AN EMPIRICAL STUDY OF PLAN-BASED REPRESENTATIONS OF PASCAL AND FORTRAN CODE

Scott P. Robertson
Chiung-Chen Yu

Department of Psychology
Rutgers University
Busch Campus
New Brunswick, NJ 08903

June 1987

Sponsored by:
Perceptual Science Programs
(Code 1142PS)
Office of Naval Research
Contract No. N00014-86-K-0876
Work Unit No. NR 4424203-01

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.
REPRODUCTION IN WHOLE OR IN PART IS PERMITTED FOR ANY
PURPOSE OF THE UNITED STATES GOVERNMENT.
An Empirical Study of Plan-Based Representations of Pascal and Fortran Code

Scott P. Robertson
Chiung-Chen Yu

Cognition and Computing Laboratory
Psychology Dept., Rutgers Univ.-Busch Campus
New Brunswick, NJ 08903

Perceptual Science Programs
Office of Naval Research
Arlington, VA 22217

Software psychology, human computer interaction, program comprehension planning.

The first step in program modification is comprehension. Several researchers have argued recently that programmers utilize a plan-based representation when composing or comprehending program code. In a series of studies we are testing the psychological validity of this proposal and examining the nature of plan-based program representations. Here we report the results of our first study in which programmers segmented code and sorted programs. The segmenting data showed...
that programmers agree on the major components of a program and that these components are defined by goals in a plan representation. Pascal and Fortran programs that employ the same plan structures were segmented into similar components. These components were labelled with similar subgoal descriptions. The majority of subgoals described were abstract, with few being task-specific. Program sorting data also shows clustering into plan groups, however some secondary dimensions, like the type of data used (in Pascal programs), may also be important parts of program representation.
Introduction

How is computer program code conceptually represented, and how do programmers utilize conceptual representations of code in the task of program modification? In a series of experiments, we have set out to explore these questions using a variety of psychological methodologies. Here the first of these experiments is reported.

Several researchers have argued recently that programmers utilize a plan-based representation when composing or comprehending program code (Adelson, 1981; Bonar & Soloway, 1985; Soloway, Bonar & Erlich, 1983; Soloway & Erlich, 1984; Soloway, Ehrlich, Bonar & Greenspan, 1982; Ehrlich & Soloway, 1983; Rist, 1986). Soloway and his colleagues are at the forefront of theory in this area. They have developed a taxonomy of programming plans and plan types. For example, Bonar & Soloway (1985) note that novice programmers bring "step by step knowledge" about how to make choices, iterate, and perform other sequential activities from everyday life into the programming task. They must then acquire "programming knowledge," which consists not only of the syntax and semantics of a programming language, but also the plans, or hierarchically organized sequences of goals and actions that achieve specific tasks.

Some empirical studies of the claim that programmers utilize plans have appeared. Rist (1986), for example, asked novice and expert programmers to group lines of Pascal code that "did the same things" together. Novice and expert
programmers grouped lines on several criteria including "global plans" like initialize, input, calculate, and output, "task-level" plans like sorting wallpaper costs for a specific room or calculating the tax for a particular item, and "syntax", like assignment statements or loop control statements. Interestingly, novices grouped many more lines based on syntax while experts grouped lines based on function.

In this experiment, we explored the way in which expert programmers chunk code by looking at several different programs, including programs in different languages, that utilize the same plans. Previous researchers have tended to focus on plans in individual programs, assuming that the abstract plans are transferable across programs. Also, previous research has almost exclusively dealt with a single language, usually Pascal. If we truly believe that plans are abstract knowledge structures that programmers utilize when they write or read code, then we should be able to demonstrate their common properties across programs and across languages.

Plans are knowledge structures that organize steps in a procedure into chunks. Each chunk achieves a subgoal in the goal hierarchy of a particular task. Program plans organize sections of code into chunks. Task-level plans consist of subgoals that are specified in the task language, to "get an address from a buyer's list" for example. General plans, on the other hand, consist of subgoals that are abstractions
from a specific task, and may in fact apply in several contexts, "iterate in a loop" for example. Programs that perform different tasks but use the same general plans should be chunked the same way. To examine this claim, we asked programmers to segment code from Pascal and Fortran programs and to sort the programs into groups. Within each language group, there were subgroups of programs that utilized the same general plans. A major goal of our initial study was to demonstrate that plan subgroups are recognizable to programmers by showing that programs sharing a plan would be sorted together and by showing that programs sharing a plan would be segmented and described the same way.

A programming language is usually designed to support general plans. Thus, languages contain "loop constructs" but do not contain "compare phone lists" constructs. To the extent that general program plans are abstract from specific tasks, programs that are written in different languages but that utilize the same plan should be recognized as similar. A second goal of this study was to show that Pascal and Fortran programs which used the same plan would be segmented and labelled in the same way.

Method

Subjects. Fifteen Pascal programmers and fifteen Fortran programmers were recruited from the student population at Rutgers University. Most of the Pascal programmers were
graduate students in computer science while most of the Fortran programmers were engineering graduate students. Each subject was paid $8.00 per hour for participation, and most subjects spent 1.5-2.5 hours in the experiment.

Materials. Nine Fortran programs and nine Pascal programs were written for use in this (and subsequent) experiments. All of the programs are debugged, working code. The nine programs in each language group achieved nine different tasks, but they were written in accordance with the three plans shown in Table 1. Within each language group, there were three programs that utilized each of the three plans.

Pascal programs Pas1, Pas2, and Pas3 and Fortran programs For1, For2, and For3 were written in accordance with the first plan in Table 1, the "MGOM" plan. The MGOM plan consisted of five subgoals: 1) declare data structures, 2) display a MENU, 3) GET an input from the menu, 4) perform the OPERATION selected by the input, and 5) return to the MENU state or quit. Programs Pas1 and For1 were data analysis programs, Programs Pas2 and For2 were computer mail programs, and programs Pas3 and For3 emulated an electronic calculator. The texts of these programs appear in Appendix A.

Pascal programs Pas4, Pas5, and Pas6 and Fortran programs For4, For5, and For6 were all written in accordance with the second plan in Table 1, the "RCP" plan. The RCP plan consisted of four subgoals: 1) declare data structures,
2) READ lists from files, 3) COMPARE lists and get common elements, and 4) PRINT the common elements. Programs Pas4 and For4 found common courses in transcripts and printed these as transfer courses, programs Pas5 and For5 compared two schedules and printed possible meeting times, and programs Pas6 and For6 compared two mailing lists and printed common customers. The texts of these programs appear in Appendix B.

Pascal programs Pas7, Pas8, and Pas9 and Fortran programs For7, For8, and For9 were written in accordance with the thir'd plan in Table 1, the "RTRDP" plan. The RTRDP plan consisted of five subgoals: 1) declare data structures, 2) READ and TEST an initial input, 3) display further information and READ new inputs, 4) DO a transaction or calculation, and 5) PRINT the results. Programs Pas7 and For7 emulated a bank teller machine, programs Pas8 and For8 presented a stimulus and collected a reaction time as if for a psychology experiment, and programs Pas9 and For9 controlled a computer login sequence.

Procedure. Subjects were run individually or in small groups. Each subject received a packet containing instructions and the nine programs in either Pascal or Fortran. Subjects were first instructed to draw lines between statements in the code in order to "identify the parts" of the program and to divide each program into "several major sections." Each time a subject drew a segment
Table 1: Components of the three programming plans.

**Plan 1: "MGOM"**

- a. declare data structures.
- b. display a MENU.
- c. GET an input from the menu.
- d. perform the selected OPERATION.
- e. return to the MENU state or quit.

**Instantiations of plan 1**

Data analysis (For1, Pas1).
Computer mail (For2, Pas2).
Electronic calculator (For3, Pas3).

**Plan 2: "RCP"**

- a. declare data structures.
- b. READ lists from files.
- c. COMPARE lists and get common elements.
- d. PRINT the common elements.

**Instantiations of plan 2**

Course transfer (For4, Pas4).
Schedules (For5, Pas5).
Mailing lists (For6, Pas6).
Table 1. (cont.)

Plan 3: "RTRDP"

a. declare data structures.
b. READ and TEST an initial input.
c. display further information and READ new input.
d. DO a transaction or calculation.
e. PRINT the results.

Instantiations of plan 3

Computer login sequence (For7, Pas7).
Stimulus-response psychology experiment (For8, Pas8).
Bank teller (For9, Pas9).
line it was numbered in order. After segmenting the major sections of a program the subjects were instructed to write a descriptive label for each major section "in terms of the program's task." For each program, after segmenting and labelling the major sections, the subjects were instructed to draw segment lines within the major sections to identify subsections. Finally, subjects were asked to sort the programs into groups. The subjects were told that programs belonged in a group if they "work the same way." Subjects were allowed to form as many groups as they wished but they could not leave a single program in a group by itself nor could they put all of the programs together into a single group.

Results

Subject Programming Experience. Subjects in both the Pascal and Fortran groups had an average of 3.6 years of programming experience. However, subjects in the Pascal group reported having worked with more programming languages (a mean of 5.8 languages) than subjects in the Fortran group (a mean of 2.8 languages), t(27)=4.59, p<.001.

Segmenting. Each subject drew line segments in the code of nine programs. We predicted that line segments would be drawn at plan boundaries. For each program, we calculated the frequency of line segments drawn after each line. If 60% or more of the subjects segmented a program at a
Table 2. Frequencies of segmenting by 60% or more of the subjects at predicted and not predicted positions in the Pascal programs.

<table>
<thead>
<tr>
<th></th>
<th>Segmenting predicted</th>
<th>Segmenting not predicted</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Observed</td>
<td>Observed</td>
</tr>
<tr>
<td>Pas1</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Pas2</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Pas3</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Pas4</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Pas5</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Pas6</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Pas7</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Pas8</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Pas9</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>

Pascal Totals 29 7 0 458
Table 3. Frequencies of segmenting by 60% or more of the subjects at predicted and not predicted positions in the Fortran programs.

<table>
<thead>
<tr>
<th>Segmenting</th>
<th>Not</th>
<th>Not</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Observed</td>
<td>Observed</td>
</tr>
<tr>
<td>For1</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>For2</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>For3</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>For4</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>For5</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>For6</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>For7</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>For8</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>For9</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fortran</th>
<th>Totals</th>
<th>5</th>
<th>3</th>
<th>403</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
particular line, we considered that line an important chunk boundary. Important chunk boundaries should correspond to the predicted plan boundaries.

Tables 2 and 3 show the frequencies of important chunk boundaries (those that were segmented by 60% or more of the subjects) at predicted and not-predicted locations for the nine Pascal programs and the nine Fortran programs respectively. Chi-squares on the frequencies for all programs were significant, ranging from $x^2(1)=24$, $p<.05$ for Pas6 to $x^2(1)=78$, $p<.001$ for Pas5. Twenty-nine out of 36 (81%) of the plan boundaries in the Pascal programs were segmented according to our criterion. Thirty-one out of 36 (86%) of the plan boundaries in the Fortran programs were segmented according to our criterion. None of the 458 non-boundary lines were segmented in the Pascal programs, and only 3 out of 406 (0.7%) non-boundary lines were segmented in the Fortran programs.

Modal Labels of Program Segments. After segmenting the programs, the subjects labelled each section with a description of its function. We were concerned with whether these descriptions corresponded with the subgoals that we claim control each chunk. Tables 4, 5, and 6 show the modal descriptive labels that subjects gave to each chunk of each program in the MGOM, RCP, and RTRDP plan groups respectively. Included in this list are labels that were given to major chunks, those which were identified by a
Table 4. Modal descriptive labels for plan components in Pascal and Fortran programs using the MGOM plan.

**Data analysis**

<table>
<thead>
<tr>
<th>Pascal</th>
<th>Fortran</th>
</tr>
</thead>
<tbody>
<tr>
<td>Declare.</td>
<td>Declare.</td>
</tr>
<tr>
<td>Print instruction.</td>
<td>Display menu.</td>
</tr>
<tr>
<td>Get number.</td>
<td>Read key.</td>
</tr>
<tr>
<td>Compute means.</td>
<td>Calculate mean and update result.</td>
</tr>
</tbody>
</table>

**Computer Mail**

<table>
<thead>
<tr>
<th>Pascal</th>
<th>Fortran</th>
</tr>
</thead>
<tbody>
<tr>
<td>Declare variable.</td>
<td>Declare.</td>
</tr>
<tr>
<td>Print instruction.</td>
<td>Print our menu.</td>
</tr>
<tr>
<td>Process message.</td>
<td>Get input and print message.</td>
</tr>
<tr>
<td>Quit.</td>
<td>Check if end.</td>
</tr>
</tbody>
</table>

**Electronic Calculator**

<table>
<thead>
<tr>
<th>Pascal</th>
<th>Fortran</th>
</tr>
</thead>
<tbody>
<tr>
<td>Declare.</td>
<td>Declare.</td>
</tr>
<tr>
<td>Print Menu.</td>
<td>Print out menu.</td>
</tr>
<tr>
<td>Read in value and allow choice.</td>
<td>---</td>
</tr>
<tr>
<td>Do calculation.</td>
<td>Calculate.</td>
</tr>
<tr>
<td>---</td>
<td>Continue or end.</td>
</tr>
</tbody>
</table>
Table 5. Modal descriptive labels for plan components in Pascal and Fortran programs using the RCP plan.

**Course transfer**

<table>
<thead>
<tr>
<th>Pas4</th>
<th>For4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Declare.</td>
<td>Define variables.</td>
</tr>
<tr>
<td>Read file.</td>
<td>Read data file.</td>
</tr>
<tr>
<td>If same then transfer.</td>
<td>Compare data.</td>
</tr>
<tr>
<td>Output results.</td>
<td>Print results.</td>
</tr>
</tbody>
</table>

**Schedules**

<table>
<thead>
<tr>
<th>Pas5</th>
<th>For5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Declare.</td>
<td>Declare.</td>
</tr>
<tr>
<td>Read file.</td>
<td>Read files.</td>
</tr>
<tr>
<td>Compare lists.</td>
<td>Compare.</td>
</tr>
<tr>
<td>Print result.</td>
<td>Print out.</td>
</tr>
</tbody>
</table>

**Mailing Lists**

<table>
<thead>
<tr>
<th>Pas6</th>
<th>For6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Declare.</td>
<td>Declare.</td>
</tr>
<tr>
<td>Read data.</td>
<td>Read data file.</td>
</tr>
<tr>
<td>Compare lists.</td>
<td>Compare data.</td>
</tr>
<tr>
<td>Print result.</td>
<td>Print out.</td>
</tr>
</tbody>
</table>
Table 6. Modal descriptive labels for plan components in Pascal and Fortran programs using the RTRDP plan.

**Bank teller machine**

<table>
<thead>
<tr>
<th>Pascal</th>
<th>Fortran</th>
</tr>
</thead>
<tbody>
<tr>
<td>Declare.</td>
<td>Declare.</td>
</tr>
<tr>
<td>Check password.</td>
<td>Read data.</td>
</tr>
<tr>
<td>Display options.</td>
<td>Print menu.</td>
</tr>
<tr>
<td>Print account.</td>
<td>Decrement account and print result.</td>
</tr>
</tbody>
</table>

**Psychology experiment**

<table>
<thead>
<tr>
<th>Pascal</th>
<th>Fortran</th>
</tr>
</thead>
<tbody>
<tr>
<td>Declare.</td>
<td>Declare.</td>
</tr>
<tr>
<td>Initialize variable.</td>
<td>Give instruction.</td>
</tr>
<tr>
<td>Print out message and receive response.</td>
<td>Get response and update count.</td>
</tr>
<tr>
<td>Calculate percentage and print result.</td>
<td>Output result.</td>
</tr>
</tbody>
</table>

**Computer login sequence**

<table>
<thead>
<tr>
<th>Pascal</th>
<th>Fortran</th>
</tr>
</thead>
<tbody>
<tr>
<td>Declare.</td>
<td>Declare.</td>
</tr>
<tr>
<td>Print account.</td>
<td>Check input.</td>
</tr>
<tr>
<td>Do transaction.</td>
<td>Choose.</td>
</tr>
<tr>
<td>Print result.</td>
<td>Print result.</td>
</tr>
</tbody>
</table>
segment line drawn by 60% or more of the subjects. Each label listed is the most frequent of the set of labels given to that chunk (the experimenters judged paraphrases and close matches in wording to be the same label).

In glancing over these lists, note that descriptions of the Pascal and Fortran programs which did exactly the same thing (e.g. Pas1 and For1, Pas2 and For2, Pas3 and For3, etc.) sound very similar. Also, the six programs within a plan group also sound similar.

Almost all of the labels are abstract, describing general computational functions such as "declare variables," "read data file," "display menu," "calculate," and "print results." Only a few labels are task specific, namely "compute means" and "calculate means" in Pas1 and For1 respectively, "if same then transfer" in Pas4, "check password" in Pas7, "decrement account" in For7, "calculate percentage" in Pas8, and "print account" in Pas9.

**Descriptions of the plan chunks.** Table 7 shows the major chunks of each plan and indicates whether or not 60% or more of the subjects provided an appropriate descriptive label for each chunk in each of the six programs. Subjects provided appropriate descriptions for all of the chunks in all of the instances of the RCP plan. This was the most successful set of programs in terms of matching label data to a plan.
Table 7. Production of appropriate descriptions for plan components. "Yes" indicates that 60% or more of the subjects provided an appropriate description.

<table>
<thead>
<tr>
<th>MGOM Plan</th>
<th>Pas1</th>
<th>Pas2</th>
<th>Pas3</th>
<th>For1</th>
<th>For2</th>
<th>For3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Declare data structure.</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Display menu/instruct.</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Get/read input.</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Calculate/compute.</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Quit.1</td>
<td>no</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RCP Plan</th>
<th>Pas4</th>
<th>Pas5</th>
<th>Pas6</th>
<th>For4</th>
<th>For5</th>
<th>For6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Declare data structure.</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Read files.</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Compare lists.</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Print results.</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RTRDP Plan</th>
<th>Pas7</th>
<th>Pas8</th>
<th>Pas9</th>
<th>For7</th>
<th>For8</th>
<th>For9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Declare data structure.</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Test/initialize inputs.</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Display instr./read inp.</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Do transaction.</td>
<td>no</td>
<td>yes2</td>
<td>yes</td>
<td>yes2</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Print results.</td>
<td>yes</td>
<td>yes2</td>
<td>yes</td>
<td>yes2</td>
<td>yes</td>
<td>yes</td>
</tr>
</tbody>
</table>

1 "Quit" was an unexpected label, see text for a discussion.

2 These components were described together in one label.
For the KGOM plan, a majority of the subjects provided descriptions for the first two chunks, "Declare data structure" and "Display Menu/Instructions," in each program. Fewer than our 60% criterion provided a label for the "Get/Read Input" chunk in Pas2, but this chunk was included in descriptions of all the other programs. The final chunk, "Calculate/Compute", was included in descriptions of all the Pascal programs and For1, but not For2 and For3. Apparently many subjects felt that getting input and performing a computation were part of the same chunk in these latter two programs. Finally, subjects included an unexpected chunk, which they labelled "Quit," in Pas2, For2 and For3. This chunk is branched to when the "Quit" option is chosen in the "Get Input" part of the program.

For the RTRDP plan, descriptions were provided by a majority of subjects for all of the plan chunks in Pas8 and For7. In Pas9 and For8 the second chunk, "Test/Initialize Inputs" did not meet the 60% criterion and in those cases the chunk was included as part of the "Display Instructions/Read Input" subgoal. In For9, the "Display Instructions/Read Input" and "Test/Initialize Inputs" chunks were also combined, but described as "Check/Initialize Inputs." Finally, "Do Transaction" and "Print Results" were described as separate chunks in Pas9, For8 and For9, but were described together in Pas8 and For7. "Do Transaction" did not meet the 60% criterion in Pas7.
Table 8. Stress values for 1-3 dimensional solutions to multidimensional scaling of Pascal and Fortran program sorting data.

<table>
<thead>
<tr>
<th>Dimensionality</th>
<th>Pascal</th>
<th>Fortran</th>
</tr>
</thead>
<tbody>
<tr>
<td>One</td>
<td>.196</td>
<td>.124</td>
</tr>
<tr>
<td>Two</td>
<td>.002</td>
<td>.000</td>
</tr>
<tr>
<td>Three</td>
<td>.000</td>
<td>.000</td>
</tr>
</tbody>
</table>
Program Sorting. After segmenting and labelling, the programmers were asked to sort the programs into groups according to "the way they work." They were instructed to sort the programs into as many groups as they wished with the constraints that no program could be left by itself and all the programs must not be sorted together into a single group.

Multi-dimensional scaling (MDS) was used to determine if the Pascal and Fortran programs were sorted into three distinct plan groups. For each language group, the input to the MDS algorithm was a matrix of the frequencies with which each program was sorted with each of the other programs. Use of the frequency data is based on the assumption that programs which are more similar will be sorted together more frequently. Separate MDS analyses were performed on the Pascal and the Fortran data. The strongest prediction is that a one-dimensional solution will fit both data sets well and that the plot of the stimulus coordinates will show three clusters based on the plan groups.

Table 8 shows the "stress" values for one, two, and three-dimensional MDS solutions for both the Pascal and the Fortran data. Lower stress values indicate a good fit to the data, and values below .15 are considered to be good fits (Kruskal & Wish, 1978). On these criteria, the one dimensional solution fits the Fortran data very well and the Pascal data fairly well. A two dimensional solution
Figure 1. Plots of the stimulus coordinates for one-dimensional solutions to MDS of Pascal (A) and Fortran (B) program sorting data.
completely explains the distributions of data for both the Fortran programs (although Kruskal & Wish, 1978 suggest that a one-dimensional solution with stress below .15 is adequate) and the Pascal programs.

Figure 1 presents one-dimensional plots of the stimulus coordinates for Pascal (Figure 1A) and Fortran (Figure 1B) program sorts. Note that three clusters are present in both plots. One cluster contains a tight distribution of Pas1, Pas2, and Pas3 in Figure 1A and For1, For2, and For3 in Figure 1B, all members of the MGOM plan group. Another cluster contains a tight distribution of Pas4, Pas5, and Pas6 in Figure 1A and For4, For5, and For6 in Figure 1B, all members of the RCP plan group. A third cluster contains Pas7 and Pas9 in Figure 1A and For7, For8, and For9 in Figure 1B, all members of the RTRDP plan group. Note that Pas8, which should be in the RTRDP plan group, is near the members of the MGOM group. This program was the "psychology experiment" program which presents stimuli, collects reaction times, and writes means to a file. Many subjects commented that they did not really understand this program. Several subject said that they sorted it with the MGOM programs because they perform numerical calculations. Pas1 and For1, in fact, calculate means and therefore share a task with Pas8 and For8. When subjects did not understand the structure of the program, they sorted on this common task feature.
Figure 2. Plots of the stimulus coordinates for two-dimensional solutions to MDS of Pascal program sorting data.
Figure 3. Plots of the stimulus coordinations for two-dimensional solutions to MDS of Fortran program sorting data.
Figures 2 and 3 present the two-dimensional plots of the stimulus coordinates for Pascal and Fortran program sorts respectively. We have circled the original plan groups in these two figures, and drawn a line to separate Pas7 and Pas9 from the other programs in Figure 2 and For7 and For9 from the other programs in Figure 3. Addition of the second dimension seems to draw these two programs away from the rest in both language groups. In looking at the descriptions that subjects gave and the contents of the programs themselves, we conclude that these programs (one is the bank teller program and the other is the login program) are distinctive since they both contain requests for passwords and require a test of the passwords before continuing.

Finally, hierarchical clustering (Johnson, 1967) is often used with sorting data to show group structure. Figure 4 shows hierarchical clustering of the sorting data for the Pascal (Figure 4a) and Fortran (Figure 4b) programs. Highly dissimilar items, indicated by infrequent sorts into the same group, cause branching high in the tree structures. More similar items cause branching lower in the trees.

For the Pascal programs (Figure 4a), the highest branching creates two groups. One group contains Pas4, Pas5, and Pas6 while the remaining programs are in the second group. Pas4, Pas5, and Pas6 are all members of the RCP plan group, programs which handle non-numerical information. The remaining programs all handle numerical information. Thus,
Figure 4. Hierarchical clustering of Pascal (A) and Fortran (B) program sorting data.
an important dimension for the Pascal code may be the type of data that is handled. Among the Pascal programs that handle numerical data, two more clusters emerge high in the tree. One cluster contains Pas7 and Pas9, both members of the RTRDP plan group and the two programs which check passwords. In the other cluster are Pas1, Pas2, and Pas3, all members of the MGOM plan group, and the deviant program, Pas8. The three clusters (Pas4-Pas5-Pas6, Pas5-Pas9, and Pas1-Pas2-Pas3-Pas8) do not begin to break up until much lower in the tree, suggesting that they form three important clusters which (with the exception of Pas8) correspond to the three plan groups examined in this experiment.

For the Fortran programs (Figure 4b), a similar, but not exactly equivalent picture emerges from hierarchical clustering. At the highest branching level, For7 and For9, the password programs in the RTRDP plan group, form a cluster distinct from the other programs. At the second branching level, which is still very high, For4, For5, and For6, the non-numerical RCP programs, form a cluster distinct from For1, For2, and For3, all members of the MGOM plan group, and the deviant For8. At this point, the hierarchical structure of the Pascal and Fortran programs looks very similar. Unlike Pas8 in the Pascal programs, For8 breaks away from the For1-For2-For3 cluster at a high level. This leaves three plan clusters in the Fortran data (For4-For5-For6, For7-For9, and For1-For2-For3) that remain together until low in the tree and that correspond to the
three plan groups examined in this experiment. For8 is not cleanly in any cluster.

Discussion

In this experiment subjects segmented and labelled sections of several programs and then sorted the programs into groups. The positions of segmenting lines in the programs was consistent with the predicted positions of plan chunks for both Pascal and Fortran programs written in accordance with three plans. The labels that subjects gave to these chunks were similar within plan groups, even across Pascal and Fortran language groups. A majority of subjects (60% or more) provided labels that reflected the major subgoals that plan components achieved for most of the plan chunks in the programs. Examination of the modal labels for plan chunks shows both abstract descriptions (e.g. "print results") and more task specific descriptions (e.g. "compute means"), however the bulk of the descriptions are abstract. In those cases where a majority of subjects did not provide a chunk label, we must assume that they perceived two subgoals as being combined. This occurred most often when the subgoals were "Calculate" and "Print." In some cases where programs either performed a calculation and returned to a menu or quit, subjects described the "Quit" subgoal as separate from the "Calculate" subgoal.

Sorting data for both the Pascal and Fortran programs shows that they cluster into plan groups. This suggests
that subjects perceive the abstract plan structure common to all of the programs within a plan cluster and use it as a basis for classifying the programs. A secondary classification criterion is based on common features. In one case, when the structure of a program was not clear to subjects, they based their sorting judgment on the fact that other programs calculated means. When a second dimension is examined, subjects appeared to be sorting on a task-specific feature, namely whether or not a program had password checking. For Pascal programs, the data type was an important feature for distinguishing programs.

We conclude from this data that programmers consider both general plan information that is common to many tasks and task-specific program constructs when comprehending code. The similarity of labels for both Pascal and Fortran data suggests that some general programming plans are common across languages. In future studies, we expect to examine this issue more carefully. Pilot data on sorting of descriptions of these Pascal and Fortran programs suggests that language information is not present in the abstract representations that are used to label the programs.

Finally, we should note that although the data, especially the sorting data, provides good evidence for abstract plan structures, we were not able to generate perfect stimuli. One of the programs was unexpectedly sorted into a different plan group, apparently on the basis of non-plan related criteria. This suggests a practical
recommendation that all complex stimuli to be used in studies of programmers and their tasks should be empirically validated on the constructs that the experimenters feel are important. The deviant program also brings up a theoretical question. How are different types of knowledge, like general plan knowledge, task-specific knowledge, and knowledge of language constructs related and used together to reason about code? In future studies (using these materials, by the way) we will examine some of these questions.
Acknowledgements

Our thanks to Dr. John O’Hare as the principal advocate and critic of this research program and to the Office of Naval Research for their generous support. We are also grateful to David Koizumi for his assistance in the MDS and clustering analyses.
References


Appendix A. Texts of Pascal and Fortran programs that belong to the "MGOM" plan group (6 pages).
PROGRAM Pasi(input,output);( 10/03/'86
CONST
  No = 5;
VAR
  I,J,T,Intrvl,Temp,ERR,NoKey,Num : integer;
  Result : array [1..No] of real;
  Key : string [4];
BEGIN
  for I := 1 to 6 do writeln;
  writeln ('********** MANUAL **********');
  writeln;' 'NUM LOCK : press it before using');
  writeln ('
B or b : press it to begin processing');
  writeln ('
BACKSPACE : press it to backspace');
  writeln ('
ENTER : press it after keying');
  writeln ('
"=" : press it for mean of single');
  writeln ('
group');
  writeln ('
E or e : press it to end one task');
  writeln ('
C or c : press it to clear screen');
  writeln ('
and continue');
  writeln ('
and q : press it to quit');
  read (Key);
  if (Key = 'B') or (Key = 'b') then
  begin
    writeln.writeln.writeln;
    write (' How many groups do you want to analyze ? ');
    read(Num)
  end;
  Key:='c';
  repeat
    J := 0;
    if (Key = 'C') or (Key = 'c') then clrscr;
    for I := 1 to 6 do writeln;
    for I := 1 to Num do Result[I] := 0;
    repeat
      I := 0;
      J := J + 1;
      Temp := J;
      read(Key);
      write ('');
      I := I + 1;
      T := I;
      val(Key,NoKey,ERR);
      Result[J] := Result[J] + NoKey;
      until (Key = "=") or (Key = 'E') or (Key = 'e');
    if (Key <> 'E') and (Key <> 'e') then
    begin
      Result[J] := Result[J] /(T-1);
      writeln ("=" MEAN : ',Result[J],',',',J,'');
    end
    until (Key = 'E') or (Key = 'e');
    writeln;'write writeln;
    writeln ("*** Q or q for QUIT, C or c for Starting again ***");
    read(Key)
    until (Key = 'Q') or (Key = 'q')
END.
C*** PROGRAM FORTRANI (11/12/’86)
INTEGER I,J,T,TEMP,NUM,NOKEY
REAL RESULT
CHARACTER*4 KEY
DIMENSION RESULT(5)
WRITE(*,10)
FORMAT(///
WRITE(*,*) '*** MANUL ***'
WRITE(*,*)'NUM LOCK : PRESS IT BEFORE USING'
WRITE(*,*)'[B]' : TO BEGIN'
WRITE(*,*)'[BS]' : BACKSPACE'
WRITE(*,*)'ENTER : PRESS IT AFTER KEYING'
WRITE(*,*)'=[I]' : TO GET ONE MEAN'
WRITE(*,*)'[E]' : END ONE TASK AND START'
WRITE(*,*)'[Q]' : QUIT'
READ(*,20) KEY
20 FORMAT(A)
50 IF (KEY.EQ.'B') THEN
   WRITE(*,*)'* HOW MANY GROUPS YOU WANT ANALYSE ?'
   READ(*,NUM)
ENDIF
IF (KEY.NE.'Q') THEN
   DO 150 I=T,NUM
      RESULT(I)=0
   150 CONTINUE
   J=0
   IF (KEY.NE.'E') THEN
      200 I=0
      J=J+1
   300 READ(*,20) KEY
   IF((KEY.NE.'=').AND.(KEY.NE.'E').AND.(KEY.NE.'Q')) THEN
      NOKEY=ICHAR(KEY)-48
      I=I+1
      RESULT(J)=RESULT(J)+NOKEY
      GOTO 300
   ELSEIF (KEY.EQ.'=') THEN
      RESULT(J)=RESULT(J)/I
      WRITE(*,*)'==) MEAN :'
      WRITE(*,RESULT(J))
      GOTO 200
   ELSEIF (KEY.EQ.'E') THEN
      KEY='B'
      GOTO 50
   ENDIF
END
ENDIF
END
STOP
END
PROGRAM Pas2(input, output); (10/13/'86)

VAR
    I : integer;
    KeyStr : string [40];
    KeyPath : string [15];
    Key : char;
BEGIN
    for I := 1 to 6 do writeln;
    writeln(' ****************** MANUAL ******************');
    writeln('Mail : to enter massage');
    writeln('ENTER : press it after completing');
    writeln('BACKSPACE : press it to backspace');
    writeln('Erase : to erase massage');
    writeln('From : from whom');
    writeln('To : to whom');
    writeln('Next : done and for next message');
    writeln('Quit : done and quit');
    read(Key);
    clrscr;
    while Key in ['M', 'm', 'E', 'e'] do begin
        for I := 1 to 10 do writeln;
        write(' '); read(Key);
        write(': '); readln(KeyStr); writeln;
        write(' '); read(Key);
        if not (Key in ['E', 'e']) then begin
            writeln(KeyPath);
            read(KeyPath);
            writeln(KeyPath);
            read(Key);
        end;
        if Key in ['N', 'n']) and (not (Key in ['e', 'E'])) then begin
            Key := 'm';
            clrscr;
        end;
    end;
    if Key in ['Q', 'q'] then begin
        writeln; writeln;
        writeln('------- ALL JOBS DONE, BYE ! -------');
    end
END.
** Program FORTRAN2 (11/5/’86) 

```fortran
INTEGER I
CHARACTER KEY
CHARACTER*15 KEYSTR, KEYPATH
J=0
WRITE(*,10)
10 FORMAT(////////)
WRITE(*,*)'***** MANUL *****'
WRITE(*,20)
20 FORMAT(//)
WRITE(*,*)' [M]AIL :
ENTER MASSAGE'
WRITE(*,*)' [E]NTER :
END OF MASSAGE'
WRITE(*,*)' [BACKSPACE] :
BACKSPACE'
WRITE(*,*)' [E]RASE :
ERASE MASSAGE'
WRITE(*,*)' [F]ROM :
FROM WHOM'
WRITE(*,*)' [T]O :
TO WHOM'
WRITE(*,*)' [N]EXT :
DONE, FOR NEXT'
WRITE(*,*)' [Q]UIT :
DONE AND QUIT'
READ(*,30) KEY
30 FORMAT(A)
100 IF ((KEY .EQ. 'M') .OR. (KEY .EQ. 'E')) THEN
   WRITE(*,*)' '*
   READ(*,30) KEYSTR
110 READ(*,30) KEY
   IF (KEY .EQ. 'E') GOTO 100
   IF (KEY .NE. 'F') THEN
      GOTO 110
   ELSE
      WRITE(*,*)' FROM :
      READ(*,30) KEYPATH
   ENDIF
120 READ(*,30) KEY
   IF (KEY .EQ. 'E') GOTO 100
   IF (KEY .NE. 'T') THEN
      GOTO 120
   ELSE
      WRITE(*,*)' TO :
      READ(*,30) KEYPATH
   ENDIF
ENDIF
READ(*,30) KEY
IF (KEY .EQ. 'N') THEN
   KEY='M'
   GOTO 100
ELSEIF (KEY .EQ. 'Q') THEN
   WRITE(*,*)'!! JOBS DONE, BYE !!'
ENDIF
STOP
END
```
PROGRAM Pas3(input,output);(09/26/'86)
VAR
  I : integer;
  NoKey,Result : real;
  Key : char;
BEGIN
  for I := 1 to 6 do writeln;
  writeln ('********** MANUAL **********');
  writeln; writeln;
  writeln ('NUM LOCK : press it before using');
  writeln ('B or b : press it to begin computing');
  writeln ('ENTER : press it after keying');
  writeln ('C or c : press it to clear screen');
  writeln ('and continue');
  writeln ('Q or q : press it to quit');
  read (Key);
  if (Key = 'B') or (Key = 'b') then Key := 'c';
  repeat
    if (Key = 'C') or (Key = 'c') then clrscr;
    Result:=0;
    Key:='+';
    repeat
      read(NoKey);
      case Key of
        '+' : Result:=Result+NoKey;
        '-' : Result:=Result-NoKey;
        '*' : Result:=Result*Nokey;
        '/' : Result:=Result/NoKey
      end;
      read(Key)
    until Key = '=';
    writeln(Result);
    read(Key)
  until (Key = 'q') or (Key = 'Q')
END.
C*** PROGRAM FORTRAN3(10/27/'86)

INTEGER I, NUM
REAL NOKEY, RESULT
CHARACTER KEY

NUM=10
WRITE(*,10)
10 FORMAT(//)
WRITE(*,*) '**** MANUAL ****'
WRITE(*,*)
20 FORMAT(//)
WRITE(*,*) 'NUM LOCK : PRESS IT BEFORE USING'
WRITE(*,*) ( B ) : TO BEGIN COMPUTING'
WRITE(*,*) 'ENTER : END OF SINGLE DATA'
WRITE(*,*) [ C ] : GO ON NEXT TASK'
WRITE(*,*) [ Q ] : QUIT'
READ(*,100) KEY
100 FORMAT(A)

200 IF ((KEY .EQ. 'B') .OR. (KEY .EQ. 'C')) THEN
    WRITE(*,*) 'HERE WE BEGIN....'
    RESULT=0
    KEY=''
ELSEIF (KEY .EQ. ') THEN
    RESULT=RESULT+NOKEY
ELSEIF (KEY .EQ. ') THEN
    RESULT=RESULT-NOKEY
ELSEIF (KEY .EQ. ') THEN
    RESULT=RESULT*NOKEY
ELSEIF (KEY .EQ. ') THEN
    RESULT=RESULT/NOKEY
ENDIF
READ(*,100) KEY
IF ((KEY .NE. 'C') .AND. (KEY .NE. 'Q')) GOTO 650
IF (KEY .EQ. ') THEN
    GOTO 600
ELSE
    GOTO 300
ENDIF
500 CONTINUE
ENDIF
600 WRITE(*,610) RESULT
610 FORMAT(F10.3)
650 READ(*,100) KEY
IF ((KEY .NE. 'C') .AND. (KEY .NE. 'Q')) GOTO 650
IF (KEY .EQ. 'C') THEN
    GOTO 200
ELSE
    WRITE(*,*) '**** THANK ****'
ENDIF
STOP
END
Appendix B. Texts of Pascal and Fortran programs that belong to the "RCP" plan group (6 pages).
PROGRAM Pas4; (10/08/'86)

TYPE
  Word = string [15];
  Coursetype = record
    Course : Word;
    Crts : Integer
  end;

CONST
  N1 = 2;
  N2 = 3;

VAR
  I, J, K, Ctr : Integer;
  SUNY, Transf : array[1..N1] of Coursetype;
  MIT : array[1..N2] of Coursetype;
  Data1, Data2: text;

BEGIN
  Ctr := 0;
  assign(Data1, 'data1.3');
  reset(Data1);
  for I := 1 to N1 do readln(Data1, SUNY[I].Course, SUNY[I].Crts);
  close(Data1);
  assign(Data2, 'data2.3');
  reset(Data2);
  for J := 1 to N2 do readln(Data2, MIT[J].Course, MIT[J].Crts);
  close(Data2);
  for I := 1 to N1 do
    begin
      for J := 1 to N2 do
        begin
          if (SUNY[I].Crts) = MIT[J].Crts) and (SUNY[I].Course = MIT[J].Course) then
            begin
              Ctr := Ctr + 1;
              with Transf[Ctr] do begin
                Course := SUNY[I].Course;
                Crts := MIT[I].Crts
              end
            end
        end;
    end;
  for I := 1 to 8 do writeln;
  writeln(' *** COURSES CAN BE TRANSFERED ***');
  writeln; writeln;
  for I := 1 to Ctr do begin
    with Transf[I] do begin
      writeln(' * ',I:3,' ',Course:15,Crts:5)
    end;
  end;
  writeln; writeln(' ***** ------------ END ------------ *****');
END.
C*** PROGRAM FORTRAN4 (11/6/ '86)

INTEGER I,J,K,C,CRT1,CRT2,CRT
CHARACTER*15 SUNY,MIT,TRANSF
DIMENSION CRT1(5),CRT2(5),CRT(5)
DIMENSION SUNY(5),MIT(5),TRANSF(5)
C=0
OPEN(20,FILE='DATA1.3')
OPEN(21,FILE='DATA2.3')
10 FORMAT(A)
20 FORMAT(I2)
DO 100 I=1,5
READ(20,10) SUNY(I)
READ(20,20) CRT1(I)
100 CONTINUE
DO 200 J=1,5
READ(21,10) MIT(J)
READ(21,20) CRT2(J)
200 CONTINUE
DO 400 I=1,5
DO 400 J=1,5
IF (SUNY(I).NE.MIT(J)) GOTO 400
IF (CRT1(I).LT.CRT2(J)) GOTO 400
C=C+1
CRT(C)=CRT2(J)
TRANSF(C)=MIT(I)
400 CONTINUE
WRITE(*, 410)
410 FORMAT(///)
WRITE(*,'**** COURSES CAN BE TRANSFERED ****')
WRITE(*,'COURSE CREDITS')
DO 500 I=1,C
WRITE(*,420) TRANSF(I),CRT(I)
420 FORMAT(A,' ',I2)
500 CONTINUE
WRITE(*,'************** END **************')
STOP
END
PROGRAM Pas5; (10/01/'86)

TYPE
  WeekDay = (Mon, Tue, Wen, Thu, Fri);
  Schedule = record
    Morning : char;
    Noon     : char;
    Afternoon: char
  end;

  I, OrdDay : integer;
  Lori, Bruce, ComTime : array (Mon..Fri) of Schedule;
  Day : WeekDay;
  Data1, Data2 : text;

BEGIN
  assign(Data1,'data1');
  reset(Data1);
  for Day:=Mon to Fri do
    with Lori[Day] do readln(Data1,Morning, Noon, Afternoon);
  close(Data1);
  assign(Data2,'data2');
  reset(Data2);
  for Day:=Mon to Fri do
    with Bruce[Day] do readln(Data2,Morning, Noon, Afternoon);
  close(Data2);
  for Day:=Mon to Fri do begin
    with Lori[Day] do begin
      if (Morning = Bruce[Day].Morning) and (Morning = '*')
        then ComTime[Day].Morning := '*'
      else ComTime[Day].Morning := '-';
      if (Noon = Bruce[Day].Noon) and (Noon = '*')
        then ComTime[Day].Noon := '*'
      else ComTime[Day].Noon := '-';
      if (Afternoon = Bruce[Day].Afternoon) and (Afternoon = '*')
        then ComTime[Day].Afternoon := '*'
      else ComTime[Day].Afternoon := '-';
    end
  end;
  for I:=1 to 8 do writeln;
  writeln('***** THE COMMON SCHEDULE *****');
  writeln; writeln;
  writeln('',' Morning Noon Afternoon');
  for Day:=Mon to Fri do begin
    OrdDay:=ord(Day)+1;
    write('','*',' OrdDay',
    with ComTime[Day] do writeln(Morning:6, Noon:12, Afternoon:13)
  end
END.
*** PROGRAM FORTRAN5 (31/10/'86)

INTEGER I,J,ORDAY,DAY
CHARACTER LORI,BRUCE,COMTIME
DIMENSION LORI(5,3),BRUCE(5,3),COMTIME(5,3)
OPEN(20,FILE='DATA1')
OPEN(21,FILE='DATA2')
10 FORMAT(A)
DO 100 I=1,5
DO 100 J=1,3
READ(20,10) LORI(I,J)
READ(21,10) BRUCE(I,J)
100 CONTINUE
DO 200 I=1,5
DO 200 J=1,3
IF((LORI(I,J).EQ.BRUCE(I,J)).AND.(LORI(I,J).EQ.'*')) THEN
   COMTIME(I,J)='*
ELSE
   COMTIME(I,J)='-'
ENDIF
200 CONTINUE
WRITE(*, 300)
300 FORMAT(//////)
DO 500 I=1,5
WRITE(*,*) I
WRITE(*,*) COMTIME(I,1),COMTIME(I,2),COMTIME(I,3)
500 CONTINUE
STOP
END
PROGRAM Pas6;(09/24/'86)

TYPE
   Word=string[15];
   Psnfl=record
      Name:Word;
      Tele:Word
   end;

CONST
   N1=2;
   N2=3;

VAR
   I,J,K,Ctr:integer;
   JJ,CoList:array[1..N1] of Psnfl;
   ATT:array[1..N2] of Psnfl;
   Data1,Data2:text;

BEGIN
   Ctr:=0;
   assign(Data1,'data1');
   reset(Data1);
   for I:=1 to N1 do readln(Data1, JJ[I].Name, JJ[I].Tele);
   close(Data1);
   assign(Data2,'data2');
   reset(Data2);
   for J:=1 to N2 do readln(Data2, ATT[J].Name, ATT[J].Tele);
   close(Data2);
   for I:=1 to N1 do begin
      for J:=1 to N2 do begin
         if JJ[I].Name=ATT[J].Name then begin
            Ctr:=Ctr+1;
            with CoList[Ctr] do begin
               Name:=ATT[J].Name;
               Tele:=ATT[J].Tele
            end;
         end;
      end;
   end;
   writeln('   ***** THE COMMON CUSTOMERS *****');
   for I:=1 to Ctr do begin
      with CoList[I] do
      begin
         writeln('', I, '', Name, Tele)
      end;
   end;
END.
PROGRAM FORTRAN6 (10/20/’86)

CHARACTER*15 BELL, RCA, COLIST
INTEGER I, J, K, CTR
INTEGER*4 TEL1, TEL2, COTEL
DIMENSION BELL(2), RCA(3), COLIST(2)
DIMENSION TEL1(2), TEL2(3), COTEL(2)
CTR=0
OPEN(20, FILE='DATA1.1')
OPEN(21, FILE='DATA2.1')
DO 100 I=1, 2
READ(20, 10) BELL(I)
READ(20, 20) TEL1(I)
10 FORMAT(A)
20 FORMAT(I11)
100 CONTINUE
DO 200 J=1, 3
READ(21, 10) RCA(J)
READ(21, 20) TEL2(J)
110 FORMAT(A)
120 FORMAT(I11)
200 CONTINUE
210 DO 300 I=1, 2
DO 300 J=1, 3
IF (.NOT. (BELL(I).EQ.RCA(J))) GOTO 300
CTR=CTR+1
COLIST(CTR)=RCA(J)
COTEL(CTR)=TEL2(J)
300 CONTINUE
WRITE(*, *) '**** THE COMMON CUSTOMERS ****'
DO 500 K=1, CTR
WRITE(*, *) ',K,COLIST(K)', ',COTEL(K)
500 CONTINUE
STOP
600 WRITE(*, *) 'NO SUCH FILE'
END
Appendix C. Texts of Pascal and Fortran programs that belong to the "RTRDP" plan group (9 pages).
PROGRAM Pas7;(10/09/'86)

TYPE
LogType = record
  Date : string[8];
  IDNo : string[9];
  PassWd : string[7];
  Account : real
end;

VAR
  TempA : real;
  LogIn : LogType;
  KeyS,TempD : string[12];
  Key : char;
  I,J,NoKey : integer;
  DataC : text;
BEGIN
  assign(DataC,'datac.2');
  reset(DataC);
  with LogIn do readln(DataC,Date,IDNo,PassWd,Account);
  close(DataC);
  TempD:=LogIn.Date;
  TempA:=LogIn.Account;
  for I:=1 to 10 do writeln;
  writeln('Date
readln(LogIn.Date);
  writeln('ID No.
readln(KeyS);
if KeyS<>LogIn.IDNo then
  begin
    writeln(chr(007),'
    writeln('ID No.
    repeat readln(KeyS) until KeyS=LogIn.IDNo
  end;
readln(KeyS);
if KeyS<>LogIn.PassWd then
  begin
    writeln(chr(007),'
    writeln('Password
    repeat readln(KeyS) until KeyS=LogIn.PassWd
  end;
clrscr;
  for I:=1 to 10 do writeln;
  writeln('RECORD OF ',LogIn.IDNo,'*');
  writeln;
  writeln('DATE of last time : ',TempD:9);
  writeln('MONEY left : ',TempA:9);
  writeln;writeln;writeln;
  writeln('- HIT SPACE TO CONTINUE --');
  repeat read(Key) until Key in ['p','c','z','1','P','F','C','Z','L'];
  clrscr;
  for I:=1 to 7 do writeln;
  writeln('OPTIONS :');
  writeln('P : Pascal');
  writeln('C : C language');
  writeln('Z : Zbasic');
  writeln('L : Lisp');
  writeln('Q : Quit');
  writeln;writeln;writeln('repeat read(Key) until Key in ['p','c','z','1','P','F','C','Z','L'];
  clrscr;
  for I:=1 to 10 do writeln
'C','c' : writeln(' **** NICE TO MEET YOU IN "C" ****');
'Z','z' : writeln(' **** WELCOME TO Zbasic ****');
'L','l' : writeln(' **** NICE TO MEET YOU IN LISP ****');

'Q','q' :
end;
if Key in ['Q','q'] then
else repeat read(Key) until Key in ['Q','q'];
crscr;
LogIn.Account:=Logln.Account-0.3;
for I:=1 to 10 do writeln;
writeln(' Date : ',LogIn.Date:9);
writeln(' MONEY left : ',LogIn.Account:9);
writeln;writeln;
writeln('----- GOOD BYE ------ 1
END.

END.
**C*** PROGRAM FORTRAN? (10/29/'86)

```fortran
INTEGER   I,J,NOKEY
REAL      TEMPA,ACCOUNT
CHARACTER KEY
CHARACTER*7 PASSWRD
CHARACTER*8 DATE
CHARACTER*8 IDNO,KEYS,TEMPD
OPEN(20,FILE='DATAC.2')
READ(20,10) DATE
READ(20,10) IDNO
READ(20,10) PASSWRD
READ(20,20) ACCOUNT

10 FORMAT(A)
20 FORMAT(F7.2)
TEMPD=DATE
TEMPA=ACCOUNT

100 WRITE(*,*) ' ',* DATE :'
READ(*,10) DATE

150 WRITE(*,*) ' ', ID NO :'
READ(*,10) KEYS
IF (KEYS .NE. IDNO) THEN
    WRITE(*,*) ' ! WRONG, PLEASE REENTER !!'
    GOTO 150
ENDIF

200 WRITE(*,*) ' ', PASSWORD :'
READ(*,10) KEYS
IF (KEYS .NE. PASSWRD) THEN
    WRITE(*,*) ' ! WRONG, PLEASE REENTER !!'
    GOTO 200
ENDIF

    WRITE(*,*)' ', ' ', ' ', ' ', ' ', ' ', ' ', ' ', ' ', ' ', ' ', ' ', ' ',
    WRITE(*,*)' ', ' ', ' ', ' ', ' ', ' ', ' ', ' ', ' ', ' ', ' ', ' ', ' ',
    WRITE(*,*)' ', OPTIONS :
    WRITE(*,*)' ', [ 0 ] : 'ZBASIC'
    WRITE(*,*)' ', [ 1 ] : 'PASCAL'
    WRITE(*,*)' ', [ Q ] : 'QUIT'
    WRITE(*,*)' ', ==>
READ(*,*) NUMKEY
IF (NUMKEY .EQ. 2) NUMKEY=-1
IF (NUMKEY) 310,320,330

310 WRITE(*,*)' ',*** WELCOME TO LISP ***'
GOTO 400

320 WRITE(*,*)' ',*** WELCOME TO ZBASIC ***'
GOTO 400

330 WRITE(*,*)' ',*** WELCOME TO PASCAL ***'
GOTO 400
READ(*,10) KEY
IF (KEY .NE. 'Q') GOTO 400
ACCOUNT=ACCOUNT-3.00
```

```fortran
WRITE(*,*) ' ', DATE : ',DATE
WRITE(*,*)' ', MONEY LEFT : ',ACCOUNT
WRITE(*,*)' ', =========== GOOD BYE ! ==========
```
STOP
END
PROGRAM Pas8;(10/03'86)
CONST
Trlno = 2;
VAR
  PercntY,PercntN : real;
  Key : char;
  I,J,NoKey,SubNo,Num,ERR,Postv,Negv : integer;
  SaveKey : array [1..Trlno] of char;
BEGIN
  repeat
    read(Key);
    val(Key,SubNo,ERR)
  until SubNo in [1..30];
  for I:=1 to 10 do writeln;
  writeln(!!! PLEASE LOOK AT FIXATION POINT AFTER HITTING SPACE !!!);
  repeat read(Key) until Key = 
  Num:=0;Postv:=0;Negv:=0;
  repeat
    clrscr;
    for I:=1 to 11 do writeln;
    writeln(chr(007));
    writeln(*** Is "P" in second line (Y/N) ? **);
    repeat read(Key) until Key in ['Y','N','y','n'];
    Num:=Num+1;
    SaveKey[Num]:=Key;
    if SaveKey[Num] in ['Y','y'] then Postv:=Postv+1;
    if SaveKey[Num] in ['N','n'] then Negv:=Negv+1
until Num = Trlno;
PercntY:=Postv/Trlno;
PercntN:=Negv/Trlno;
clrscr;
for I:=1 to 10 do writeln;
writeln(******* RESULT *******);
writeln('Percentage of Yes response =',PercntY:9));
writeln('Percentage of No response =',PercntN:9))
END.
PROGRAM FORTRAN8 (10/23/’86)

CHARACTER*1 KEY
INTEGER I, J, SUBNOV, NUM
REAL Y, N, POSTV, NEGTV

WRITE(*,*) 'NO. OF SUBJECT : #'
READ(*,5) KEY

5 FORMAT(A)
DO 10 I=1,20
WRITE(*,5)
10 CONTINUE

WRITE(*,**)'!!! PLEASE FIXATE AT THE SCREEN !!!'
POSTV=0
NEGTV=0
DO 400 J=1,2
DO 20 I=1,20
WRITE(*,**)
20 CONTINUE
DO 25 I=1,19000
25 CONTINUE
WRITE(*,**)
WRITE(*,**)
WRITE(*,**)
DO 27 I=1,29000
27 CONTINUE
DO 30 I=1,50
WRITE(*,**)
30 CONTINUE
WRITE(*,**)' ?? IS [P] IN THE FIRST LINE ??'

35 READ(*,5) KEY
IF ((KEY.NE.'Y').AND.(KEY.NE.'N')) GOTO 35
IF (KEY.EQ.'Y') THEN
  POSTV=POSTV+1
ELSE
  NEGTV=NEGTV+1
ENDIF

400 CONTINUE
Y=POSTV/2
N=NEGTV/2
DO 600 I=1,20
WRITE(*,**)
600 CONTINUE
WRITE(*,**)
WRITE(*,605)

605 FORMAT(/)
WRITE(*,610) Y

610 FORMAT(' PERCENTAGE OF YES RESPONSE= ',F5.2)
WRITE(*,620) N

620 FORMAT(' PERCENTAGE OF NO RESPONSE= ',F5.2)
STOP
END
PROGRAM Pas9;(10/08/’86)

TYPE
    AccnType = record
        Date : string [8];
        Name : string [12];
        PassWd : string [7];
        Balance : real
    end;

VAR
    TempB,Amount : real;
    Account : AccnType;
    KeyS,TempD : string [12];
    Key : char;
    I,J,ERR,NoKey : integer;
    DataC : text;
BEGIN
    assign(DataC,'datac');
    reset(DataC);
    with Account do readln(DataC,Date,Name,PassWd,Balance);
    close(DataC);
    writeln(Account.Date,Account.Name,Account.PassWd,Account.Balance);
    TempD:=Account.Date;
    TempB:=Account.Balance;
    for I:=1 to 10 do writeln;
    writeln('DATE of last time :',TempD:9);
    writeln('BALANCE :',Account.Balance:9);
    writeln('HIT SPACE TO CONTINUE');--'
    clrscr;
    for I:=1 to 7 do writeln;
    writeln('OPTIONS :');
    writeln(' [ + ] : receive money');
    writeln(' [ - ] : deposit');
    writeln writeln writeln write('');
    repeat read(Key) until Key in [ ' + ',' - ',' / ',' ];
    writeln('');
    if Key in [' + ' , ' - '] then readln(Amount);
    case Key of
end;
clrscr;
for I:=1 to 10 do writeln;
writeln(' RECORD OF ',Account.Name,' ');
writeln(' DATE : ',Account.Date:9);
writeln(' BALANCE : ',Account.Balance:9);
writeln('');
writeln('***** THANKS ***** ');
END.
C*** PROGRAM FORTRAN9 (10/22/'86)

CHARACTER KEY
CHARACTER*7 PASWRD
CHARACTER*8 DATE
CHARACTER*12 NAME, KEYS, DTEMP
INTEGER I, J, NUMKEY
REAL BALNC, BTEMP, AMNT

OPEN(20, FILE='DATAC')
READ(20, 10) DATE
READ(20, 10) NAME
READ(20, 10) PASWRD
READ(20, 15) BALNC

10 FORMAT(A)
15 FORMAT(F8.2)
WRITE(*, **) DATE, NAME, BALNC
BTEMP=BALNC
DTEMP=DATE
WRITE(*, **) DATE:
READ(*, 10) DATE
WRITE(*, **) NAME:
READ(*, 10) KEYS
IF (KEYS .NE. NAME) THEN
WRITE(*, **) ! WRONG, PLEASE REENTER !!
GOTO 20
ENDIF
30 WRITE(*, **) PASSWORD:
READ(*, 10) KEYS
IF (KEYS .NE. PASWRD) THEN
WRITE(*, **) ! WRONG, PLEASE REENTER !!
GOTO 30
ENDIF

WRITE(*, **) -------------------------------
WRITE(*, **) DATE OF LAST ENTER: ', DTEMP
WRITE(*, **) BALANCE: ', BALNC
-------------------------------
WRITE(*, **) OPTIONS:
WRITE(*, **) [ 1 ] : RECEIVE MONEY
WRITE(*, **) [ 0 ] : DEPOSIT
WRITE(*, **) ->
READ(*, **) NUMKEY
100 READ(*, 15) AMNT
IF (NUMKEY) 100, 200, 300
200 BALNC=BALNC-AMNT
GOTO 400
300 BALNC=BALNC+AMNT
400 WRITE(*, **) -------------------------------
WRITE(*, **) RECORD OF ', NAME, ' *
WRITE(*, **) DATE: ', DATE
WRITE(*, **) BALANCE: ', BALNC
WRITE(*, **) *************** THANKS ***************
STOP
END
OSD

Dr. Earl Alluisi
Office of the Deputy
Under Secretary of Defense
OUSDRE (E&LS)
Pentagon, Room 3D129
Washington, D. C. 20301

Dr. Stanley Collyer
Office of Naval Technology
Code 222
800 North Quincy Street
Arlington, VA 22217-5000

Commander
Naval Air System Command
Crew Station Design
NAVAIR 5313
Washington, D. C. 20361

Dean of the Academic
Departments
U.S. Naval Academy
Annapolis, MD 21402

DEPARTMENT OF THE NAVY

Aircrew System Branch
System Engineering Test
Directorate
U.S. Naval Test Center
Patuxent River, MD 20670

Dr. Glen Allgaier
Artificial Intelligence Branch
Code 444
Naval Electronics Ocean System Center
San Diego, CA 92152

Mr. Philip Andrews
Naval Sea System Command
Navsea 61R2
Washington, D. C. 20362

Mr. Norm Beck
Combat Control System Department
Code 221
Naval Underwater System Center
Newport, RI 02840

Dr. Lyle D. Broemeling
Code 1111SP
Office of Naval Research
800 N. Quincy Street
Arlington, VA 22217-5000

LCDR R. Carter
Office of Chief
on Naval Operations
OP-933D3
Washington D. C. 20350

Dr. L. Chmura
Computer Science & Systems
Code 5592
Naval Research Laboratory
Washington, D. C. 20350

Dr. Robert A. Fleming
Human Factors Support Group
Naval Personnel Research & Development Center
1411 South Fern Street
Arlington, VA 22217-5000

Dr. Sherman Gee
Command and Control
Technology (Code 221)
Office of Naval Technology
800 N. Quincy Street
Arlington, VA 22217-5000

Dr. Eugene E. Gloye
ONR Detachment
1030 East Green Street
Pasadena, CA 91106-2485

Mr. Jeff Grossman
Human Factors Laboratory
Code 71
Navy Personnel R&D Center
San Diego, CA 92152-6800
Dr. A. L. Slafkosky
Scientific Advisor
Commandant of the Marine Corps
Washington, D. C. 20380

Mr. James Smith
Code 121
Office of Naval Research
800 N. Quincy Street
Arlington, VA 22217-5000

Special Assistant for Marine Corps Matters
Code OOMC
Office of Naval Research
800 N. Quincy Street
Arlington, VA 22217-5000

Mr. H. Talkington
Engineering & Computer Science
Code 09
Naval Ocean System Center
San Diego, CA 92152

DEPARTMENT OF THE ARMY

Director, Organization and Systems Research Laboratory
U.S. Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333-5600

Dr. Edgar M. Johnson
Technical Director
U.S. Army Research Institute
Alexandria, VA 22333-5600

Dr. Milton S. Katz
Director, Basic Research
Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333-5600

Technical Director
U.S. Army Human Engineering Laboratory
Aberdeen Proving Ground, MD 21005

DEPARTMENT OF THE AIR FORCE

Mr. Charles Bates, Director
Human Engineering Division
USAF AMRL/HES
Wright-Patterson AFB
OH 45433

Dr. Kenneth R. Boff
AF AMRL/HE
Wright-patterson AFB
OH 45433

OTHER GOVERNMENT AGENCIES

** Defense Technical Information Center
Cameron Station, Bldg. 5
Alexandria, VA 22314

Dr. Clinton Kelly
Defense Advanced Research Projects Agency
1400 Wilson Blvd.
Arlington, VA 22209

Dr. Alan Leshner
Division of Behavior and Neural Science
National Science Foundation
1800 G. Street, N.W.
Washington, D.C. 20550

Dr. M. C. Montemerlo
Information Science & Human Factors, Code RC
NASA HQS
Washington, D.C. 20546

OTHER ORGANIZATIONS

Dr. Deborah Boehm-Davis
Department of Psychology
George Manson University
4400 University Drive
Fairfax, VA 22030
Dr. Stanley Deutsch  
NAS-National Research Council (COHF)  
2101 Constitution Avenue, N.W.  
Washington, D.C. 20418

Dr. Richard Pew  
Bolt Berneek & Newman, Inc.  
10 Moulton Street  
Cambridge, MA 02238

Dr. Bruce Hamlil  
The Johns Hopkins University  
Applied Physics Lab  
Laurel, MD 20707

Dr. William B. Rouse  
School of Industrial and System Engineering  
Georgia Institute of Technology  
Atlanta, GA 30332

Dr. James H. Howard, Jr.  
Department of Psychology  
Catholic University  
Washington, D.C. 20064

Dr. James H.Howard, Jr.  
Department of Psychology  
Catholic University  
Washington, D.C. 20064

*** END OF LIST ***

Ms. Bonnie E. John  
Department of Psychology  
Carnegie-Mellon University  
Pittsburgh, PA 15213

* 3 copies needed

Dr. Thomas G. Moher  
Department of Electrical Engineering & Computer Science  
University of Illinois at Chicago  
P.O. Box 4348  
Chicago, IL 60680

** 2 copies needed

Dr. Allen Newell  
Department of Computer Science  
Carnegie-Mellon University  
Pittsburgh, PA 15213

Dr. Jesse Orlansky  
Institute for Defense Analysis  
1801 N. Beauregard Street  
Alexandria, VA 22311