawn regarding the best workshop style because of differences in individuals, topics, and systems involved in each workshop. Every participant indicated that he or she had benefited from the experience. The nature of the benefit included the important personal contact among scholars as well as the experience with new systems and new approaches to theoretical problems. The availability of computer resources on the premises was mentioned by most participants as a uniquely valuable aspect of the workshops. The extent of interaction with the machine may perhaps be judged by the amount of computer usage. A total of 2120 hours of connect time were logged on the PDP-10 computer by participants and staff in the course of the workshop period. This corresponds to 42 hours per person per workshop. The total computer cost (including systems preparation time and disc storage charges accumulated during the six week period of the workshop) was $90,161 for the PDP-10 and an additional $830 for the Burroughs machine at UCSD. No costs were incurred from the use of the ARPA network since these are borne by ARPA, nor are times available on the use of the MIT or BBN machines since this time was donated to the workshop.

The computer resources used by the workshop between June 17 and July 29 represent 14.3% of all the PDP-10 computer usage during this period. The breakdown of usage by workshop is approximately as follows:

Workshop	Number of users	hrs per user	cost
1. (PAS-II)	7	89	11,066
2. (Concept Attainment)	7	47	3,017
3. (Semantics I)	5	38	1,894
4. (Semantics II)	5	43	2,498
5. (Semantics III)	5	17	1,390
6. (Development)	13	21	3,246
7. (PSG)	6	25	3,265

The above figures are not a reliable indicator of relative usage, however, because of a number of serious confounding factors. For example several of the workshops involved different machines, some workshops evolved a style in which several participants worked together at one terminal, and in a number of cases participants took part in more than one workshop and it was not possible to allocate their time usage to the separate workshops.

Among the positive comments regarding format which were received were ones relating to the small number of participants and durations of workshops. There was also general agreement concerning the importance of on-line interaction with the computer - especially when the system designers were available to explain what was happening.

Among the issues which were discussed was the question of the appropriate amount of time which should optimally be spent learning a new system or programmed theory. Some systems appeared to contain more theoretical psychological ideas than others. On the other hand large systems which are rich in theoretical and technical content could not be thoroughly assimilated in the time available. There appeared to be a plateau in the learning process whose onset differed for different systems. While this problem was discussed several times it was not resolved nor in fact was it clear that students of a new system are always in a good position to judge when they had learned most of the interesting aspects of the system.

In summary, if immediate reports are a guide the workshops must be considered a success. The extent and longevity of the impact, however, remains to be seen. At least in a few cases it appears from early reports that the workshop has precipitated several new directions in research being carried out by participants.

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Appendix A

Summary of Systems Used

PAS-II: A modular system for automotive analysis of verbal protocols. Given a protocal, grammatic and semantic rules and a problem description this system produces an analysis and a Problem Behavior Graph. Described in Waterman and Newell (1973). Also adapted by Hayes for the analysis of problem instructions (Hayes and Simon, 1973).

SNOBOL: A general purpose string processing language. Several programs were written in SNOBOL and are described in Simon and Lea (1973). They include:

GRAIND - a program for grammar induction
CONATT - a program for concept attainment
NEWTRA - a program for sequence extrapolation

SCHOLAR: A large semantically organixed data base and tutor system (described in Carbonell and Collins, 1973; Collins, Carbonell, and Warnock, 1973) which embodies some theoretical ideas relevant to human memory (described in Collins and Quillan, 1972). This is a very large system which was run at BBN through the ARPA net.

MEMOD: Also a large semantic system intended as a model of human memory. It contains an English parser and - in the version we used - a data base specializing in verbs called VERBWORLD. It is described in Rumelhart and Norman, 1973; and LNR Research Group, 1973. This system was run on a Bourroughs computer at UCSD through the ARPA net.

SHRDLU: Also one of the very large systems. It is a program which understands English statements and questions concerning a mini-world of moveable blocks. SHRDLU has been taken by many people to be a model of human language comprehension. An explorable version

of SHRDLU was rewritten to run on the C-MU PDP-10 for the 1972 workshop. It is described in Winograd (1972, in press).

TOPLE: Another very large system for understanding discourse. TOPLE accepts statements in a restricted format and builds up internal belief systems or "rings" by tentatively accepting the entailments of its current interpretation. It can later reconstruct a new belief ring if the "cost" of maintaining one interpretation becomes too high - thus it models the psychological process of accomodation. TOPLE is described in McDermott (1973). It is written in CONNIVER and provides a good illustration of the use of the facilities of this language.

WHATIF*: This is a medium sized system which plays tic-tac-toe (naughts and crosses) and answers questions about the game. It provides a model for the interpretation of conditionals - e.g., "What would you have done had I played 5 when I played 6?" This system was written in POP2 and illustrates certain interesting features of this language (e.g., closure functions). The ideas behind WHATIF are described in Davies and Isard (1972).

SPOUT*: Like WHATIF this is a POP2 program which plays TIC-TAC-TOE and then, on command, describes the game which is in progress or completed. It illustrates the problems involved in constructing a description of a sequence of events in a natural manner. It was written by Tony Davey as part of a dissertation at the University of Edinburgh and a written description is not yet available.

STORY.GEN*: This is a medium sized LISP program which randomly generates stories subject to certain precondition constraints. It illustrates Abelson's (1972) notions about the structure of belief systems.

FARMER.BRN: This is another relatively small language comprehension system which illustrates the handling of logical connectives and quantifiers in representations of language. It was demonstrated as an illustration of the use of facilities of a powerful language called POPLER 1-5 (Davies, 1973).

BG: A production systems interpreter developed primarily for production system models of children's performance in seriation tasks (Baylor and Gascon, 1973).

PSG2: A "theory-laden" language interpreter for production systems of the type introduced in Newell and Simon (1972). Several of the programmed models written in PSG (e.g., for the Sternberg memory scanning task, cryptarithmetic, STM chunking experiments etc) are described in Newell (1972; in press).

IMAGER*: This is a system which simulates the processes underlying a mental imagery task. It is programmed as a set of productions and was developed by Tom Moran from an analysis of several verbal protocals (Moran, 1973).

* These systems did not have official names. They are referred to here by their file names for brevity.

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13. ABSTRACT

A series of seven workshops on information processing psychology were held at CMU in the summer of 1973 under the sponsorship of the Mathematical Social Science Board (MSSB). They followed on a similar workshop held in 1972. The topics were: (1) automatic protocol analysis; (2) concept attainment and rule induction; (3), (4), (5) semantic representation; (6) developmental psychology; (7) short term memory and the immediate processor (production systems). They all involved the interactive exploration of programs that embodied theories in the respective areas. One purpose of the workshops was to discover how intense interactive use of computers can aid in scientific communication. Participants were scientists in cognitive psychology and artificial intelligence.

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