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ABSTRACT

This examination of the effectiveness of various methods of cuing users to their location in a videotex information system used five different versions of an electronic edition of a college catalog: "simple" (no cues), "headers" (textual cues), "color" (color cues), "icons" (graphic cues), and "fancy" (textual, color, and graphic cues). The 99 graduate students who acted as subjects were each asked to complete 10 search tasks working with one version of the catalog, and data were gathered from videotaped sessions on time, number of false turns during searches, and number of right and wrong answers. A post-questionnaire assessed ease of use and satisfaction with the database as well as the perceived usefulness of the various cues. Subjects differed in awareness of cues and their functions, but color cues seemed less impressive than textual or graphic cues. Although subjects did not differ in their immediate perception of ease of use or satisfaction, differences in attitudes and recall of screen attributes were noted in follow-up interviews conducted six weeks after the initial experiment. A discussion of the importance of users' mental models in understanding electronic environments and suggested topics for further research conclude the paper. Statistical analyses and a list of 30 references are appended. (MES)

Finding One's Way in Electronic Space: The Relative Importance of Navigational Cues and Mental Models

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ABSTRACT

Difficulties with "wayfinding" are common among users of electronic information systems. A study of strategies (textual, graphic, color) to cue users to their location in a database showed that the presence or absence of physical cues was less important to successful searching than the user's ability to represent internally the structure of the information. Users with more detailed and complete representations of the information searched faster and made fewer wrong turns. But the variety of different representations of the database suggest it may be very difficult to create generic models as a help to novice users.

Finding One's Way in Electronic Space:

The Relative Importance of Navigational Cues and Mental Models

The rapid spread of electronic databases raises a set of perplexing questions for researchers and designers concerned with how information may best be structured and displayed. One the one hand, there is the attractiveness of being able at last to create interactive resources of considerable size and sophistication; the ability to provide 54,000 still images on a videodisc or 250,000 pages of a major encyclopedia on a CD-ROM are encouraging many to undertake design work using interactive databases. On the other hand, there are suggestions that naive users may have difficulty acquiring the skills necessary to navigate in such large seas of data. The system of cues and information that guide the user of a database to desired information and that allow the user to navigate from that information, once found, to other parts of the database is what I call a "wayfinding system." What kinds of cues can help to make such a system efficient, and the influence on wayfinding ability of a user's own model of system structure and function, are the topics for examination here.

Background: From Print to Screen

The Psychological Heritage of Print

Our ways of working with printed materials are so closely interwoven into our unexamined view of how information should be organized that it is very difficult to step back and see clearly just how much we take for granted. The "metastructure" of printed material is an integral part of our 500-year experience with print (Febvre & Martin, 1976). Page numbers, title pages, chapter titles, line leading, headings, tables of contents, indexes, appendices, footnotes and references--all help us find what we want and locate ourselves with respect to other material. We often forget, however, that these aids did not all come into being with the advent of printing but rather had to be individually invented and accepted. The pace of development may be more rapid now, but the conceptual problems are no less severe when we move to electronic systems for storing and retrieving information.

Aspects of Electronic Wayfinding

The metastructure of electronic text is not parallel to that of print. Indexes and tables of contents give way to hierarchical database structures or keyword searching. Chapter headings and other cues on the page are supplanted by icons and on-screen menus. We know more about some of these aspects of the metastructure of electronic text than about others. For example, on the level of the individual screen, we know something about menu formats: users seem to prefer and work more effectively with "broad" menus that present medium or large numbers of choices on each screen (Lee & MacGregor, 1985).

But menus have problems: many errors occur at the initial menu level (where users are least likely to know what categories are subsumed under the top-level items; in one study, 18% of all search time was spent using the top-level menu [Irving, Elton, & Siegeltuch, 1982]). Users may also become frustrated by working up and down through layers of menus without finding desired information; in one study, 28% gave up even though they knew that "the information is in there somewhere" (Latremouille, Mason, McEwen, Phillips, & Whalen, 1981). And 50% of users of a menu-based system had to backtrack at least once before finding information they wanted (Carey, 1981).

Keywords are helpful to more experienced and frequent users, but are less useful for occasional users (Geller & Lesk, 1982; Shneiderman, 1982). There may in fact be little objective reason to prefer keywords over menus, since users' problems often lie in realms other than the mechanics of access (Van Nes & Van der Heijden, 1982).

Icons have also attracted attention as wayfinding aids, but validating their usefulness empirically has been a problem (Mackett-Stout & Dewar, 1981). Some have suggested that learning to use an icon-based system may be no easier--just different--than learning one based on text or menus (Samet, Geiselman, & Landee, 1982). Color also may be an effective cue, and while its use is rarely perceived as mandatory (e.g., Tullis, 1981), color is an "attractive nuisance"--a feature that users will consistently ask for and claim to like, even if it adds nothing to performance (Christ, 1975; Reynolds, 1979).

On the level of the document or database, a number of navigation methods remindful of print have been proposed (Benest & Potok, 1984; Engel et al., 1983; Lochovsky & Tsichritzis, 1981; Spence & Apperley, 1982). Some of these use on-screen menu-plus-text systems to allow the user to keep track of present location, and to permit retracing steps through previous menus to an earlier point. None of these systems, however, has gained general acceptance. And because making wayfinding information accessible also implies making it visible, these approaches all quickly encroach on limited screen space.

Several studies have concluded that design for electronic information must not focus merely on specification of mechanical aspects of the interface. Rather, the most critical element may be to understand how the user conceptualizes the material at hand--what categories it contains, how it is organized, and so on (Hills, 1983; Vigil, 1983). Waern and Rollenhagen (1983) observe that we know little about how to capitalize on metacognitive processes (setting goals, planning, recognizing problems) in using electronic text.

The Value of Cues in Wayfinding: A Study

Method

A study was done to determine the effectiveness of various methods of cueing users as to their location in a videotex information system (full report: Kerr et al., 1985). Using VAST, a PC-based videotex frame creation and database management system, five different versions of a database (an electronic edition of a college catalog) were created: "Simple" (no cues), "Headers" (textual cues), "Color" (color cues), "Icons" (graphic cues), and "Fancy" (textual, color, and graphic cues).

The subjects were 99 graduate students at a large urban graduate school of education and human services. Prior to the experiment, subjects were asked to complete a brief questionnaire on their background, employment, and previous experience with computers (especially databases and on-line information retrieval systems). The subjects were then asked to work with the electronic catalog to complete ten search tasks.

Tasks typically required that the user search through three to five levels of menus; some searches required scrolling through multiple frames making up a single "page" of information. The Ss were videotaped as they worked; the information thus gathered was coded for time, number of false turns during searches, and number of right and wrong answers found. A post-questionnaire requested that Ss make an assessment of the ease of using the database and the degree of satisfaction in using it; experimenters also asked the Ss for their perception of the usefulness of the various cues.

Follow-up interviews were conducted with 50 Ss (ten per condition) six weeks after the initial experimental trials. Interviewers inquired about Ss' memory of the database, the cues incorporated in it, the structure of the database, the content of the search tasks, and perceived satisfaction with/ease of using the database at that point.

peed, Efficiency, and Accuracy Effects

Table 1 summarizes the main quantitative results of the study. There were no significant differences among groups in the speed with which subjects completed the search tasks ($F[4,96] = .745$, $p > .5$), in their efficiency (choice of a search path involving a minimal number of screens; $F[4,96] = 1.759$, $p > .1$), or in their accuracy (ability to find the correct answer on the first try; $F[4,96] = .213$, $p > .9$). In fact, when the index of previous computer use was introduced as a covariate, it accounted for significantly more variation than the cueing conditions for both speed ($F[1,96] = 7.788$, $p < .01$) and efficiency ($F[1,96] = 5.021$, $p < .03$).

Table 1 here

Awareness of Cue Function and Use in Navigation

Since subjects were not informed at first of the function of the various cueing conditions, they were asked at the conclusion of the experiment if they had in fact been aware of the cues, if they were aware of the function of the cues, and if they had actually used the cues when navigating in the database. Two measures appear in the following analyses: cue awareness--a simple rating of how aware the subject was of the cue's function (ranging from 0, not at all aware, to 2, fully aware), and cue use--a composite index of cue-use-in-navigation. This included the subject's awareness of the existence of the cues, the awareness rating (as above), and a measure of the extent to which the subject claimed to have used the cue for navigation. To stress actual use of cues for navigation (rather than simple awareness), the last of these components (cue use in navigation) was weighted 3 times as heavily as simple awareness of the cue itself, and 1.5 times as heavily as awareness of the cue's function.

Note that in the analyses that follow, data for subjects who used the "Simple" (no cues) database are ommitted. There were no cues in that database, and therefore those subjects were not asked about their awareness of cues or use of them.

Awareness of cue function. An analysis of variance for these data showed significant differences among cell means, $F\ (3,78) = 6.556$, $p < .001$. A multiple classification analysis showed that about 21% of the variance in awareness is accounted for by the cue differences. Further, a Tukey HSD multiple range test shows that the cueing conditions can be clustered with "Color" and "Fancy" in one subset, and "Fancy," "Headers,"and "Icons" in a second subset. This further suggests that "Color" on the one hand, and "Headers" and "Icons" on the other, do in fact differ in terms of subjects' awareness of the function of those cues as navigational aids.

Table 2 here

Use of cues for navigation. As with simple awareness of cue function, the data for navigational use of cues were subjected to analysis of variance. The results are shown in Table 3.

Table 3 here

Once again, the differences among the various cell means are significant, F (3,78) = 5.833, $p < .001$. The effect of cueing condition is slightly less powerful here, but still explains almost 19% of the variance. A Tukey HSD multiple range test shows that the groups can be clustered with "Color" and "Fancy" in one subset, "Fancy," "Icons," and "Headers" in another subset. As above, this suggests that "Color" differs significantly (in a negative direction) from both "Icons" and "Headers" in terms of its attractiveness to users as a wayfinding aid.

What might explain these differences in both awareness of cues' navigational potential and actual cue use? Certainly we could hypothesize that subjects would pay more attention to the graphic icons. They are simply more novel than color alone. Color on a video screen has become so commonplace in most peoples' daily lives that it may no longer arouse great interest. Graphics, however, probably have more residual power in that they may match in their outline, "broad brush" form the kinds of mental schemata that people create to identify categories internally. Textual header lines, however, may generate more awareness simply because people are used to using such devices as wayfinding tools.

Section summary. Subjects differed, therefore, in their awareness of the cues and the function of those cues. Color cues seemed less impressive than textual or graphic cues and subjects also said that they used color cues less frequently in searching. Perhaps color has, through intensive use on video in general, lost some of its power as a cue; text is commonly used in this sort of environment as a cue; graphics may both be novel to many users and also match (or aid in constructing) an internal schema of how the database is organized.

Perceived Ease, Satisfaction, Memorableness

In this study, differences between conditions in the levels of ease and satisfaction perceived by subjects in their searching operations were also of interest. In other words, regardless of the length of time subjects took searching or the number of errors subjects actually made, did they think that the experience of searching was a satisfying one, and did they subjectively find the database easy to use. To investigate these questions, subjects were asked to rate their experience (in terms of both ease of use and satisfaction) on a 7-point Likert scale immediately after they completed the search tasks.

As part of the follow-up study, subjects were again asked to rate their experience with the database. We thus were able to determine whether there were differences in users' subjective experiences immediately following searching or in reflection on looking back at their work several weeks later.

An additional set of questions revolved around the issue of memorableness. We were concerned to discover whether there were any differences among users in terms of their recall for a number of aspects of the database and the user interface. Among the variables that we asked about in the follow-up were: numbers of screen attributes recalled, memory of specific search tasks, number of questions or tasks recalled, recall of the main menu categories, and the type of language used by the subjects in describing the database. Only some of these data are discussed here.

Immediate ease/difficulty in using the database. There were no great differences among the conditions in subjects' immediately expressed reactions to the ease or difficulty of using the database. Means for the groups are shown in Table 4.

Table 4 here

The group means are not significantly different one from another, F (4,98) =

Immediate satisfaction in using the database. Here again, there were no large differences among the grou_ in their subjective satisfaction with using the database. The means for the five groups are presented in Table 5.

Table 5 here

As above, an analysis of variance does not show any significant differences among the groups, F (4,98) = .373, p > .8.

While there are no significant differences here, it is worth noting that there is a consistent irectionin the findings. Subjects using database "Fancy" showed the highest ratings for both ease of use and satisfaction.

Recalled ease/difficulty in using the database. Interestingly enough, there are some significant differences in the data for subjects' recalled ease or difficulty in using the database. Table 6 shows cell means.

Table 6 here

These data indicate a significant difference between groups, F (4,48) = 5.438, p < .001. Those who used database "Headers" gave quite low ease-of-use ratings compared with other groups. Those who used "Color" were generally more positive. A Tukey HSD multiple range test showed that "Headers" and "Icons" are in one subset, while "Icons," "Simple," and "Color" are in another. Subjects recalling their experiences with "Headers" are at least distinct from those remembering their work with "Simple," "Fancy," and "Color."

Why should this be? The results would be less puzzling if we had found "Simple" off by itself at the low end in recall. Then one might have been able to argue that it was the unhelpful quality of the interface that led to the decline in evaluation of this database by its users. But "Headers" has information for users--note that subjects in "Headers" claimed to have been aware of the function of and to have used those textual cues more than did users of some other cues. Perhaps it is the case that "Headers" is simply too prosaic, and that users of "Simple," for example, remembered the experience as more of an "adventure game"--moving off into uncharted electronic space with no map or compass.

Recalled satisfaction in using the database. Again here some differences appear among the various groups in their recalled satisfaction in using the database. The cell means are displayed in Table 7.

Table 7 here

As was the case with the data on recalled ease-of-use, users of "Headers" were more negative about their remembered satisfaction in using the database, while those who used "Fancy" were most positive. The ANOVA results are ambiguous--F (4,48) = 2.242, p = .08. Additionally, a multiple range test here shows no differences between subsets of groups. Nonetheless, with 17% of the variance in recalled satisfaction explained by the differences in cueing conditions, the possibility exists that these differences are worthy of further consideration.

Recall of specific database attributes. The follow-up study asked subjects to recall a number of attributes of the database and the search tasks: specific aspects of the screen design, the search tasks themselves, and the categories used on the main menu of the database. We also asked the subjects to describe the database, and coded their responses for the type of metaphorical or figurative language used in their descriptions. Only information on the recall of numbers of attributes is presented here.

There were some differences among the groups in terms of the number of screen attributes recalled. (Screen attributes included such aspects of screen design as specific text, placement of text, shape of border polygons, bottom prompts, and the cues themselves.) The results are shown below in Table 8.

Table 8 here

There is a curious aspect to these findings. In examining the group means, note that users of "Color" recalled the largest number of screen attributes, while those who used "Headers" recalled the fewest. While the sigificance of the results is ambiguous--F (4,48) = 2.535, $p < .06$--they are in a direction that might have been assumed. Research on instructional film and television has shown that use of color tends to promote the recall of unrelated peripheral details, and perhaps the effect here is a parallel one.

How are we to explain the apparent lack of memorableness of the interface design of the "Headers" database? Perhaps the use of textual headers turns the task into one of tracking one's way through a textual manual. "Headers" subjects claimed to have been more aware of the function of their cues and also to have used the cues more for navigational purposes. This suggests that users of a textually-cued database might see consulting that database as more of a dull, routine task--fairly easy to do, but more like other text-oriented tasks that are encountered all the time in our contemporary textually influenced life. Perhaps, then, those who use databases cued by icons see the task as more of a "computer game," a situation to be explored, an environment to be sensually savored.

Section summary. Subjects did not differ in their immediate perception of the ease of using the database or on their satisfaction with it. On later reflection, however, users of textual cues were significantly more negative about the ease/difficulty of the experience, while those using color cues, all cues, or no cues were more positive. Users of the color-cued database also recalled significantly more screen attributes, while those using textual cues recall fewer. It may be the case that textual cues remind users of other types of information-search tasks that are typically accomplished using textual cues (working with an encyclopedia or dictionary, for example), while those who use color or iconic cues may see the exercise as one more like a computer game.

Subjects' Conceptualizations of the Database

At the conclusion of the experimental session, subjects were asked to "give us your impression" of the database. The request was purposely phrased in such a way that Ss would not necessarily take the task as being "write a description of the database" or "draw a diagram of the database." The impressions were coded as basically verbal, basically graphic, or a combination of the two.

Impressions of database structure. When asked to give a representation of the structure of the database, faster users generally gave more detailed, more graphic impressions. Slower users gave simpler, more verbal descriptions. A number of themes emerged in the impressions: "tree" and "pyramid" metaphors, "book" language and descriptions, and other descriptions that made the analogy to filing cabinets or loose-leaf notebooks. These findings are particularly interesting and warrant further examination here.

<u>Faster and slower searchers' impressions</u>. There were correlations between the complexity (amount of detail and use of graphic elements) in subjects' impressions and speed ($r = -.18$) and efficiency ($r = -.06$), with more accurate, efficient searching associated with more detailed impressions. While these are not strong relationships, the consistency in direction of the figures suggests that subjects who move through the database more rapidly or with fewer problems may have a more articulated internal representation of how the database is structured.

Some of the representations of subjects who searched faster and slower are shown here. Figures 1 through 3 are the representations of the three fastest subjects; their total search times range from 590 to 684 seconds. Figures 4 through 6 show the impressions of the slowest subjects, with search times ranging from 2685 to 2870 seconds.

Figures 1-3 here

The faster users tend to have more graphically detailed representations. All of these subjects provided what was basically a sketch of the tree structure of the database. One subject (58) realized that some information was shared across categories, although this was never explicitly brought to the subjects' attention.

Figures 4-6 here

Among the slower subjects, the representations tend to be more verbal. They also show the seemingly greater naiveté of these users. Subject 9, for example, indicates that while this "was a wonderful machine," that it would likely be easier to use after having "been exposed to it for awhile." A similar theme is sounded by subject 38--"I am not used to computers." The impression of Subject 62 was basically graphic, but not as comprehensive as some of the faster searchers' sketches.

The representation of another slow searcher (32, Figure 7) is a puzzle here, for s/he had had previous experience with a database system at an insurance company. Perhaps the slower search time was due to the need to learn a new system that was similar (but not identical) to a known one. This is a problem we shall return to below.

The existence of a slight correlation between complexity of representation and efficiency in searching may not be the most important of these findings. What stands out above is the diversity in ways of modeling a structure of electronic information. There may in fact be underlying elements that repeat from one model to another, but the surface differences suggest that caution is in order if we attempt to create one sort of mental model with which to initiate novice computer users.

The Centrality of User Understanding

A shift away from concern with mechanical aspects of the interface and toward developing a better picture of how users understand the workings of computer systems is visible in much recent work in the field of human factors and human-computer interaction. Users' understandings, explanations, and representations may be seen as aspects of mental models that users must create and bring to bear as they work in electronic environments. (See, for example: diSessa, 1986; Gentner & Stevens, 1983; Lewis, 1986; Mark, 1985; Quinn & Russell, 1986; and Suchman, 1985.)

Users' mental models are probably most important when the user first learns how to work with a system, or when the user returns to working with it after a long hiatus (Norman, 1986). This raises a set of interesting questions, for research in educational technology suggests that while one can train people to use a particular mental model in addressing a particular task, this may not always be the best thing to do. People differ in their abilities to figure out appropriate models for themselves, and supplying a new model to someone who already has a satisfactory internal understanding of how to solve the problem may actually interfere with that understanding. On the other hand, supplying a model may be very efficient when the user is not capable of generating an internal model of how to proceed (Salomon, 1979).

Other work on the generation and use of mental models may provide some assistance here. In a study of how learners approach a material assembly task by Baggett and Ehrenfeucht (1985), "typical" and "minority" conceptualizations of the task were first identified, then used to instruct naive subjects to perform the task. The authors found that "people studying typical instructions yield typical conceptualizations [of their own], and importantly, people studying minority instructions also yield typical conceptualizations, although they are significantly less typical than those from typical instructions" (p. 2). The authors could not decide whether this was a result of some subjects' simply ignoring the minority model, or whether such models competed with some persons' "typical" model.

In another study, closer in focus to the work discussed here, Borgman (1986) found that providing a conceptual model of the functions of an on-line information system helped subjects more with complex tasks requiring extrapolation than it did with routine search tasks. But Borgman, while noting that subjects had difficulty articulating their models of system function, did not attempt to provide alternative models or to identify individual differences on which such models might be based.

What is needed at this point is more empirical testing of the value of supplied vs. internally constructed models of system functioning and information structure for both naive and sophisticated users of computer systems. Are there, for example, low levels of system use at which it will simply make sense to provide a model of the system's function and structure even though that model may interfere with an individual's "natural" or preferred way of representing the system internally? Are there long-term problems in efficiency or satisfaction with system use that arise as naive users with a supplied model employ a system more frequently and in a more sophisticated way? And does variation in models reflect only surface differences, or are there in fact underlying distinctions to which we should pay attention? As computer systems become more complex and as the number of users to be trained on them increases, finding where supplied models are useful and where they are not is a question that will continue to have both theoretical and practical importance.

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Table 1

Effect of Cues on Speed, Efficiency, Accuracy of Search
(Cell Means--by Cueing Condition)

CONDITION	Simple (N = 20)	Headers (N = 19)	Color (N = 19)	Icons (N = 19)	Fancy (N = 20)	GRAND MEAN (N = 97)
Speed (Seconds)	805.50	957.37	924.47	1057.32	861.80	919.48
Efficiency (Number of Screens Accessed)	31.2	30.16	37.47	43.16	25.00	33.29
Accuracy (Correct Answers on First Try)	8.55	8.68	8.26	8.63	8.45	8.52

Table 2

Cell Means for Awareness of Cue Function across Cueing Conditions

CONDITION Headers	Color	Icons	Fancy	GRAND MEAN
1.25 (20)	.40 (20)	1.47 (19)	1.05 (20)	1.04 (79)

Table 3

Cell Means for Navigational Use of Cues across Cueing Conditions

CONDITION Headers	Color	Icons	Fancy	GRAND MEAN
3.15 (20)	1.25 (20)	2.79 (19)	2.35 (20)	2.38 (79)

Table 4

Cell Means for Immediate Ease/Difficulty in Using the Database
(Range: 10 = low; 70 = high)

CONDITION

Simple	Headers	Color	Icons	Fancy	GRAND MEAN
58.75	54.75	55.50	57.26	59.50	57.15
(20)	(20)	(20)	(19)	(20)	(99)

Table 5

Cell Means for Immediate Satisfaction in Using the Database
(Range: 10 = low; 70 = high)

CONDITION

Simple	Headers	Color	Icons	Fancy	GRAND MEAN
55.50	55.25	54.50	53.16	58.00	55.30
(20)	(20)	(20)	(19)	(20)	(99)

Table 6

Cell Means for Recalled Ease/Difficulty in Using the Database

CONDITION

Simple	Headers	Color	Icons	Fancy	GRAND MEAN
54.00	39.50	58.60	51.11	54.00	51.45
(10)	(10)	(10)	(9)	(10)	(49)

Table 7

Cell Means for Recalled Satisfaction in Using the Database

CONDITION

Simple	Headers	Color	Icons	Fancy	GRAND MEAN
48.00	43.00	55.00	56.67	58.00	52.04
(10)	(10)	(10)	(9)	(10)	(49)

Table 8

Cell Means for Number of Screen Attributes Recalled

CONDITION

Simple	Headers	Color	Icons	Fancy	GRAND MEAN
3.30	2.10	4.10	2.44	3.80	3.16
(10)	(10)	(10)	(9)	(10)	(49)

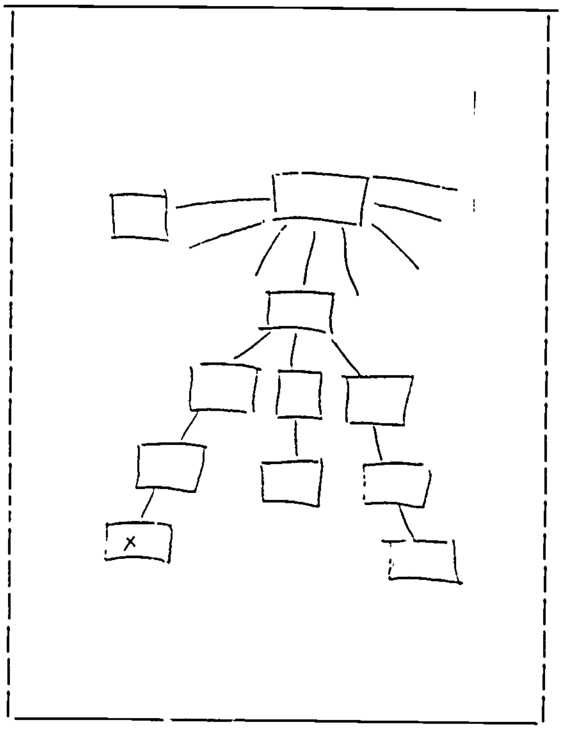

Figure 1
(Subject 33; 590 secs.)

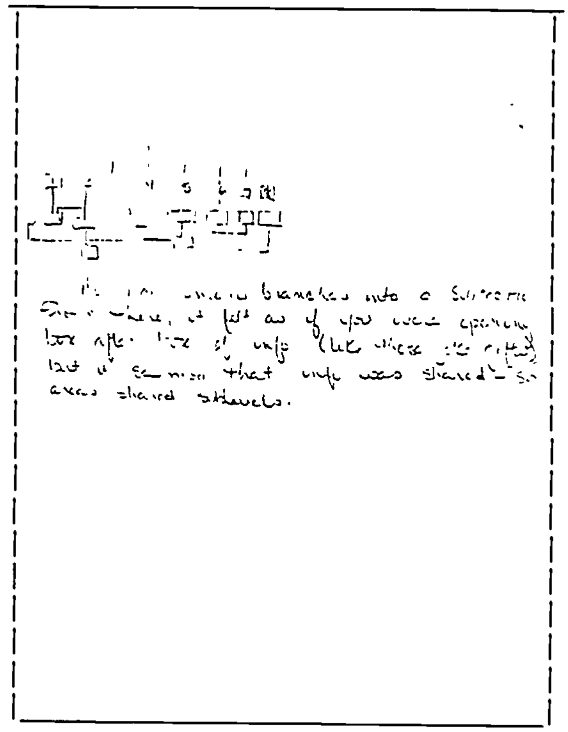

Figure 2
(Subject 58; 668 secs.)

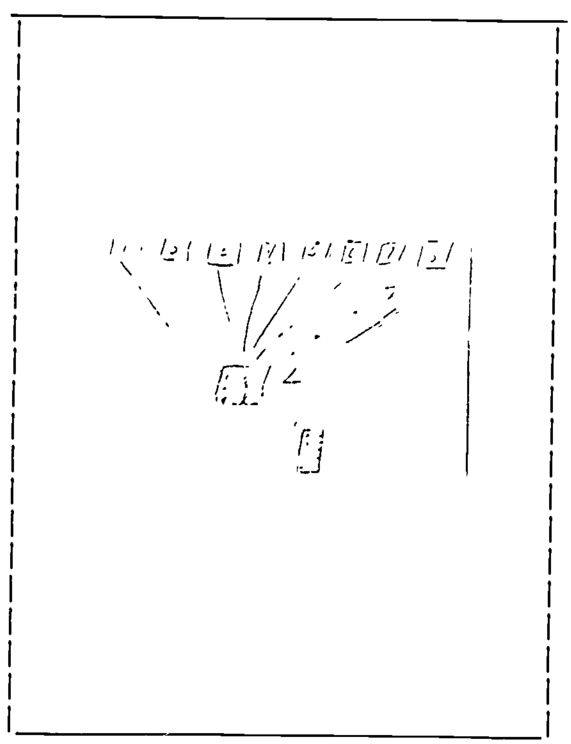

Figure 3
(Subject 25; 684 secs.)

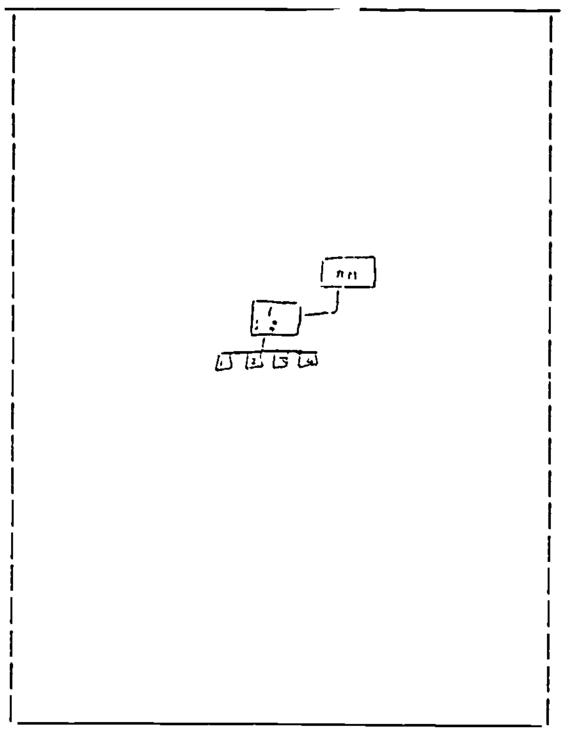

Figure 4
(Subject 62; 2685 secs.)

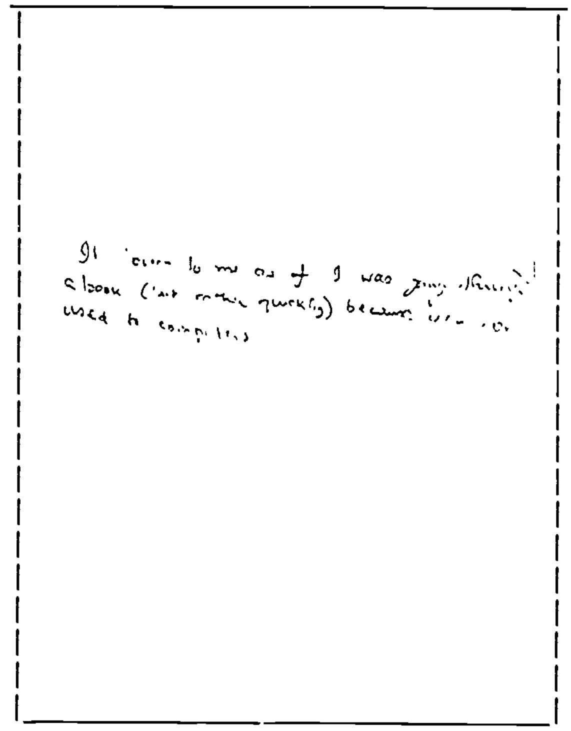

Figure 5
(Subject 38; 2753 secs.)

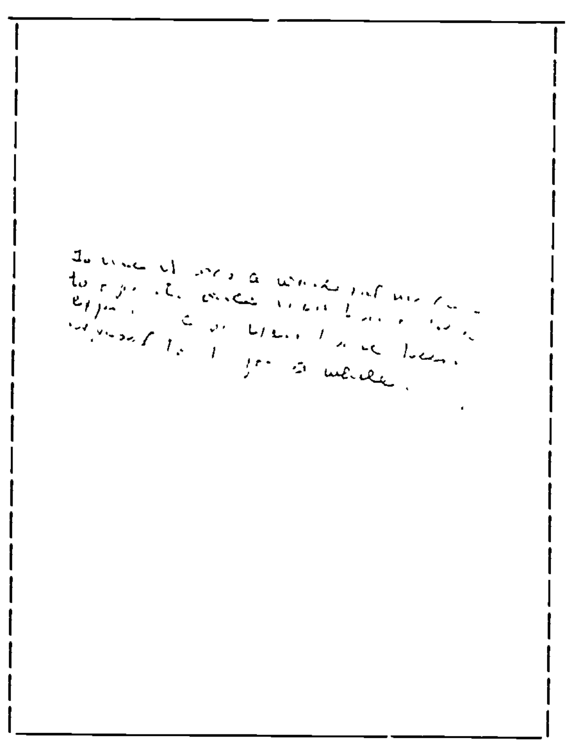

Figure 6
(Subject 9; 2870 secs.)