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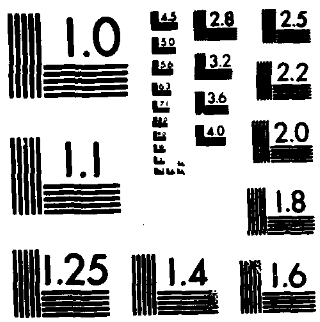

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This research is part of an ongoing effort to understand the processes people employ in reading technical material and the ways in which information engineering can facilitate those processes. This study provided a detailed and hierarchically organized information structure as part of a computer-assisted job-aiding procedure for an assembly task. The central questions were: Where people have easy access to many kinds of information what information do they select to help them do the job? How do people vary?

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How does information selection differ across sites in the text and graphics? The results of this experiment provide preliminary answers to these questions and serve as the basis for our continuing research in this area.

ABSTRACT

This research is part of an ongoing effort to understand the processes people employ in reading technical material and the ways in which information engineering can facilitate those processes. This study provided a detailed and hierarchically organized information structure as part of a computer-assisted job-aiding procedure for an assembly task. The central questions were "Where people have easy access to many kinds of information, what information do they select to help them do the job? How do people vary? How does information selection differ across sites in the text and graphics?" The results of this experiment provide preliminary answers to these questions and serve as the basis for our continuing research in this area.

This technical report presents preliminary results of on-going research. A second report containing a substantially more detailed analysis and discussion of results is currently under preparation.

Information Engineering: On-line Analysis of Information Search and Utilization

When people engaged in a procedural task have ready access to a wide variety of information, what information do they seek to aid them in doing the job? How do people differ in their information search and how does the information affect their performance? This report addresses these questions through description of information seeking responses made during an assembly task, for which not only basic instructions (surface text) but a rich, hierarchically organized supplemental information structure (Hypertext), subject to user control, were instantly accessible by means of interactive computer terminal. Responses to blocks in information are discussed in terms of problem solving strategies.

Information Engineering as an Approach to Job Aiding

The approach to job aiding followed here might best be described as information engineering, in which development and delivery of a complex information structure are fully integrated components in a total system (Figure 1). In job-related literacy, such as reading the directions for a procedural task, some users may not grasp essential technical terms or spatial orientations. Yet to include all potentially necessary information in the text would increase considerably the time required and possibly obscure the structure of the text even for those who do not need that information. One approach to this problem is to provide, via computer display screen, a concise, step-by-step surface text of directions, yet to provide instant access to Hypertext, a detailed, well-organized information structure that may include a wide range of graphic overviews and definitions of terms, as well as an easy means of reviewing earlier text segments. A user can thus call up with the touch of a light pen any information he/she requires but need not wade through information he/she doesn't need.

One critical feature in the information engineering required to allow these options is design and implementation of a detailed, well organized information structure. The second critical feature is design and implementation of a delivery system that can provide instant access to this supplemental information, yet return the user to the site from which the information search was initiated. These, of course, must be embedded within a computer system capable of immediate, high quality, networked responses.

But when varied, relevant information is available, what do people select and how do they use it? Answers to this question can contribute to our knowledge of how best to design job aiding procedures and to our understanding of how people solve (and ultimately can be helped to solve) problems of comprehending technical material.

Responses to Blocks in Information

Even when instructions in a task are informative and well organized, an information block (such as failure to understand the referent for a technical term or the intended orientation or relationship of two parts) may occur. What responses are possible? Ordinarily, in encountering an information block in written text a reader has only a few options--to plunge forward, either ignoring the block or hoping to resolve it with information later in the text, or to move backward to review earlier information that might provide clarification.

With the use of Hypertext, however, the reader's potential responses are increased. Figure 2 represents these options schematically. Faced with a block in information, the user can move forward (in which case we may not know a block has occurred except through performance deficits), move backward to recheck earlier text or Hypertext, move down to check the definition of a specific technical term or even the meaning of a familiar word in this context, or move up to a graphic overview of the assembly completed to this step or a graphic overview of the completed object.

The levels of the hierarchy thus include not only the surface text of directions but a more detailed level of definitions of terms and a more global level, in this case graphics (though in other content the global level might be verbal). This conception of the hierarchical structure of information is implicitly rooted in Frederiksen's (1975) analysis of discourse processes, though those notions are operationalized in a new way.

Information Search in Technical Literacy as Problem Solving

The overall goal in this assembly task is to complete the correct assembly of the miniature loading cart. Subordinate to that goal are the subgoals of completing 17 sequentially arranged steps, each guiding transformation of the object from one state to the next. (At each step there are also 1 to 3 substeps to be checked off by touching the light pen to the screen as completed, but our analysis focuses on the 17 steps of the surface text.) Subordinate to completion of a given step are the information-seeking moves undertaken within that step. These can include forward moves, directly completing and checking off each step and substep; backward moves, rechecking information received earlier; upward moves (this term is an arbitrary convention but psychologically useful in visualizing moves within the information structure from a given point in the surface text to graphic information), and downward moves to secure definition of terms by touching the light pen to a word in the surface text displayed on the screen.

While the overall goal and the subgoals are the same for all subjects in this study, the information each subject requests to enable himself/herself to complete each step may vary widely.

The focus in this study is on the problem solving strategies individuals use in overcoming information blocks. Not discussed here are the evaluation and selection processes that guide a given user in selection of information from the information structure provided, from his/her own information structure, and from the object in hand; emphasis is on the directly observable moves to various parts of the computer information system. Newell and Simon (1972, p.88) described aspects of the overall organization of an information processing system in this way:

1. Input translation, producing in the problem solver an internal representation of the problem (in this case, the information block) to be solved. "The problem solving then proceeds in the framework of the internal representation thus produced--a representation that may render problem solutions obvious, obscure, or perhaps unattainable."

2. Selection of a problem solving method: "A method is a process that bears some rational relation to attaining a problem solution, as formulated and seen in terms of the internal representation." In this case the available methods may include searching the total information structure (prior knowledge, surface text, Hypertext, and the object itself), drawing inferences, self-monitoring, and integrating the information bearing upon comprehension of a particular point.

3. Application of the problem solving method to the information block. "At any moment, as the outcome either of processes incorporated in the method itself or of more general processes that monitor its application, the execution of the method may be halted." The information block may be overcome, apparently overcome, or left unresolved.

4. Regrouping if necessary. Newell and Simon note (p. 88, footnote) that "The continuous flux of new information from the environment may offer new solution possibilities or demands that cause the problem solver to interrupt (his/her) current activities to try different ones." They also state that "when a method is

terminated, three options are open to the problem solver: (a) another method may be attempted, (b) a different internal representation may be selected and the problem reformulated, or (c) the attempt to solve the problem may be abandoned", at least for the moment.

5. Generation of subgoals. While the method is being applied, new problems may be recognized. "The problem solver may elect to attempt one of these" or may set aside the new subgoals, "continuing instead with another branch of the original method."

In order to understand the problem solving processes engaged in during computer-assisted technical literacy, information seeking strategies initiated during an assembly task were analyzed in terms of these categories: forward moves, rechecks (backward moves), requests for graphics, and requests for dictionary. These responses were examined in terms of overall group patterns, individual patterns, and sites in the text that tended to provoke given types of information search. The questions to be answered were:

1. What is the relative frequency of various types of information requests across the group?
2. How do individuals vary in information selection and use?
3. Do various sites in the surface text provoke different numbers and kinds of information search?

Method

Sample

The subjects in this sample were not a homogeneous or random sample but a wide-ranging convenience sample of 13 adults. They ranged in background, including electrical engineers, stockboys, secretaries, graduate students and teachers. This diversity curbed any tendency to generalize too freely from a narrow sample, and presented a strong test of the ability of the Hypertext system to respond to the information needs of users ranging widely in background.

Materials and Equipment

The materials used include 17 frames of directions for assembly of a miniature loading cart to be assembled from blocks. This surface text, presented on a computer display screen, was written at fifth grade level and presented each step clearly and concisely, as shown in Figure 3. Each text frame, however, gave the viewer the option of rechecking text seen earlier or branching into Hypertext. By touching with a light pen almost any substance word on the screen, the viewer called up a frame (cf. Figure 4) that defined the term or explained its meaning in that context; often the definitions were accompanied by small illustrations of the part or operation defined.

The viewer also had the option of viewing several types of color graphics. By touching one of the boxes centered below the directions for each substep, the user could view an illustration of the loading cart as it should appear at that step in the assembly process (Figure 5). Or, by touching a box in the upper left corner, the user could, at any point in the program, branch to a graphic depicting the completed object. Touching certain sections of that graphic, such as the axle assembly, shown in front view, could call up a more detailed "blow-up" of that component. For some subassemblies or parts it was also possible to request another view (front, back, side, up-side-down).

The detached display screen was linked to Hazeltine's TICCIT (Time-shared Interactive Computer Controlled Information Television). A central feature of the system for this purpose was the Hypertext™ Display System. Technically, this term includes the organization of both surface text and the supplemental graphics and definitions, though we will at times speak of contrasts between text and Hypertext. Fuller description of this system is given in Stone and McMinn (1982) and Stone, Israelite, Mudrick, and Hutson (1983).

Data-gathering Procedures

Each subject, tested individually, was seated at a computer display console equipped with a light pen. The parts needed to assemble the miniature loading cart were spread out on the table. The examiner explained the purpose of the study and led the subject through the introductory phase of the program, which explained and illustrated the information search options available. Then, as the subject progressed through the steps of the program, the examiner made notes on his/her performance.

An internal tracking program recorded and later printed out the sequence of numbers of the frames viewed by each subject. The sequence of moves for each subject was transformed into a schematic profile for each subject, and the types of information moves were tabulated by subject and by frame.

Data Analysis Procedures

Operationally defined, the key variables were:

Directness - 100 minus the number of forward and backward steps:

Use of Hypertext - Number of requests for graphic information or for dictionary

Rechecks - Starting point for long or short backward moves to text or Hypertext

Based on the conceptualization of information blocks and information search strategies discussed earlier, the computer's internal tracking records of the sequence of frame numbers viewed were transformed into visually salient graphic representations of each subjects' performance. This facilitated explicit description of each move by each subject yet made it easy to detect the larger patterns within which individual moves were embedded. The next step was to tabulate relative frequency of levels of directness and various information requests for each subject and across the whole group. A similar procedure was used to examine differences between program frames in the relative frequency of various information moves. Described later is the development of a coding system for cluster analysis (to be conducted after more subjects are observed) in order to develop a taxonomy of frame types.

Results

The results of this analysis are organized in terms of 1) overall patterns of information search and utilization, 2) individual variability, and 3) analysis of the program steps that provoked various information requests.

What is the relative frequency of various information requests, across the group?

People vary in the background and strategies they bring to a task like this, and they va·v in the information they seek during the task. The major dimensions along which they differ in performance are directness, use of Hypertext, and rechecks. It's tempting to think of directness (use of a minimum number of forward moves) as efficient, but it's not really efficient to plunge ahead blindly if needed information is readily available. Use of Hypertext and a few recursions may aid performance. Heavy use of recursions, on the other hand may indicate problems.

Across the whole group (Table 1) there were 238 information requests, for a mean of 17.3 information request moves per user. The most frequently requested category was graphics, with 129 requests (54% of the total), followed by dictionary requests, 73 (31%). The remaining 15% of the requests took the form of rechecks of text (24 requests) or Hypertext (12 requests).

Across the group the average figure for directness (100 - the total number of forward and backward moves) was 72.4. The minimum number of forward moves for the 17 frames was expected to be 17 (though one subject viewed only 16 frames).

This would yield a directness index of 83, which was attained by several subjects. On the average, subjects took eleven more moves forward and backward than the minimum needed to complete the task, but one took thirty moves more than the minimum, and several took only the minimum.

How did individuals vary in information selection and use?

One variable on which subjects hardly differed was success on the task. The directions were designed to be clear and readable, yet previous studies using the same surface text (Stone & Glock, 1981) showed that two-thirds of the subjects completed the task with some uncorrected errors. In this study, with the addition of Hypertext, almost no errors were uncorrected by the end of the task. Subjects varied, however, in the strategies they used in selecting information they needed to succeed on the task.

Schematic representations of performances by several subjects are displayed in Figure 6. The center lines represent the 17 steps of the surface text, the concise sequential set of instructions for assembling the loading cart. Requests for graphics are represented as moves up to the boxes above the line, and requests for definitions of terms are represented as moves down to circles below the line. Rechecks are represented as moves backward (right to left).

The subjects shown in Figure 6 are relatively direct in approach. Subject 109 moves straight through the task on the level of the surface text, but at the end checks back at two points, apparently to view the graphic displays there. Subjects 102, 119, 110, 115, and 111 make few or no rechecks but make increasing use of Hypertext. While subject 111 has 27 requests for Hypertext (17 for graphics, 10 for dictionary), as contrasted with 2 by subject 109, his/her forward progress is equally direct.

Patterns for the subjects shown in Figure 7 show low-moderate use of rechecks and varying use of Hypertext. Even in some of these subjects' profiles there is a suggestion of increased action around frames 5, 11, and 16. Subject 117 requests definition of terms at frame 5, moves on to frame 6, but rechecks several points in text or Hypertext, apparently resolves the problem and moves on. Subject 108 does not stop at that point, but on reaching the last frame makes a long sweep back to frame 5, then moves forward to frame 11, checks one graphic and one definition, then checks out, having successfully completed the task.

More complex and less direct patterns are seen for subjects 103, 116, and 105 (Figure 8). For 103 and 116 the patterns differ more in degree than in kind from the group just discussed; some problems around frames 4-5, some near frames 10-11, some rechecks back to the earlier trouble spot, and a long sweep back from the last frame. Subject 105 is perhaps the most complex, with recursions within recursions. Except for a swirl of text and Hypertext rechecks around frames 4-5, apparently resolving the problem, he/she proceeds with only a few asides to the next to the last frame, checks a term, moves back a few frames to check some graphics, moves forward one frame, checks a graphic, then moves on for one more frame. At that point, however, he/she reverses direction, returning to check the text on frame 10, moves forward two frames, then reverses to recheck a term on frame 11, then checks out, job completed.

We present here simply a description rather than an evaluation of the effectiveness of users' search strategies, but even these preliminary findings suggest several tactics for aiding performance or learning. Where there are clearly defined effective and ineffective search strategies, an on-line Diagnosis subroutine can provide visually salient feedback such as the users' profile or mapping of that individual's performance against a background of typical or ideal performance.

It can also be programmed to intervene in one of several ways, triggered by the pattern of information moves in a given area of the text and some if-when-then statements. Such interventions can range from gentle advisor messages: "Are you lost? If you'd like to view the completed object, touch the green box") to more direct measures (locking in or out certain portions of the information structure for a given user, either to induce new strategies or to prevent disasters in safety or security).

In this study all subjects succeeded, but they succeeded in different ways, making use of the information they felt they needed at various points. The total number of information requests and the kinds of information requested varied across subjects.

Which program steps provoke search?

Some steps in the set of directions for this assembly task appeared to set off more searches and different kinds of seraches than others. As shown in Table 2 and Figure 9, the total number of searches springing off a given program step ranged from 2 for step 15 to 36 for step 5. In general, steps that provoked a number of dictionary requests or text rechecks were the same as those that provoked graphic requests, signalling a general need for clarification that some users satisfied in one way and some in another. Step 5 provoked both 17 requests for graphics (several of them repeats by the same user), most for graphic 10, the component as completed to that step, and 14 for dictionary. Step 11 elicited 16 requests for graphics and 16 for dictionary. Graphic 27, an overview of the completed object, was requested most often at frames 4 and 16. As a rule, there were more requests for graphics than for dictionary on a given frame, but on step 16 a substantial number of requests were made for clarification of the term "grooves."

Some steps (notably 5 and 10) provoked more text rechecks than most, as though the new step made users realize that there was something earlier they hadn't understood. For step 5, however, a number of the rechecks to step 4 and to the related graphic were repeats by the same user. For frame 17 the rechecks were in some cases responses to the invitation on that frame: "This completes the assembly of the loading cart. You may go back over any part of these instructions to check your work, however." Both the small number of text rechecks and the uneven proportion that were repeats by the same user suggest that while this is a dimension useful in describing individual differences, use of text rechecks on a given step as a signal of program problems would require a larger sample.

Across the group as a whole, the largest numbers of information searches emanated from frames 5 and 11, with frames 16 (mostly definitions) and 10 (mostly graphics) not far behind. There were very few information requests initiated at frames 2, 6, 15, and 7.

It is also possible to analyze more carefully the information requests at any point. Frame 5, for example, directed the user to form the axle assembly. At this frame the graphic selected at least once by 10 of the 13 subjects was the illustration of that step when completed. One person rechecked the graphic of the prior step and two requested a view of the finished object. The terms for which clarification was requested by one person were "attached," "end groove of column one," and "end groove of column two." Terms requested by three people were "angle block" and "are oriented correctly."

An on-line Debug subroutine of the computer program can provide graphic and quantitative data as input in the human judgement of the best fix-up strategy for observed trouble spots. If the number of information requests for a given program step is small, it's usually best to leave it alone. Only a few people needed the help available there, but for those who needed it the help may have been critical. The cost of developing and storing the supplemental information in Hypertext is likely to be far smaller than the cost of mistakes made in technical operations.

If the number of requests for information at a given program step is large, it's useful first to determine whether the requests take the form of graphics and/or dictionary or of text rechecks. If the former, the software designer may decide to import the information into the surface text (adding a graphic detail or defining a term in context) or may decide to leave it as is, reasoning that if no more than a quarter of the users need that information, it's still easily available to them, while leaving the surface text uncluttered for those who don't need that information. Number of errors or rechecks following this step may also be considered.

A large number of rechecks in a given area of the program usually signals a problem, but the action to be taken depends upon the nature of the problem. If the total is a reflection of repetitions on the same frames by only a few people, it's probably an individual problem of lack of knowledge or lack of assurance. The problem may be alleviated indirectly if requests for Hypertext on the same frames lead to the changes described earlier. If rechecks in a given area are made by more than a few people, it is useful to examine not only the frames that are the starting point and ending point for the recheck but the relationship between them. Is there anything misstated or misinterpreted in the first frame? Does the problem become apparent only in the next frame? Or is there a new term for the same part mentioned earlier? As stated earlier, text rechecks may be more useful in flagging possible problems than in spelling out the solutions.

Although this informal analyses was based on only a few users, it indicates that some sites in the surface text provoke more information requests than others. It also points up the feasibility of a strategy for responding to a serious practical problem: the need for early debugging of software. As Bunyard and Coward (1982) point out, errors (or less than optimal solutions) detected late in the development of software cost far more to correct than those detected early.

The complex information structure available to users in this study appears not only to facilitate performance through individual control of information needs, but to facilitate debugging by pointing out both the sites where more information is required and the kinds of information sought. These patterns can readily be diagnosed on-line and accumulated over a modest number of subjects, flagging trouble-spots and suggesting the needed fix-up strategies. Some changes might be made even while the software is still in the development phase, substantially reducing life-cycle costs (Grove, 1982) and minimizing performance errors. Such a Debug subroutine could form the core of a software quality assurance program, as described by Baker & Fisher (1982).

Development of a Taxonomy of Information Search Patterns

This segment discusses the preparation for an aspect of analysis that will not be conducted until profiles of more subjects have been analyzed. The intent at that time is to conduct cluster analysis in order to determine a taxonomy of types of frames, described in terms of the information moves they provoke.

The first step in that process is to develop a coding system to describe in a limited number of dimensions the complexity of the total activity (not just a single move, but all the activity) undertaken by a given subject on a given frame.

Each subject's activity on a frame is described in terms of three digits, each representing one dimension of the taxonomy. Presented in Table 3 are the three dimensions: Numbers of passes (forward and backward) a subject makes through that frame either during initial progress or later for rechecks; use of Hypertext; and beginning or end of recheck.

To illustrate the application of the coding system, consider frames 1 through 6 for subject 105. The first frame is coded as 100 (1 pass, no Hypertext, no rechecks), the second as 103 (1 pass, no Hypertext, the end of a 1 step recheck), the third as 345 (3 passes, 1 request for dictionary, the beginning and end of a 1-step recheck). Frame 4 is coded as 315 (3 passes, 1 request for graphics, beginning and end of 2 or more rechecks (long or short). Frame 5 is coded as 787 (7 passes, both kinds of graphics, more than 1 of either, beginning of more than 1 recheck). And Frame 6 is simply 100 (1 pass, no Hypertext, no rechecks); coders learn to treasure such simple items. By coding and analyzing frames in this way it should be possible to locate the clusters of similar responses to frames.

Final Comments

This report is part of an ongoing effort to understand the processes people employ in reading technical material and the ways in which information engineering can facilitate those processes. This study provided a detailed and hierarchically organized information structure as part of a computer-assisted job aiding procedure for an assembly task. The central questions were "When people have easy access to many kinds of information, what information do they select to help them do the job? How do people vary? How does information selection differ across sites in the text?"

Subjects as a group selected graphic information most often, dictionary next, and sometimes made rechecks of text or nontext information. Individuals varied, however, in the directness of their approach, the frequency of their requests for graphics or dictionary, and their use of long and short rechecks. Yet at a higher level of generality some common patterns were observed. Sites in the text also differed widely; some were the starting point for far more rechecks and requests for Hypertext than were others.

Performance was noticeably better than in previous studies using the same materials but without the Hypertext feature of ready access to a hierarchically organized information structure. This suggests that when people can get the information they need when they need it, performance on procedural tasks is facilitated. But people vary in the information they feel they need, so it may be advisable to have more information (and more forms of information) available than any one person is likely to need, yet to keep the surface text uncluttered in order to avoid information overload for those who don't need that information.

There are several levels of generality at which the procedures described here may be useful (apart from their central function in job aiding): early debugging of software, systematic objective study of the design of job aiding procedures, aiding the study of processes involved in comprehending technical material, and aiding the study of problem solving in a specific technical context. For example, the objective on-line data-gathering can be complemented by think-aloud or stimulated recall techniques to understand how individuals conceptualize a particular problem and organize relevant information.

In terms of the aspects of information identified by Newell and Simon (1972), we have little direct information about input translation, an aspect that will deserve a closer look after the more easily observed aspects are better mapped. We have indirect evidence about selection of problem solving methods; analysis by frames show that the types of information requests provoked differed across frames. We have a clear record of those aspects of application of problem solving method manifest in requests for various kinds of information (though no documentation of the more internal aspects such as inference and integration and linkage to prior knowledge). The same data base indicates that subjects often regroup (request more information) when the problem of comprehending a particular frame resists initial attempts at solution. On the point of subgoals, our evidence is only suggestive. Bursts of requests for rechecks or Hypertext may suggest that the individual sets as subgoals clarification of one or more points before he/she can usefully attend to the larger goal of successfully completing that step. Protocols that show an individual moving through a trouble spot but later making a long recheck to that spot may illustrate Newell and Simon's point that problem solvers sometimes set aside new subgoals (in this case, a desire for greater clarity about some terms, spatial orientations or relationships between subcomponents) but may later have to return to resolve that problem. Perhaps most clearly suggestive of the generation of subgoals is the protocol of subject 105, in which the individual on more than one occasion reversed direction, or 116, who, in the middle of a recheck, sent out requests for Hypertext.

Experts on problem solving such as Newell and Simon (1972) or Shulman and Elstein (1975) invested many years, close analysis, and much thoughtful analysis and, undoubtedly, reconceptualization before presenting formal models of the process. It would take more chutzpah than the authors of this report collectively possess to present a formal model at this point. The results we present here are only a beginning, and we have elected to start from the outside with objectively observable behavior, then gradually to circle closer.

Some major patterns, however, seem to be emerging. It seems legitimate to describe and interpret these behaviors as problem solving in a specific technical context. That context to some degree defines the problem space add thus the solutions likely to be tried, yet individuals, differing in background and having access to many kinds of relevant information, varied in the strategies they applied. Nonetheless, there were some patterns across the group (though none that were universal). The more obvious patterns were linked to difficulties present in certain segments of the text, as indicated by the greater number of information searches around certain frames or the greater tendency to seek definitions for some kinds of information blocks, graphics for others.

We hope that the procedures and analyses described here will prove useful both in enhancing job performance and training and in exploring the information search and utilization processes used in solving important practical problems.

Table 1

Individual Variability in Information Search Patterns

Subject	Directness (100 - forward and backward moves)	Use of Hypertext (including repeats)			No. of Rechecks[1]	Total Number of Information Requests
		graphics	dictionary	total		
101	77	12	2	(14)	3	17
102	83	7	1	(8)	0	8
103	56	8	10	(18)	6	24
104	67	22	1	(23)	4	27
105	57	8	9	(17)	11	26
108	65	12	3	(15)	2	17
109	78	2	0	(2)	2	4
110	83	7	7	(14)	0	14
111	83	17	10	(27)	0	27
115	82	15	1	(16)	1	17
116	53	4	11	(15)	3	18
117	75	5	17	(22)	3	25
119	82	10	1	(11)	1	12
		129	73	(202)	36	238

[1] If long text rechecks were interrupted to seek Hypertext information, then resumed leftward, a second recheck was tallied; includes long and short rechecks for text or Hypertext.

Table 2

Frequency of Information Requests Initiated at Each Program Step[1]

Frame	Graphic Requests	Dictionary Requests	Start of Text Recheck	Start of Non-text Rechecks	Total
1	9	2	0	0	11
2	3	0	1	0	4
3	4	3	1	0	8
4	12	3	3	0	18
5	17	14	4	1	36
6	3	1	1	1	6
7	8	1	2	0	11
8	4	1	0	3	8
9	12	3	0	0	15
10	13	5	3	1	22
11	16	16	0	0	32
12	8	2	1	1	12
13	8	0	2	0	10
14	9	4	0	1	14
15	0	1	0	1	2
16	3	17	1	1	22
17	0	0	5	2	7
	129	73	24	12	238

[1]Analysis based on the first 13 subjects

Table 3

Taxonomy of Search Activity by Subjects at Each Frame

First digit

No. of Passes Forward or Backward

- 0 = none
- 1 = one time
- 2 = two times
- 3 = three times
- 4 = four times
- 5 = five times
- 6 = six times
- 7 = seven times

Second digit

Use of Hypertext

- 0 = none
- 1 = graphics (1), including repeats
- 2 = graphics (2)
- 3 = graphics (3 or more)
- 4 = dictionary (1)
- 5 = dictionary (2)
- 6 = dictionary (3 or more)
- 7 = one of each
- 8 = both, more than 1 of either

Third digit

Beginning or End of Text or Hypertext Recheck

- 0 = not beginning or end of recheck
- 1 = beginning of recheck of 1 step
- 2 = beginning of recheck of 2 or more steps
- 3 = end of recheck of 1 step
- 4 = end of recheck of 2 or more steps
- 5 = beginning and end of 2 or more rechecks of 1 step
- 6 = beginning and end of 2 or more rechecks, at least 1 of which is 2 or more steps long
- 7 = beginning of 2 or more rechecks, short or long
- 8 = end of 2 or more rechecks, short or long

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We are indebted to Carl Frederiksen for his generous help in analyzing the comparability of text and graphic materials used in the series of studies begun in 1976; those materials, though now transfromed, serve as the basis for this study. We greatly appreciate Peggy McMinn's assistance in running subjects and the creative staff of Hazeltine Corporation for helping to develop the materials. The patient typing by Maggie Sharp was invaluable. Most of all we thank those who participated as subjects in this study.

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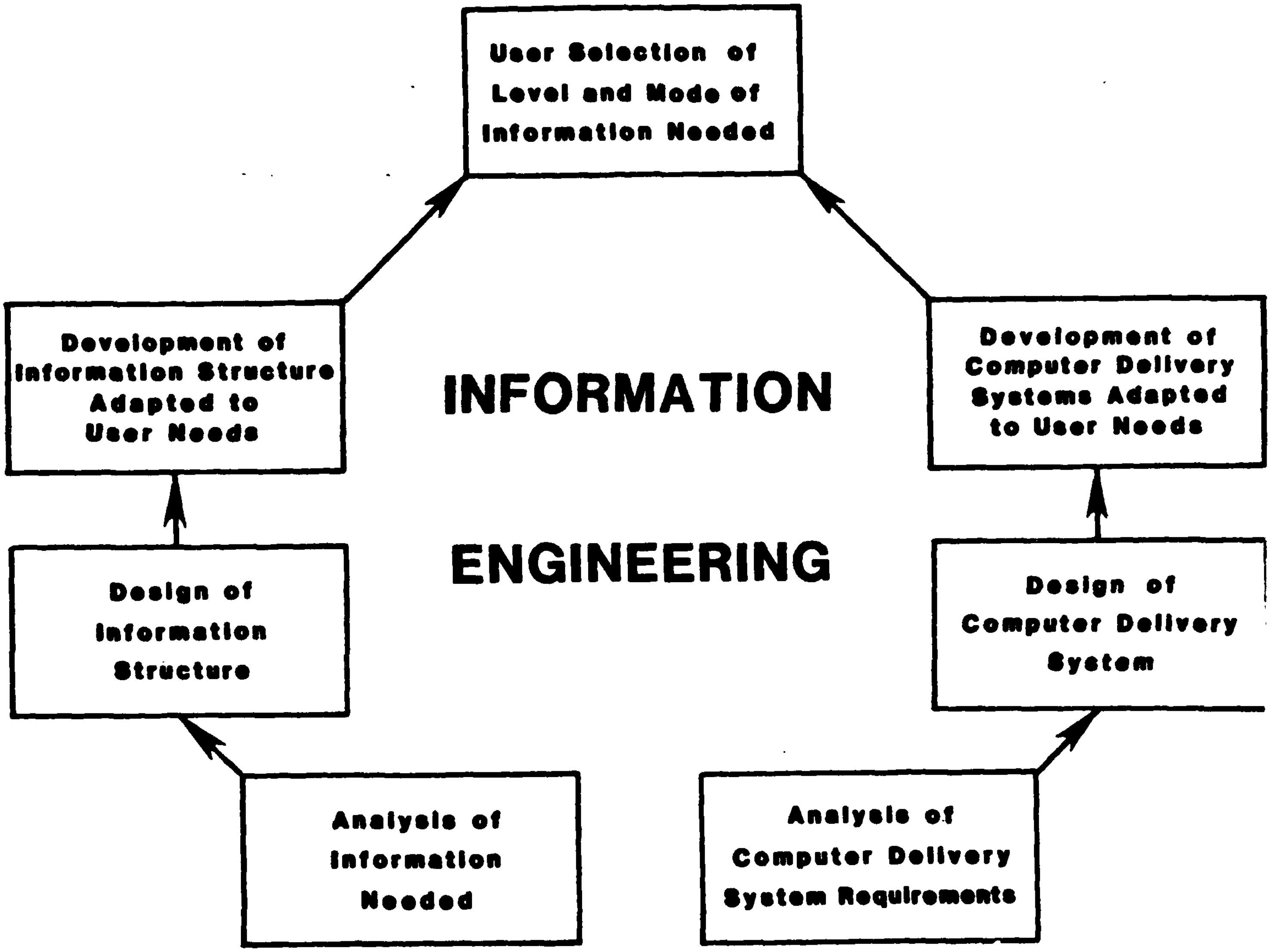


Figure 1

Integration of components in an information engineering system

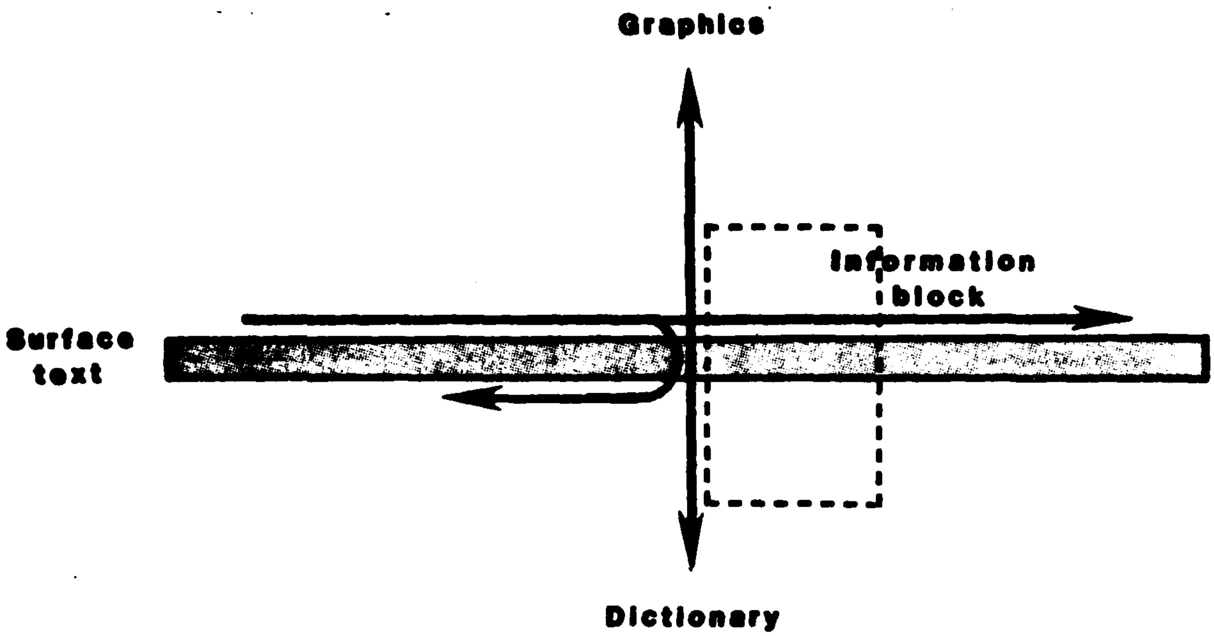
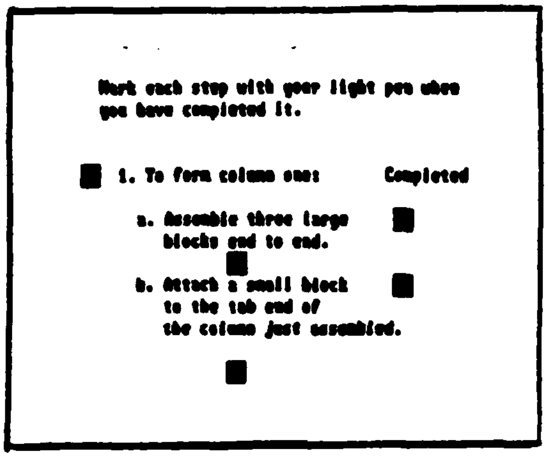
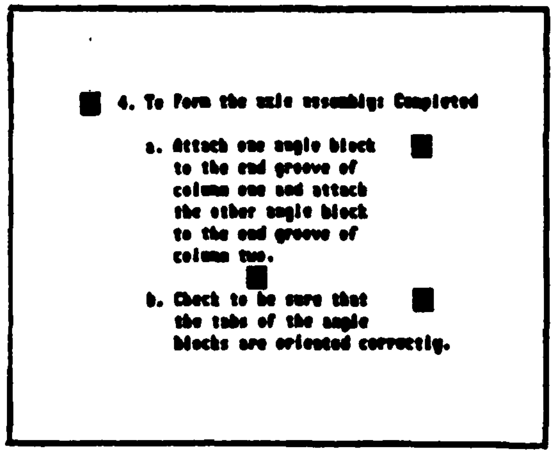


Figure 2. A schematic representation of the information search strategies for resolving an information block when Hypertext display is available. Options include moving forward, moving up to a graphic overview, down to clarification of a specific term, or rechecking the surface text or Hypertext.

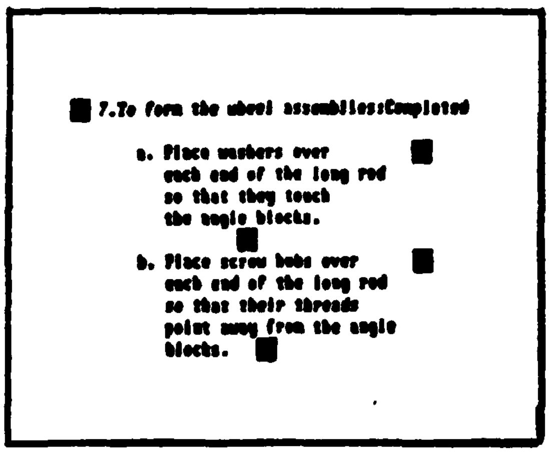
Figure 3. Examples of steps in surface text



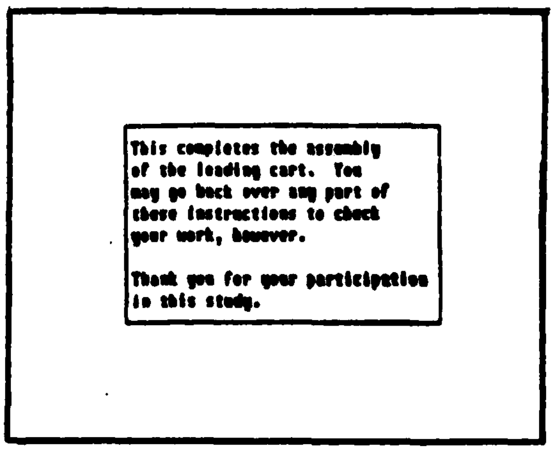
Step 1



Step 5

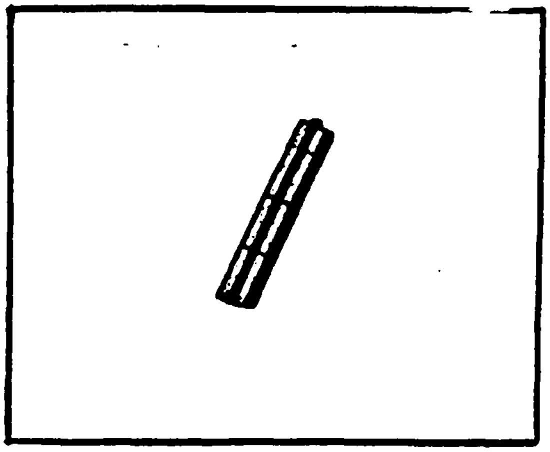


Step 11



Step 17

Figure 4. Examples of graphics



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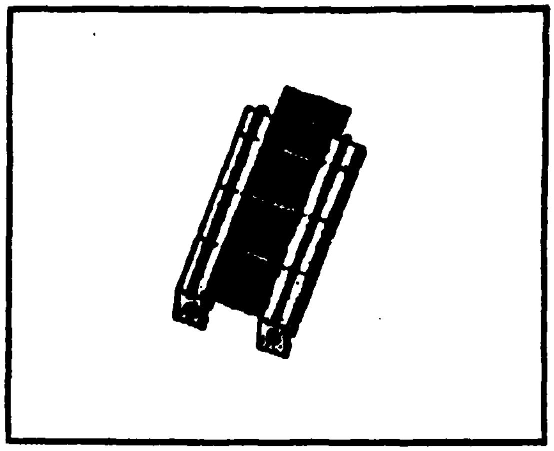

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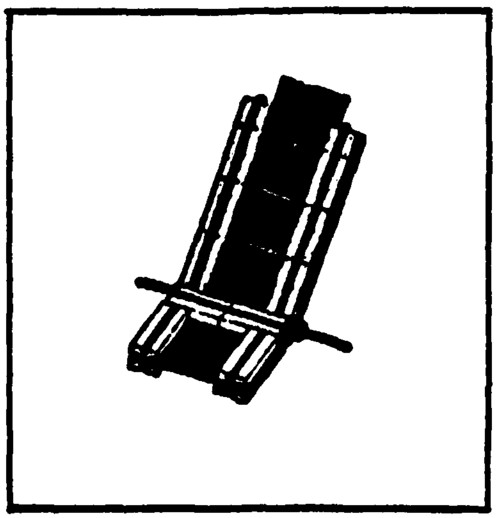

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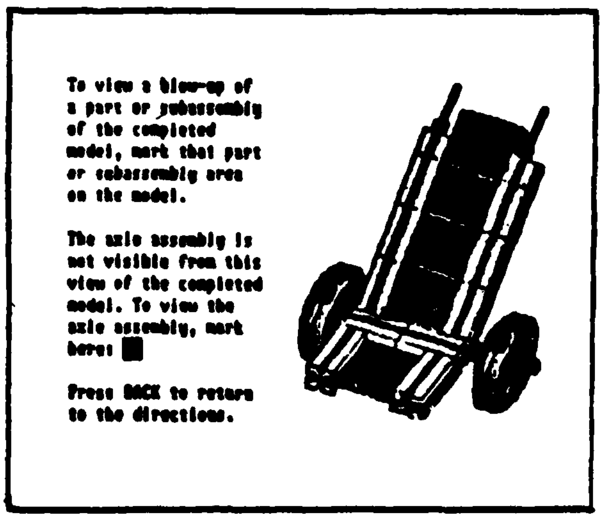

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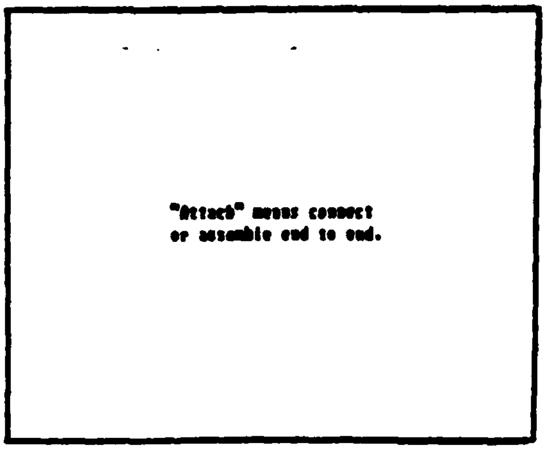
Figure 5. Examples of definitions



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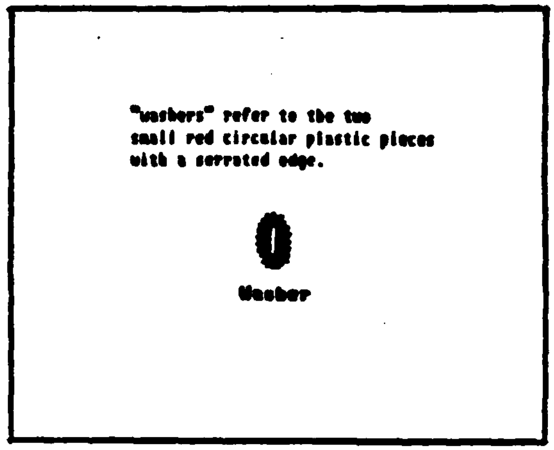

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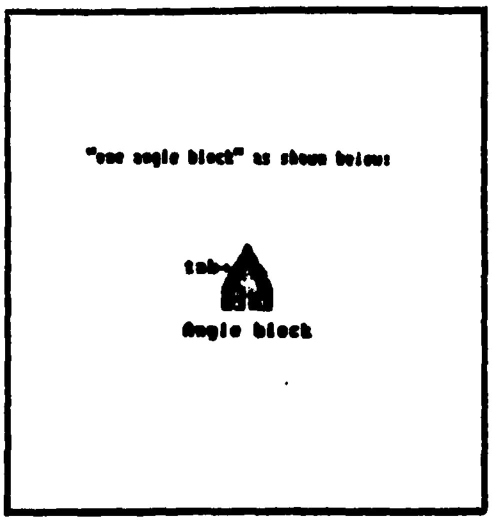

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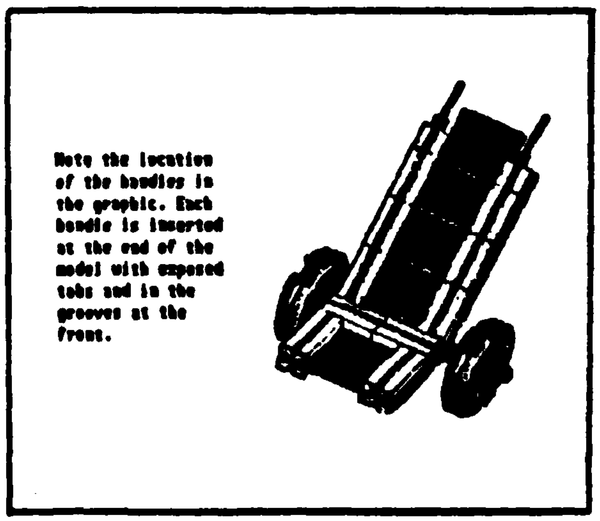

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Figure 6

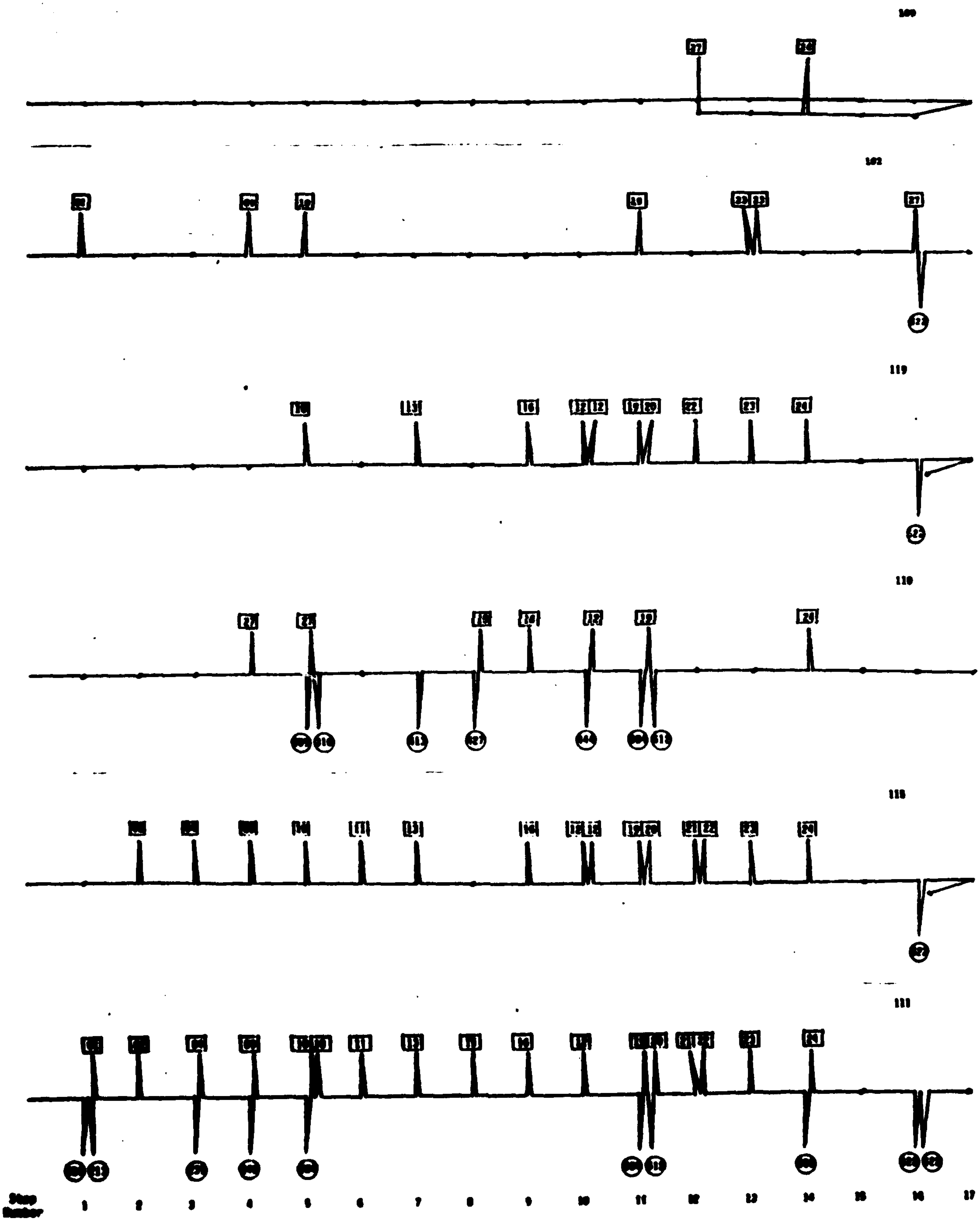


Figure 7

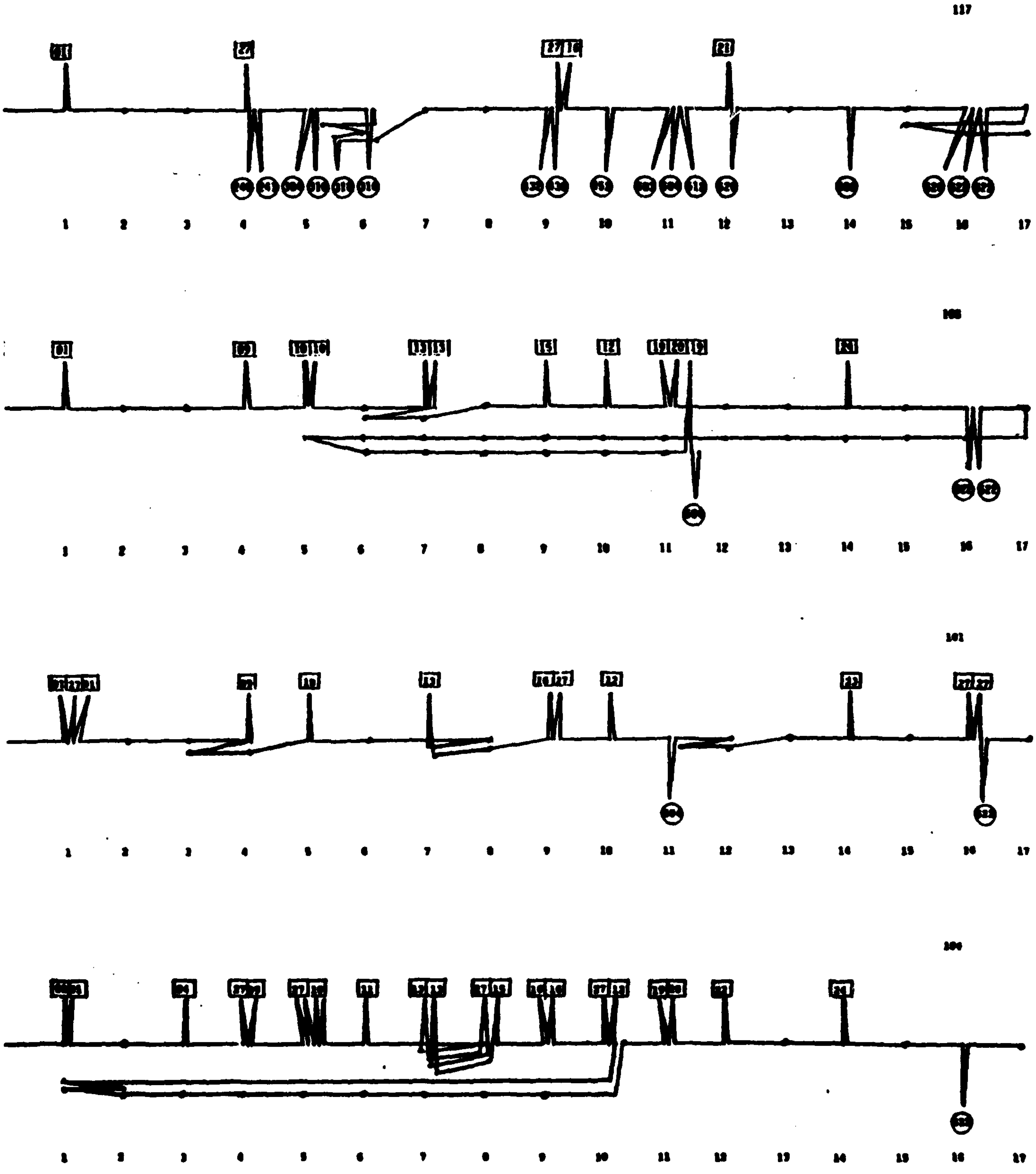
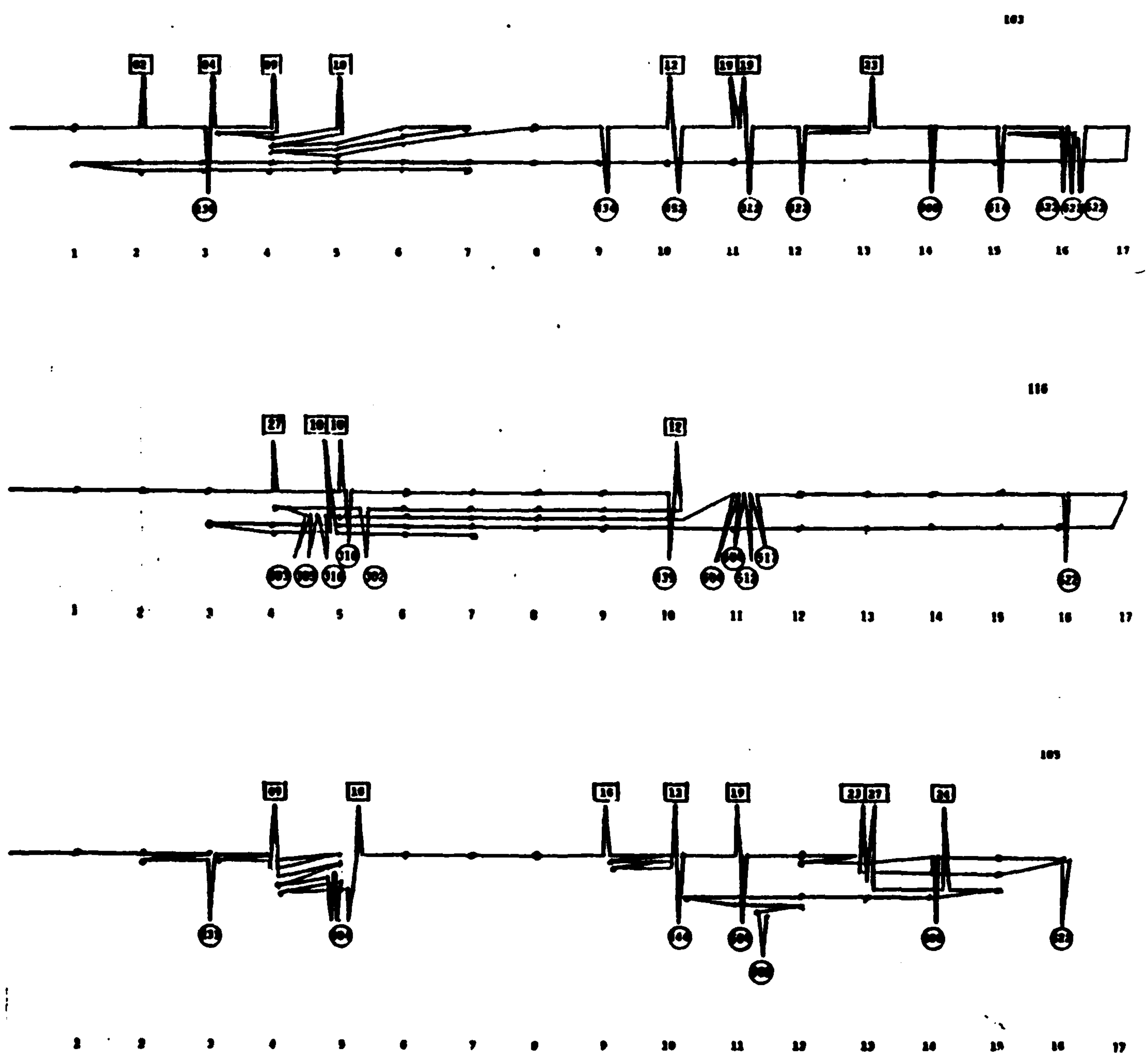
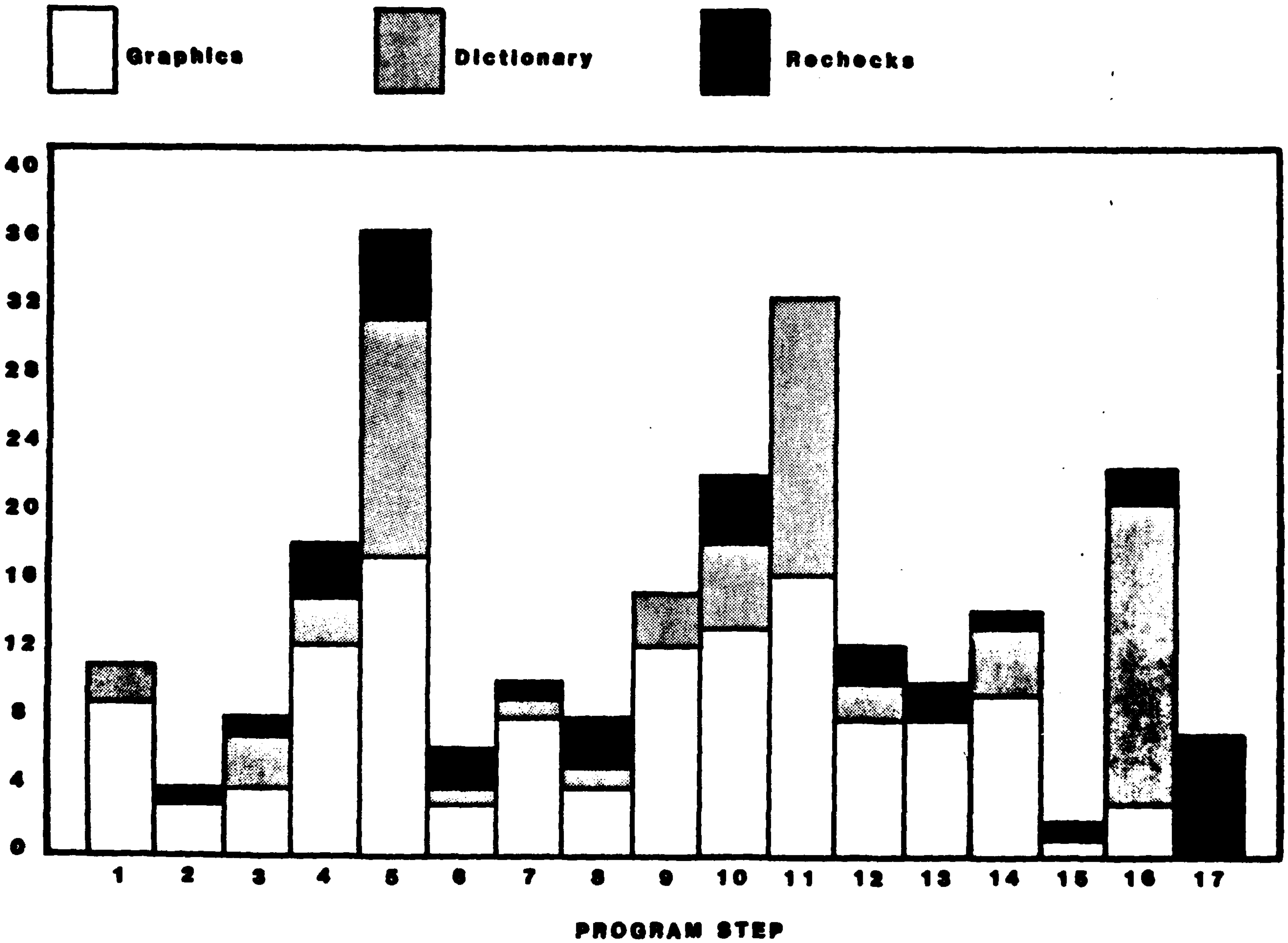


Figure 8



103
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
116
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

Figure 9. Relative frequency of various information requests at each step



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