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THE UTILITY OF GRAPHICAL REPRESENTATIONS IN THE DESIGN OF PROCEDURAL ONLINE HELP CONTENT

AN EXPLORATORY STUDY

DISSERTATION

Presented in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in the Graduate School of The Ohio State University

By

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Help content is an integral component in designing useful online help systems. Unfortunately, little is known about what this content should contain or how it should be presented. The limited literature that is available suggests that it procedures users initially want to master. Additionally, prior evidence from picture research suggests textual representations of procedural help content can be enhanced with graphics. The goal of this study was to explore the utility of textual and graphical representations in online help. Eleven college level participants completed twelve tasks designed using the Linkway Live!™ authoring program. Participants accessed either a help system which contained text-only procedures or a highly graphic system which contained textual and graphical procedures. Both help systems were designed using a GOMS (goals, operators, methods, and selection rules) analysis. Verbal protocols were collected as participants communicated with both the text-only and highly graphic help systems. Additionally, non-verbal data of the information content of errors was collected. Finally, participants were asked to complete a debrief questionnaire of their experience.

Although this effort was exploratory in nature, several conclusions can be drawn from this effort. First, the variation of problems encountered by the two groups suggest
there are differences in the utility of textual and graphical representations of online help content. Second, the explicit representations contained in the highly graphic help system appeared to facilitate task accomplishment. These representations helped participants better understand the general methods, as well as, the specific steps required to communicate with the Linkway Live!™ interface. Third, preliminary findings support the theories of cue summation and economy of processing as ways of describing the facilitative effects of graphics.

To expand the knowledge base in this area, alternative designs which explore the optimal mix of text and graphics is needed. It is also recommended that future efforts incorporate the GOMS model, or similar cognitive models, to guide the development of online help content.
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 Mostly, I thank God from whom all blessings flow. 
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CHAPTER 1

INTRODUCTION

This chapter first introduces the problem and discusses the motivation for this research project. Next, it states the objectives of the study, identifies the research questions and hypotheses, and describes the methodological approach used. The last section presents the organization of this study document.

1.1 Statement of the Problem

This research study examines the utility of graphical representations in procedural knowledge acquisition tasks. In particular, the study explores the facilitative effects of text and graphics in accomplishing procedural tasks. Two help system prototypes of procedural content, one text-only and another highly graphic, are used to address the research questions of the study. These prototypes were designed using the GOMS (Goals, Operators, Methods, and Selection Rules) cognitive model of procedural knowledge representation (Card, Moran, & Newell, 1983).
1.2 Motivation

Barker (1991) states that "while there is much being written in [online] documentation, little of it is what you would call theoretical" (pg 7). Much of the written work in the field appears as guidelines or design principles (Clark, 1981; Durst, 1992; Fenchel, 1981; Horton, 1990; Mayer, 1981; Petrauskas, 1987; Rubenstein & Hersh, 1984). Unfortunately, few of these findings are discussed within an empirical or theoretical context (Elkerton, 1988). There is especially a dearth of research on online help content. The scarce research that exists has limited applicability to the design of online help due to system limitations and the lack of differentiation between content, presentation, and access. For instance, in earlier studies by Dunsmore (1980) and Relles (1979) which found online help inferior to printed manuals, it is difficult to know if poor online performance was a result of inferior content embodied in the help dialogues themselves or system design limitations. Both Houghton (1984) and Elkerton (1988) believe it probable that design limitations such as help information scrolling off the screen prior to being processed by users contributed to poor performance findings.

Unlike most prior efforts which confound findings by combining the effects of content, presentation, and access, the present study is only concerned with help content (Borenstein, 1985; Cohill & Williges, 1985; Magers, 1983). The related literature on documentation suggests that it is procedures users initially seek from help content. Therefore, the study makes a further differentiation by focusing on procedural content. By design, this study is exploratory in nature.
This research is inspired, in part, by Elkerton and his colleagues who reasoned that graphical information contained in help dialogues may have helped users perform simple online tasks (Elkerton, Goldstein, & Palmiter, 1990). This supposition is supported by the picture research literature which has shown pictorial superiority over words in comprehension, learning, and recognition tasks (Dwyer, 1982; Haber & Myers, 1982; Levie & Lentz, 1982; Shepard, 1967; Standing, 1973). Also, there is empirical evidence that highly graphical representations may produce performance gains in procedural knowledge acquisition tasks similar to the tasks users encounter when accessing an online help facility (Booher, 1975; Stone & Glock, 1981). Additionally, several theories and models including perceptual processing, selective attention, and economy of processing provide theoretical support for graphical representations in procedural knowledge acquisition (Anderson, 1982; Gibson & Levin, 1975; Pylyshyn, 1984; Reynolds & Baker, 1987; Stone & Glock, 1981; Treisman, 1986).

1.3 Objectives

The objectives of this study are to:

1. develop a model of the procedural knowledge required to operate an authoring system application using a GOMS analysis,

2. use this model to design two prototype help systems, one text-based and the other graphics-based,
3. determine the utility of text and highly graphical representations of help content, and
4. begin to develop a framework for incorporating graphical representations in procedural online help content.

1.4 Research Questions

The research questions for the study are:

1. What problems/obstacles do participants experience in translating text-only and highly graphic representations of help content into executable actions? What are the similarities and differences encountered by the two help groups?

2. Which categories of information content impede task accomplishment? What are the particular problems participants experience with different types of information content? Do these categories differ for highly graphic and text-only help systems?

3. What are participants overall impressions of the help system?

4. What do these findings suggest regarding the design of online help systems?

1.5 Approach

To answer these research questions, data were collected using verbal protocols and a debrief questionnaire. Two groups of participants attempted to accomplish tasks using either a text-only or highly graphic online help system. This study was less interested in purely quantitative measures such as the number of errors or times participants return to
the help screen and more interested in qualitative indices which help describe the cognitive behavior of participants.

The verbal protocol technique was selected as the most appropriate methodology for the study. Verbal protocols included audio transcripts of spoken comments and video segments of physical behaviors of participants as they accomplished tasks (Ericcson & Simon, 1984; Newell & Simon, 1972; Lewis, 1982). Additionally, participants completed a debrief questionnaire to determine their overall impressions of the help system. These responses were used to assess attitudinal differences as well as corroborate findings from verbal protocols.

1.6 Limitations of the Study

This study was limited in the following ways:

1. The length of time spent with each participant. A total of one hour and forty-five minutes was allocated for each data collection session. This included: a) a brief overview of Linkway Live!™, the software program used to design the two help systems and the study tasks, b) verbal reports as participants attempted to accomplish tasks, and 3) time for participants to respond to the debrief questionnaire. Participants had a maximum of one hour to accomplish tasks, with no subsequent follow-up. The short timeframe and lack of follow-up made concurrent verbal reports (verbalizing while performing) the most appropriate form of verbal analysis. Ideally, retrospective reports would also have been collected. These reports would allow the
researcher time to review data to identify especially interesting aspects and areas
needing clarification. As time permitted, the researcher gathered retrospective reports
once participants had completed tasks but before they completed the debrief
questionnaire.

2. Lack of realism. The presence of the researcher and the demand to talk while working
may have influenced participant remarks and behaviors. Experience has shown that
participants generally become comfortable with speaking while working, but the
technique does alter behavior.

3. Design limitations. There were several limitations related specifically to the design of
the help systems used in the study. First, the highly graphic help system did not
simulate movement. The explicit representation of movement (i.e., animation) would
have provided a clearer and more realistic view of procedures contained in the help
system. Second, neither the text-only or the highly graphic help system remained
resident on the task screen. Participants had to transfer between the task and help
screens to obtain information. The inability to view help on the task screen is likely
to exacerbate forgetting and lead to errors.

4. The cognitive demands of the task. Study tasks required participants to read/process
help instructions. Given the cognitive demands required to read, sparse verbalizations
may occur. This likelihood is increased since participants had no prior experience
with Linkway Live!™.
1.7 Organization

This chapter provided an introduction to the study. It provided a description of the problem, motivation for the research project, objectives and approach. The chapter also identified the limitations and research questions used to guide the study. Chapter 2 presents a review of the related literature, including previous research on online help systems and the need for more research on help content. This chapter also presents GOMS, the model of procedural knowledge used to design the prototype help systems.

Chapter 3 presents the research methodology including research design, data collection methods and data analysis, and procedures. Chapter 4 presents the findings and Chapter 5 discusses the conclusions and implications of the study.
CHAPTER 2

REVIEW OF LITERATURE

This chapter is a review of the literature relevant to the present study. It begins with a discussion of two components of online help, presentation and content. The importance of procedural knowledge as one form of help content is then reviewed. A discussion of GOMS (Goals, Operators, Methods, and Selection Rules), the cognitive model of procedural knowledge used to design the prototype online help systems follow. The chapter concludes with a review of the picture research literature for insights into how and why graphical representations may impact the effectiveness of procedural help content.

2.1 Presentation and Content in Online Help

A preponderance of the literature on documentation, including online help, explores various presentation characteristics such as readability (Bly & Rosenberg, 1986; Gaylin, 1986; Houghton, 1984; Norman, Weldon, & Shneiderman, 1987; Roemer & Chapanis, 1982; Shneiderman, 1982; Spyridakis & Wenger, 1990), typography (Dumas,
1988; Horton, 1990; Keyes, 1993), and the use of color (Begeman & Conklin, 1988; Benbasat, Dexter, & Todd, 1986; Horton, 1990; Keyes, 1993; Williges & Williges, 1984). This vast literature offers a plethora of design guidelines to influence the communication effectiveness of both paper and online help documents.

The accumulation of such principles and guidelines serve as heuristics in the design of more effective online help (Reisner, 1987; Shneiderman, 1988). When applied in isolation, i.e., without regard to content, they possess several limitations. While it is true these principles can be used as teaching aids for new designers and "memory prompts" for more experienced ones, they currently do not comprise a sufficiently detailed toolkit of methods that can be easily applied and evaluated to better understand what works, under what conditions, and for which population of users (Reisner, 1987; Elkerton, 1988).

Further, Barker (1993) points to the weak theoretical base upon which many of these principles are based. Consequently, design principles are often based on the intuition and personal experience of particular designers with particular systems (Farooq, 1988; Williges & Williges, 1984), resulting in a multitude of guidelines that are not generalizable across help systems. Correspondingly, there is considerable complexity and decision making involved in applying such a wide array of often conflicting principles in a single interface (Keyes, 1993; Reisner, 1987).

Elkerton (1988) cautions that the sole reliance on qualitative design principles result in many online help systems which fall short of the ultimate goal of helping users
with their current problems, while also supporting continued skill acquisition of how the system functions. This final criticism is especially integral to the present study.

One way to help users solve online tasks is to provide interface knowledge of system commands and functions. This knowledge includes the actual procedures users must know in order to communicate with the computer system. The insufficiency of purely qualitative guidelines to provide procedural knowledge is clear. As Heckel (1984) notes highly communicative presentation characteristics are important, however, knowledge of the procedural methods necessary to communicate with the system are essential to effective help system design. These methods are a part of help content, not presentation.

Unfortunately, little prior research exists on online help content. Much of the available literature on content relates to documentation in print form (e.g., printed help and reference manuals). This literature identifies help, to a greater or lesser degree, as either procedural or explanatory in nature (Gwei & Foxley, 1990; Wright, 1988). Simply stated, procedural content contains the how-to-do-it knowledge or interface methods required to accomplish online tasks; while explanatory content attempts to give the user a better understanding of the system with which she is interfacing and can include definitions, examples, analogies, or summaries (Wright, 1988). In actuality, most online help systems contain both procedural and explanatory characteristics as identified in Figure 1.
Previous research on explanatory help content has resulted in mixed findings. For instance, users do follow written examples (Pepper, 1981; Ross, 1984), but they sometimes rely too heavily on these examples, especially in cases where there is conflicting information contained in the text body and the accompanying examples (Wright, 1988). Hartley and Trueman (1985) note that retention can be enhanced with written summaries that help explain facts and concepts. In contrast, Carroll and his colleagues found summaries can cause difficulties when used with text giving procedural instruction (Carroll, Smith-Kerker, Ford, and Mazur, 1986). Specifically, they report
users sometime attempt procedures on the summary information alone which in isolation is insufficient. At other times, summary information is completely ignored or in some other way misused by users.

The findings on procedural content are more definitive. Reder, Charney and Morgan (1986) in their work on elaborations in skill learning found that for users who have already developed goals for interfacing with the computer system, the necessary procedures for accomplishing these goals are paramount, rather than an explanation on any particular procedure. Further, Wright (1988) in a review of previous work on content, concludes that until procedural knowledge is acquired and internalized, explanations are of minimal benefit in helping users communicate with the computer system. It is this researchers' belief that procedural knowledge is critical to the effective design of online help. One goal of the present study is to develop a model of the procedural knowledge necessary to operate an authoring system. This knowledge will then be used to design the help system prototypes for the study.

2.2 Procedural Knowledge Representation

One way to represent procedural knowledge is through cognitive models. Cognitive models are prominent channels by which researchers in the field of human-computer interaction (HCI) test their theories of human cognition (Borgman, 1984; Carroll & Olson, 1988; Farooq & Diminick, 1988; Foss & DeRidder, 1987; Kieras, 1988; Norman, 1988; Reisner, 1987; Wilson & Rutherford, 1989). These models help determine
knowledge users possess or need to possess in order to communicate with a computer interface (Borgman, 1984; Carroll & Olson, 1988; Farooq & Diminick, 1988; Foss & DeRidder, 1987; Norman, 1988; Reisner, 1987; Wilson & Rutherford, 1989).

This study utilized a particular cognitive model, GOMS (Goals, Operators, Methods, and Selection Rules) to develop the content for the prototype help systems (Card, Moran, & Newell, 1983). Following is a description of the GOMS model including a discussion of the importance of goal structure analysis, a fundamental component of GOMS. This section concludes with a review of the literature on GOMS and online help.

2.2.1 GOMS Model Overview. GOMS was initially evaluated in the domain of text-editing. Card, Moran, and Newell (1983) sought to determine how our understanding of human text-editing performance might be enhanced by taking into account the cognitive behavior of the user. The GOMS model was developed to describe this behavior. Specifically, GOMS was an attempt to describe the procedural knowledge of experts as they completed text-editing tasks. GOMS assumes that human text editing performance is governed by several cognitive information processing components: goals are what the user is trying to accomplish such as edit a file, operators are the allowable actions of the system such as clicking a mouse, methods are the sequences of actions or steps that will accomplish a goal, and selection rules are heuristics for specifying the appropriate method when alternative methods exist for accomplishing a goal.
Once complete, the GOMS model was used to make quantitative predictions such as: (1) the amount of time required for an expert to perform specific text-editing tasks, (2) the accuracy of the GOMS model in predicting the correct sequence of methods executed by experts, and (3) the accuracy of the model in predicting choice of method to accomplish editing tasks when alternative methods are available. The GOMS model predicted the time required to complete tasks to within 36%. The model accurately predicted both correct method sequence and choice of method 90% of the time. These findings led Card, et al. (1983) to conclude that GOMS provided an accurate description of the procedural knowledge required by experts to accomplish text-editing tasks.

A number of researchers have applied the GOMS model to domains outside text-editing. It has been used to describe performance in spreadsheet and database query tasks (Olson & Olson, 1990), and identify the information needed for telephone operators to respond to customer phone requests (John, 1990). More germane to this study, Elkerton and his colleagues have shown that the procedural description garnered from a GOMS analysis can also be used to formulate the substantive procedural content of written documentation and online help (Elkerton, 1988; Elkerton, Goldstein, & Palmiter, 1990; Elkerton & Palmiter, 1991; Gong & Elkerton, 1990;). To illustrate, Figure 2 is an abbreviated GOMS analysis for the goal "Create text field" from the Linkway Live!™ authoring system used in the present study.
GOAL: Create text field

Sub-goal 1: Select text
Sub-goal 2: Define text location
Sub-goal 3: Verify text ok

METHODS
Sub-goal 1 steps: Select text
Step 1.1 Click mouse on Object pull down menu item
Step 1.2 Click on new
Step 1.3 Click on field
Step 1.4 Click outside box
Step 1.5 Verify goal accomplished

OPERATORS: Elementary motor or mental acts such as define location, verify text, click mouse, and verify goal accomplished

SELECTION RULES: Not applicable to this goal since there is only one method to select text.

Figure 2. An Example of a GOMS Analysis for the goal "Create text field" and sub-goal "Select text" from Linkway Live™

Notice that the goals and methods components of the analysis provide, at varying levels of detail, a description of the knowledge, or mental steps necessary to accomplish the goal. In form and content, the methods component is almost identical to a description of the information that would be contained in a procedural-based online help system.

The GOMS model was selected because it provides a systematic method for extracting procedural knowledge. While using a GOMS model does not guarantee completeness or total accuracy, it does allow a focused and detailed analysis of the task, thus reducing the probability of error or omission (Elkerton & Palmiter, 1991). Reisner (1987) notes that since modeling techniques such as GOMS provide general ways of
analyzing problems, they can be used in myriad ways. For instance, they can help researchers uncover system design flaws that lead to user error; make predictions about performance criteria such as time and accuracy; and evaluate overall system usability (Reisner, 1987; Elkerton, 1988; Card, Moran, & Newell, 1983).

Since cognitive models are based on psychological theories of human cognition (such as information processing) and can be tested empirically, they also help build the HCI scientific base. Although psychological theories can never be explicitly validated, that is, we will never know exactly what is going on in the brain, cognitive models are the vehicles by which these theories are formulated, hypothesized, and tested. Therefore, cognitive models have the potential of encouraging their use through empirical findings and scrutiny (Farooq & Dominick, 1988).

2.2.2 GOMS Goal Structure. GOMS assumes human behavior is goal directed and that humans will choose and execute specific actions to accomplish these predetermined goals (Olson, 1987; Polson 1987). Using a goal structure to organize documentation is not new (Carroll, et al., 1986). What is new is the application of a formal model such as GOMS to develop this organization (Elkerton & Palmiter, 1991).

A number of researchers have recognized the value of goals and goal analysis in online and human aiding dialogues (Black, Kay, & Soloway, 1987). For instance, Elkerton (1988) notes that providing assistance based on goals is a particularly appropriate strategy for advising users on what can be accomplished at the computer interface. In their work on interface design for advice giving expert systems, Carroll and McKendree
suggest that an implicit or explicit reminder of a users' goal after an error has occurred will increase subsequent performance. Similarly, in their work with natural language help systems, Gwei and Foxley (1990) urge that effective help systems should be able to translate user inputs into goals. Working with human aiding dialogues, Aaronson and Carroll (1987) found that identifying a users' goal structure was a common strategy used by consultants responding to user queries via electronic mail.

2.2.3 GOMS and Online Help. Elkerton and his colleagues were the first to apply the GOMS model to the design of online help (Elkerton et al., 1990; Elkerton & Palmiter, 1991). Focusing on help access and content, Elkerton and Palmiter (1991) found that overall performance of GOMS users was more stable when compared to users of a more explanatory based help system. These researchers surmised that the explicit procedural structure of GOMS facilitated retrieval, while the more explanatory structure of existing help required users to explore more help screens for needed information.

Elkerton, et al. (1990) concentrated their analysis on help content and concluded that GOMS users performed more consistently and spent less time per help display when compared to users of the original help system. Moreover, for more complex tasks GOMS was a superior method, and for simple tasks the original help system was superior to GOMS. In an explanation of this latter finding, Elkerton, et al. (1990) suggest graphical representations that were a part of some of the original help system screens may have helped users perform simple tasks. For example, a view of a pull-down menu item set with a highlighted selection (e.g., delete) may have helped users of the original
help system. Users may have been able to acquire and translate these graphical cues into the correct procedural steps faster than GOMS users were able to acquire and translate the procedural steps directly.

Although little empirical evidence exists on the utility of graphical representations on performing procedural tasks, the related picture research literature provides some insight (Stone & Glock, 1981; Marcel & Barnard, 1979; Booher, 1975). A primary goal of the present study is to enhance the research base in this area by exploring the utility of graphical representations in the design of procedural online help content.

2.3 The Utility of Graphical Representations

While it is true that graphics and words both help to visualize parts of reality not immediately present or accessible to one's direct experience (Monitor, Ballstaedt, and Mandl, 1989, pg. 3), words remain the primary vehicle of communication in most societies. Word dominance suggests the discursive system is more efficient than a graphical or pictorial one (Williams, 1993). Hunter, Crismore, and Pearson (1987) offer as an explanation that "language, of all symbolic expressions, is the most explicit and the most amenable to converting vague, amorphous, and fleeting thoughts into controlled and easily retrievable propositions" (pg. 117).

Ultimately, the demands of the task and the features typified in words and graphics should dictate the role each plays in human-computer interaction. Williams (1993) makes this clear with the following:
The appropriateness of the [communication] medium depends on the degree to which it can facilitate the matching of the task demands with the structure of the information needed to accomplish the task. (pg. 674).

Graphical representations in the current context refers to still or animated computer generated images of online help content. There is evidence that these representations may be more useful than text-only representations of procedural knowledge similar to that found in most online help systems. Several researchers offer rationales for the apparent facilitative effects of graphical representations. Shneiderman (1986) and Sukaviriya and Foley (1990) believe that graphical representations may aid users in understanding the interface structure, which in turn may assist users in learning and remembering how to operate the computer interface. According to Sukaviriya and Foley (1990), textual explanations enhanced with graphical animation or illustrations which portray a sense of animation aid users in following procedural directives. The remainder of this section explores the utility of graphical representations more fully. First, the picture research literature is reviewed. This is followed by a discussion of several theoretical models which help explain the differential effects of text and pictorial processing.

2.3.1 Picture Research. Little research currently exists on the utility of graphical representations, therefore, the related picture research literature is discussed. The picture literature is broad; covering a plethora of research foci. As examples, Levie (1987) provides a comprehensive overview of picture research from myriad perspectives including cognitive psychology, memory, human learning, and visual perception. A
sizable body of literature also exists on the effectiveness of pictures and illustrated texts on processing (Beck, 1984; Marr, 1982; Pylyshn, 1984; Triesman, 1986), recognition (Goldstein, et al., 1982; Haber & Myers, 1982; Shepard, 1967), recall (Ackerman, 1985; Paivio & Capo, 1973; Ritchey, 1982), and comprehension (Bransford & Johnson, 1972; Schallert, 1980). Some researchers have taken a practical approach by applying research based principles to the design of illustrated texts (Fleming, 1987); others have concentrated on the problem solving process used by experts to evaluate and revise picture/text combinations (Benson, 1993).

Given the extensiveness of the picture literature and that the term "picture" is used variously to refer to photographs, illustrations, drawings, and graphs, it is useful to make clear distinctions for study purposes. In the present study, picture research is limited to literature on illustrations in instructional text and recognition and recall memory for photographs, illustrations, and drawings. Illustrations are defined as pictures, drawings, or diagrams that help clarify textual content. Levine & Lentz (1982) define illustrated texts as occurrences where illustrations contain highly related or redundant information explained in textual content.

Recognition memory, the largest body of picture research, has shown that memory for pictures is quite extraordinary (Shepard, 1967; Standing, 1973). Typical recognition experiments involve showing subjects a series of pictures followed by either a forced-choice or single item test. After showing subjects over 600 pictures from magazine advertisements, subjects were able to accurately identify pictures seen previously 98.5%
of the time (Shepard, 1967). Similarly, Standing (1973) reported an 83% accuracy rate after showing subjects over 10,000 pictures over a five day period. The pictorial stimuli identified as contributors to this phenomenon include meaningfulness (Wiseman & Neisser, 1974), distinctiveness (Courtois & Mueller, 1981), color (Borges, Stepanowsky, & Holt, 1977), and movement (Goldstein, et al., 1982). With respect to graphical representations of online tasks, distinctiveness, color, and movement (i.e., animation) are several attributes for which computer technology can be an especially effective delivery medium.

In a meta analysis of fifty-five studies which compared learning from illustrated text with learning from text alone, Levie & Lentz (1987) found that: (1) non-detailed, text relevant illustrations facilitate learning textual content, and (2) these illustrations help learners understand and remember what they read while more detailed illustrations often go unnoticed. The conclusions of Dwyer (1978, 1982) help explain these findings.

Dwyer (1978, 1982, 1983) and his colleagues have conducted over 200 studies on the effect of pictorial illustrations on learning factual knowledge. These studies consisted of a set of illustrations of the human heart presented using a variety of instructional formats (e.g., computers, booklets, television, and slides). Several general conclusions can be drawn from this extensive research program. The first is that pictures are most helpful in visual discrimination tasks such as identifying parts of the heart. Second, there is a relationship between time to task completion and level of complexity. When time is limited, simple illustrations are most useful. With unlimited time to task completion,
limited, simple illustrations are most useful. With unlimited time to task completion, more complex illustrations result in increased performance. This latter conclusion is consistent with Elkerton (1990) who suggest simple, non-detailed pictorial illustrations may have assisted users of an online help system quickly acquire and translate procedural steps into executable actions.

2.3.2 Picture Research and Procedural Tasks. Of particular interest to the present study is the utility of highly graphical representations on learning the procedural knowledge necessary to operate a computer interface. Specifically, this study explores the facilitative effects of two informationally equivalent help systems which differ in how each represents help content. One help system consists of text-only content while the other embodies representations which are highly graphical with very limited text content. As explained by Larkin and Simon (1987), two representations are informationally equivalent if each representation could be constructed from the information contained in the other.

Several studies which compared text-only and text relevant illustrations of procedural instructions suggest graphical representations may facilitate procedural knowledge acquisition (Booher, 1975; Marcel & Barnard, 1979; Stone & Glock, 1981). Stone and Glock (1981) found pictorial representations more useful than purely verbal descriptions of the same actions and concluded the representations helped readers translate their understanding of procedure based tasks into appropriate actions. Similarly, Booher (1979) concluded highly pictorial picture/text combinations which contained
These studies offer encouraging results, but some degree of caution is necessary since they differ in several important ways from the present undertaking. First, none of these prior efforts involved computer technology as the delivery medium. The Stone and Glock (1981) study which required the physical assembly of a piece of manual equipment used printed instructions. Booher (1975) used printed pictorial and text instructions to guide the operation of a task simulator apparatus, and Marcel and Barnard (1979) used slides as the delivery medium to provide instructions on how to operate a control panel display.

Second, these prior studies focused on how-to-do-it knowledge necessary to either operate or assemble equipment. In these instances, there is a limited range of tasks to be accomplished (e.g., set switch to ON position, check power light illumination, insert short rod through clip) and a narrow range of means (e.g., buttons, switches, assembly parts). In the present study, this "user as operator" focus is replaced with a more communicative exchange between user and machine. In this exchange, both user and computer have access to a stream of symbols including mouse clicks, keystrokes, and screen displays, as well as the computer's programs for controlling the interaction—all of which are necessary to carry on the communication (Card, Moran, & Newell, 1983). The present study builds on past efforts and aims to broaden our understanding of procedural knowledge representation and acquisition in more dynamic domains such as human-computer interaction.
2.3.3 Theoretical Models of Picture Processing. Thus far, the claim that highly graphical representations may facilitate learning, comprehension, and memory has been supported with empirical findings but with little theoretical foundation. A number of models and theories have attempted to explain the differential effectiveness of text and picture processing such as Gibson and Levin's (1975) collective of models on how people learn to read pictures and text, Clark and Chase's (1972) theory of sentence and picture comparison, Rumelhart's (1977) schema theory of reading comprehension, Larkin and Simon's (1987) model of informational and computational equivalence of sentence and diagrammatic representations in problem solving, and Reynolds and Baker's (1987) model of selective attention and prose processing. The abundance of competing and complementary explanations of text and picture processing speak to the complexity of the issue. It is this researcher's belief that the cognition of text and graphic processing can not be explained by a single model or theory. However, the combination of three models, preattentive and attentive processing (Pylyshyn, 1984; Treisman, 1986), cue summation (Severin, 1967) and economy of processing (Gibson & Levin, 1975) provide a theoretical foundation for the differential effectiveness of text and graphical representations of procedural knowledge.

2.3.3.1 Preattentive and attentive processing. Perceptual processing of both pictures and words is generally thought to occur in sequential stages, first in parallel then, as needed, in serial fashion (Pylyshyn, 1984; Treisman, 1986). Preattentive processes are thought to operate rapidly, automatically, in parallel, and with little demand on cognitive
resources (Winn, 1991). Research has shown that much of the message embodied in a picture can be processed preattentively requiring little or no conscious effort (Treisman, 1986; Kolers, 1986). These preattentive processes are primarily influenced by the environment and not dependent on knowledge stored in memory (Winn, 1991) and are considered "cognitively impenetrable" (Pylyshyn, 1984) or beyond the reach of conscious thought. That is, one cannot willfully alter the information contained in a message which can be processed preattentively. Winn (1991) provides an excellent example:

However hard you try, you cannot make yourself not see the edge of the page you are reading as a border that separates this [document] from what you see beyond it (the wall or bookcase perhaps).

As evidence of preattentive processes, Loftus and his colleagues (1975, 1983) have shown that the gist, theme or global message of a picture can be processed preattentively in a single fixation. In sum, much of the information needed to "understand" a simple visual image is processed without any conscious attentive resources (Williams, 1993).

Conversely, the preattentive stage of text processing is primarily devoted to discerning the distinctive outlines of words and letters. The majority of text processing then proceeds slowly, serially, and requires considerable cognitive resources (Pylyshyn, 1984; Williams, 1993). These attentive processes operate not so much on the environment but on the knowledge we already possess such as our understanding of vocabulary and sentence structure. In picture processing, the attentive stage is devoted to extracting specific or local feature information such as distinctions between particular
objects (Loftus, 1983; Navon, 1977). Simple pictures, like the graphical representations used in the present study, contain minimal amounts of specific feature information.

The amount of attentional resources required to interpret text and graphical messages is particularly pertinent to the design of online help. As noted by Paz et al. (1989), the user of online help is already suffering from mental stress as evidenced by her need to resort to the help facility. Therefore, to avoid heightened mental dissonance, it is logical to conclude that help content should be presented in a form most amenable to preattentive processing. This suggests that if a highly graphic help system is more amenable to preattentive processing than a text-only system, it should require fewer conscious attentional resources.

In addition to requiring fewer attentional resources, a highly graphic help system may allow users to direct attention in a more economical manner than a text-only help system. Gibson and Levin's (1975) economy of processing model helps explain why. These researchers disavow that one model adequately explains how people read text and pictures. Instead of one universal process model, they have extracted common findings from numerous research studies of the reading process. One principle of the economy of processing model states users will direct attention in the most economical way possible. This principle assumes users will select relevant pieces of information and ignore that which is irrelevant or of no utility. This assumption is consistent with the selective attention theory that users will focus more attention on those elements which they deem important (Loftus, 1979; Nelson & Loftus, 1980; Parker, 1978; Reynolds & Baker,
1987). This first principle further assumes users will process the least amount of information necessary to accomplish the task. If the highly graphic representations used in the study are, in large part, processed preattentively they should require less conscious attentional resources and therefore provide more cognitive economy than text-only representations. Although the two help systems are informationally equivalent, the sentential form of the text-only help system should require more information processing than the highly graphic help system. Stated differently, highly graphic help should convey the intended content with fewer cognitive demands on participants than text-only help. The following discussion of single and multiple representations explain how a highly graphic help system which requires fewer attentional resources can also provide greater utility.

2.3.3.2 Single and Multiple Representations. Given the purported effectiveness of graphical representations, why is it that a highly graphic as opposed to a graphic-only help system is being analyzed? Cue summation theory (Severin, 1967) suggests multiple representation (text and picture) forms are more effective than single forms for performing procedural knowledge acquisition tasks so long as the information in neither form interferes with the other and information in both forms is highly related. The theory states that information not easily understood in one form can be added to information more readily understood in the other form, hence the total message being communicated is better understood than if either form were used exclusively. Cue summation theory is consistent with the available empirical evidence. Picture-text combinations used to
provide procedural instructions have resulted in fewer errors than purely pictorial or
 textual representations (Booher, 1975). Stone and Glock (1980) have also shown that at
points of ambiguity in text relevant illustrations, the presence of redundant information in
one form (e.g., illustrations) provides users with the opportunity to seek clarification
from the alternate form (e.g., text).

The second principle of Gibson and Levin's (1975) economy of processing model,
which complements the cue summation theory, posits that reducing ambiguities during a
reading episode is a built in mechanism of the human processing system. This principle
further states that one way humans seek information reduction is to resolve any
ambiguities posed by alternate representational forms.

If multiple representation forms are desirable, the question remains just how
textual and graphic information should be organized to maximize processing. Booher
(1975) conducted a study which compared the effectiveness of six different text and/or
picture forms. The design varied type of form (single or multiple), degree of information
equivalence (related or redundant), and function of text and pictures (context, focus,
and/or action-step) used to provide procedural instruction. Context informs the user of
the general surrounding and scope of actions, focus aids the user in concentrating on the
specific objects to be used to carry out instructions, and action-step are the specific
behavioral steps necessary to carry out the instructions. Considering both performance
time and speed, highly pictorial multiple representation forms were the only formats
which were consistently fast and accurate. These results suggest subjects were getting
more information in the same amount of time about many of the subroutines necessary to accomplish the task. For instance, it appears subjects acquired information about several objects and actions to form a perceptual blueprint which allowed them to organize and execute a series of commands. Similarly, more subroutines may be started earlier with pictorial than text formats since textual inputs must be read serially, from left to right, then translated into executable actions. These findings lead Booher (1975) to conclude that performance was maximized when context and focus information were presented pictorially and action-step information was presented textually as described below:

The human processing system is most efficient in comprehension of instructions when pictorial information is used to aid in the selection and organization of a range of perceptual-motor actions and textual information is available to confirm specific actions within the range. (pg. 276)

Booher (1975) concluded text-only and text dominant instructions of procedural tasks resulted in poor accuracy and time performance because textual representations alone, or in domination, do not maximize the pictorial and verbal processing mechanisms available for selecting and organizing information.

The preattentive and attentive processing and economy of processing models, and cue summation theory provide a theoretical basis for the claims of graphical superiority over text in procedural knowledge tasks. One goal of the study was to determine the extent to which these three conceptions provide adequate theoretical accounts of the utility of graphical representations in procedural knowledge tasks.
2.4 Summary

This chapter presented some of the literature relevant to the current study. The presentation component of online help continues to dominate the literature, but help content is an integral component toward understanding the interface methods necessary to communicate with the help system. The limited literature on content suggests that initially it is procedures users want to master, rather than an explanation of how the system with which they are working functions (Wright, 1988). One goal of the present study was to construct a model of the procedural knowledge necessary to operate an authoring system for a set of benchmark tasks.

GOMS was used to build this model. It was selected because it provided a comprehensive analysis of the procedural knowledge required to communicate with a system and it has been used in a number of domains including online help.

Prior evidence suggests purely textual representations of procedural knowledge, similar to that embodied in the content of most online help systems, can be enhanced with graphics. Much of the empirical support for this assertion comes from the picture research literature. This literature has uncovered significant positive results for text relevant pictorial illustrations in learning, recognition, and comprehension tasks. Pictorial illustrations have also resulted in fewer errors and more accurate performance when compared to text-only instructions.

A number of theoretical conceptions attempt to explain the differential effectiveness of text and graphics processing including preattentive and attentive
processing, selective attention, schema theory of reading comprehension, and economy of processing. The present study explores the extent to which three of these conceptions, preattentive and attentive processing, economy of processing, and cue summation provide adequate theoretical accounts of the utility of graphical representations in accomplishing procedural tasks.

The following chapter explains the research methods and procedures used in the study.
CHAPTER 3

METHODOLOGY AND PROCEDURES

This chapter provides the methodological approach for the study. It begins with an overview of the research design. The data collection instruments and participant characteristics are then described. Next, the data collection methods and testing procedures used in the study are presented. A discussion of the analysis protocols and techniques concludes this chapter. The next chapter presents the findings of this research effort.

3.1 Research Design

This study used a mixed methodological approach which is best described by separating the design, data collection, and data analysis components. The research design is descriptive. The ends sought were to explore and describe the experiences of participants as they communicated with text-only and highly graphic representations of help content. These experiences were used to uncover the facility with which participants were able to accomplish online tasks. Since in-depth, information rich cases
were desired, a case study approach was used. A purposeful sampling technique, typical case, was used to select participants (Patton, 1990). To identify the phenomena of interest, two help systems were designed; one text-based and the other graphics-based. The shared experience is between the participant and the computer interface, not the researcher. Therefore, the role of the researcher is primarily that of a non-participant observer whose purpose was to guide the participant if s/he disengaged totally from the communication with the computer, made an non-recoverable error, and to record any interesting or unusual findings.

Qualitative data collection methods were utilized. Specifically, verbal protocols were used to capture spoken comments and physical actions of participants as they completed the twelve study tasks. An open-ended debrief questionnaire was used to gather data on participants overall experience with and impressions of the help systems.

Data analysis techniques were primarily qualitative in the form of content analysis and summaries, but where appropriate, quantitative analysis techniques were used. As an example, to assist in summarizing findings, descriptive statistics including means, frequencies, and percentages were used.

3.2 Help System Development

Two help systems were developed to address the research questions of the study. Both systems were informationally equivalent meaning that all the information in one system was also inferable from the other and vice versa (Larkin & Simon, 1987). The
GOMS model was initially used to design the prototype text-only help system. This prototype was then used as the foundation for the highly graphic prototype. The highly graphic prototype, although informationally equivalent to the text-only prototype, included explicit graphical representations of the Linkway Live!™ interface such as pull down menus, dialogue boxes, and cursors.

The purpose of the GOMS analysis as applied to the present study was to identify the procedural knowledge necessary to operate the Linkway Live!™ interface. GOMS assumes human behavior is goal directed and that humans will choose and execute specific actions or steps to accomplish these pre-determined goals. Therefore, the framework for the GOMS analysis was based on the goals a user would have when communicating with Linkway Live!™. The GOMS analysis utilizes a top-down approach; first describing the highest level goals possible, then in iterative fashion describing in increasingly more detail the specific methods required to accomplish a goal. A sample GOMS analysis for “creating a text field” is presented in Appendix A.

Once methods were described as a series of executable actions, the paper-based GOMS analysis for that particular goal was complete. A completed GOMS analysis for the twelve benchmark study tasks is presented in Appendix B. Next, both help system models were programmed using Linkway Live!™ into the Linkway Live!™ authoring environment. Because Linkway Live!™ is an authoring system it was used to build both help system prototypes as well as design the study tasks.
This study differed from other implementations of GOMS in two fundamental ways. First, it incorporated graphical representations, not just text. Second, help methods were presented at two levels of detail, not just a single level as is generally the case with a GOMS analysis. As shown in Figure 3, high level methods appeared to the right of the screen. These methods are the general methods which are common to many Linkway Live!™ goals. Once a participant clicked on one of these high level methods, the specific actions, or executable level steps were presented to the left.
This particular structure was selected for two reasons. First, a goal of the help system prototypes was to not only assist participants in accomplishing the current task, but to help them also understand the general methods required to communicate with Linkway Live!™. The high level goals represent the general methods necessary to accomplish many Linkway Live!™ goals. Second, help system design was intended to
provide flexibility as participants became more knowledgeable of how to communicate with the interface.

3.3 Participant Selection

Twelve individuals participated in the study. Participants were graduate level education majors attending a five week course entitled “Computer Applications in Education” offered at a large, public university in Ohio. All participants had knowledge of computer basics, but none had experience with the Linkway Live!™ authoring program. Participants were asked to complete Linkway Live! authoring tasks using the embedded text-only and highly graphic help prototypes.

At the beginning of the course, all students were asked to submit, via e-mail, a brief profile describing their familiarity and comfort level with computers. These profiles were used to pre-screen candidates for the study. To qualify, a student had to have experience with at least one software application, be mouse literate, and have written English language proficiency. A tentative list of eighteen candidates was compiled. Each candidate was matched against his/her scheduled lab time to determine the number of possible candidates per lab. Since one-on-one data collection sessions would occur during regularly scheduled lab times, and data had to be collected within a one and a half week time period, it was important to carefully schedule sessions to guarantee maximum participation. Twelve of the eighteen candidates who met the above mentioned criteria were sent letters via e-mail requesting their participation. A sample letter is presented in
Appendix C. As needed, the remaining six candidates were used as alternates. Once confirmed for the study, students were randomly assigned to the text-only or highly graphic help system. At the end of each session, participants were provided a small gift for their participation.

3.4 Data Collection Methods

Data were collected via verbal protocols and a debrief questionnaire. Verbal protocols which included video and audio transcripts of comments, keystrokes and commands collected while participants completed assigned tasks using either the text-only or highly graphic help interface and a debriefing instrument administered after the completion of these tasks were used to collect data. Each is discussed below.

3.4.1 Verbal protocols. In discussing the cognitive domain of system design, Lewis (1982) points out that knowledge of the "mental machinery" to which systems must be fit is limited. He further states that to gain knowledge in this area, we must rely on an empirical approach that helps designers "identify the weak and strong points of a design, and learn enough about why a given design feature is good or bad to guide modification" (pg 1). The verbal protocol method is the most appropriate data collection method for studying such cognitive phenomena.

The verbal protocol technique was developed by Newell and Simon (1972) and is currently used in a wide range of applications including engineering and computer interface design (Chovan, 1990; Shute & Smith, 1993). Ericcson and Simon (1980)
describe the method in greater detail. Simply stated, participants are asked to make spoken comments as they worked through selected tasks. Insights into further design considerations were gained through the running commentary of participants' thoughts as they communicated with the text-only and highly graphic help system interfaces. Specifically, verbal protocols identified where participants encountered problems and the types of problems participants encountered.

Verbal protocols offer the researcher the advantages of: (1) postulating why problems or errors occur, (2) identifying problems when they occur, (3) detecting minor design flaws that may not be discernible with more traditional quantitative measures, and (4) learning about users' cognitive characteristics and attitudes. Moreover, small samples can be used yet still yield valuable feedback on system usability; and since representative or benchmark tasks can be identified, participants can work on pieces of a proposed system thus eliminating the cost of full blown system development (Lewis, 1982). The unnatural requirement to talk while working, the reality that not all thoughts can be verbalized, the researchers' presence, and the laborious nature of analyzing and summarizing such detailed information are the major limitations of the verbal protocol method (Stauffer, 1989; Lewis, 1982).

Although participants generally become accustomed to being observed and to the demand to verbalize their thoughts (Lewis, 1982), two procedures were followed to compensate for the possibility of sparse verbalizations. First, if spoken comments ceased for more than 15 seconds, the researcher prompted participants to continue
verbalizing. Second, given the cognitive demands on participants, namely, the amount of reading required to translate help knowledge into actions (i.e., people generally don’t verbalize while reading), and the attentional resources required of novices (i.e., none of the participants were familiar with Linkway Live!™), fewer spoken comments may be uttered than desired for a thorough analysis. Fortunately, the robustness of the verbal protocol technique allows for the recording of not only verbal data but data from physical actions as well. To compensate for the possibility of limited verbal data, an error analysis which focused primarily on participants physical actions was conducted. These findings were also used to corroborate and enhance verbalizations.

3.4.2 Debrief Questionnaire. Participants were debriefed once all tasks were completed. This debrief was in the form of an open-ended questionnaire. The purpose of the questionnaire was to determine the level of user satisfaction with each of the help systems and to corroborate findings derived from recorded observations of participants. This data collection method was chosen over a personal interview format to increase the likelihood of more candid responses. The debrief questionnaire is provided in Appendix D.

3.5 Data Gathering Sessions

Prior to actual data collection, a pilot test was conducted to make any necessary refinements to the study design. The following steps were taken to prepare for the data collection sessions:
1. Contact participants via e-mail and arrange mutually acceptable time for data collection sessions.

2. Reserve room to conduct sessions.

3. Organize and set up resources (mount video camera on tripod, make sure proper version of help system is loaded and functioning properly, check lighting and physical comfort of room).

The verbal protocols and debriefing data were collected in the following manner:

1. Participants arrived at mutually agreed upon time and place.

2. Participants sat so that the computer screen and their hands would be seen in the frame of the video camera.

3. The verbal protocol procedure was explained to participants. Participants were instructed to speak aloud what they were thinking as they completed each task. They were told to concentrate on the tasks and not on my presence during the sessions. They were further instructed to pretend that the researcher was not in the room and to relax as they worked through the tasks. Participants were informed that the researcher would only make comments if they stopped verbalizing for fifteen seconds or more. Lastly, participants were asked if they had any questions before the session began.

4. Participants were given a brief overview of Linkway Live!™. Participants then completed a sample task to familiarize them with the verbal protocol technique and
the Linkway Live!™ interface. When they felt ready, participants were asked to begin the study.

5. Participants were debriefed once they completed all study tasks or at the end of one hour, whichever came first. Upon completing the debrief, participants were thanked for their time and participation and were provided a small token for their efforts. This ended the data collection session.

3.6 Data Analysis

Both qualitative and quantitative techniques were used to analyze the findings of this study. Qualitative techniques were used to analyze: (1) the nature of problems participants encountered, (2) the information content of errors committed, and (3) written responses to the ten open-ended debrief questions. Quantitative techniques in the form of descriptive statistics were also used to augment the qualitative analysis by providing numeric measures such as frequencies and percentages. Each data analysis technique is discussed below.

3.6.1 Qualitative Analysis. Prior to analyzing findings from the problem and information content analyses, data reduction was performed. Classes of verbalizations irrelevant to the stated research questions were filtered from the transcripts. These classes included the following: (1) statements related to computer equipment; and (2) statements related to system processing time. All such statements and comments were deleted from the transcripts.
Verbal protocols were then initially analyzed to determine an instance of a problem. For purposes of this study, problem instances were defined as any difficulties or confusions with either help system which impeded task accomplishment. All such instances were first noted, then further analyzed to determine commonalities. These commonalities were then coded into one of five problem area categories. Lastly, these problem areas were then re-analyzed to uncover differences and similarities between and among the two help groups.

Next, an information content analysis was performed. The first phase of this analysis consisted of identifying all errors committed. The information content analysis served a dual purpose. First, as previously mentioned, there is a chance for incomplete verbalizations. Since the error analysis focused primarily on the physical behavior (that is, what participants did, not what they said), it yielded valuable non-verbal data. Second, it revealed the more critical problems for which participants were unable to recover.

For purposes of the study, an error was defined as any instance in which a participant omitted or added a step not included in the help instructions, or attempted to perform a step or series of steps included in help instructions but attempted out of sequence. The ultimate goal was not simply the enumeration of errors, but rather the underlying content which participants either misinterpreted or did not understand. A taxonomy of information content for the present study was adapted from the work of Bieger and Glock (1981), who were interested in identifying the essential information.
contained in text and pictures to improve the effectiveness of procedure-based materials. These researchers worked with the relatively simple case of assembling a non-mechanical device. While there are some similarities between this type of procedural task and the type proposed in this study, the requirements of the two tasks are not completely transferable. Therefore, their initial taxonomy was adapted to encompass the more complex case of human-computer interaction. The information content taxonomy is presented in Table 1.
Table 1

**Taxonomy of Essential Information Content for Task Completion**

<table>
<thead>
<tr>
<th>Information Category</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operational</td>
<td>Information that directs participants to engage in a specific action.</td>
</tr>
<tr>
<td>Element</td>
<td>Information which specifies which objects or elements of the system to act upon.</td>
</tr>
<tr>
<td>Qualifying</td>
<td>Information which modifies other information by specifying the manner or limits of the information.</td>
</tr>
<tr>
<td>Spatial</td>
<td>Information which specifies the position, orientation, or location of an object or element in space in relation to another object, element or fixed point of reference.</td>
</tr>
<tr>
<td>Higher Order</td>
<td>Information which is not attributable to any of the other four categories and which results in the non-execution of an entire task or sub-goal. Because these errors signal more pervasive misunderstandings than the others, they often result in one or more additional errors.</td>
</tr>
</tbody>
</table>

Adapted from Bieger and Glock (1981)

The final qualitative analysis was performed on responses to the debrief questionnaire. Summaries of responses were analyzed to determine both overall impressions and specific reactions to each help system. Again, data were further analyzed to determine similarities and differences between and among the two groups of participants.
3.6.2 Descriptive Statistics. In addition to the qualitative analysis just described, quantitative measures in the form of descriptive statistics were also used. The purpose of these quantitative techniques were to illustrate the degree of differences and similarities between the two groups, not to provide any measures of statistical significance. As previously mentioned, this study was exploratory in nature and the purpose was to describe, rather than make any causal comparisons. To provide a more comprehensive description of findings, frequencies and percentages of problem instances and information content were calculated.

Chapter 4, which follows, presents the findings of this research study. Chapter 5 discusses the conclusions, implications, and offers suggestions for future work.
CHAPTER 4

FINDINGS

This chapter presents the findings of the study. First, background data describing the sample are presented. Next, an analysis of problems participants encountered is discussed. This is followed by the information content analysis of errors participants committed while accomplishing study tasks. The chapter concludes with a summary of participants’ reactions to the debrief questionnaire.

4.1 Description of the Sample

As is common in qualitative summaries, participants have been assigned aliases. It is hoped that the use of aliases will allow the reader to better follow participants’ experiences and more closely share in these experiences throughout the presentation and discussion of results. For simplicity, all text-only participants have been assigned an alias which begins with the letter “T”, and highly graphic participants have been assigned aliases which begin with the letter “G”.

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A total of eleven participants participated in the study. A twelfth participant agreed to participate but did not attend the scheduled data collection session. The gender and age demographics of participants can be found in Table 2.

Table 2

**Gender and Age Demographics for Sample**

<table>
<thead>
<tr>
<th>Gender</th>
<th>Help Type</th>
<th>Text-Only</th>
<th>Highly Graphic</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td></td>
<td>4</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>Male</td>
<td></td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Totals</td>
<td></td>
<td>5</td>
<td>6</td>
<td>11</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Age</th>
<th>Help Type</th>
<th>Mean</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Text-Only</td>
<td>26</td>
<td>25-27</td>
</tr>
<tr>
<td></td>
<td>Highly Graphic</td>
<td>37</td>
<td>24-51</td>
</tr>
</tbody>
</table>

The computer experience of participants varied from limited to extensive. Figure 4 shows all participants had experience with wordprocessing and several had experience across platforms.
Figure 4. Depth of Computer and Platform Experience

4.2 Problem Analysis

The purpose of this analysis was to identify and describe the nature of problems participants encountered when translating help knowledge into correct actions. Verbal protocols were initially analyzed to determine an instance of a problem. Problem instances were defined as any difficulties or confusions with either help system which impeded task execution. In some instances, these difficulties were a result not of the differential effectiveness of text and graphics but rather of nuances of the Linkway Live!™ interface and of participants’ prior knowledge and experience. While behaviors
which reflect differences between textual and graphical representations are of primary concern to this research effort, nuances and prior knowledge are inextricably linked to the verbal behaviors of participants. Therefore, these phenomena have also been analyzed and integrated in the discussion of results.

Five problem areas and sixty-two associated problem instances emerged from the analysis. The five problem categories were: forgetting, transfer of learning, referent representation, manipulating graphical elements, and spatial arrangement of help steps. As shown in Table 3, problems with forgetting were prevalent for both text-only and highly graphic participants; while manipulating graphical elements posed a greater problem for text-only than for highly graphic participants. The frequency of transfer of learning problems was similar for both groups.
### Table 3

**Task Goal and Frequency of Problem Instances by Help Type**

<table>
<thead>
<tr>
<th>Task Goal</th>
<th>Forgetting</th>
<th>Manipulating Graphical Elements</th>
<th>Transfer of Learning</th>
<th>Referent Representation</th>
<th>Spatial Arrangement</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TO HG</td>
<td>TO HG</td>
<td>TO HG</td>
<td>TO HG</td>
<td>TO HG</td>
<td></td>
</tr>
<tr>
<td>1 Create a Field Object</td>
<td>1 1</td>
<td>4 0</td>
<td>1 1</td>
<td>2 0</td>
<td>0 0</td>
<td>10</td>
</tr>
<tr>
<td>2 Move an Object</td>
<td>0 0</td>
<td>0 0</td>
<td>1 2</td>
<td>0 1</td>
<td>0 1</td>
<td>5</td>
</tr>
<tr>
<td>3 Cut an Object</td>
<td>1 2</td>
<td>0 0</td>
<td>0 2</td>
<td>0 0</td>
<td>0 0</td>
<td>5</td>
</tr>
<tr>
<td>4 Delete an Object</td>
<td>0 0</td>
<td>0 0</td>
<td>0 0</td>
<td>0 0</td>
<td>0 0</td>
<td>0</td>
</tr>
<tr>
<td>5 Copy an Object</td>
<td>3 2</td>
<td>3 0</td>
<td>1 0</td>
<td>1 1</td>
<td>0 0</td>
<td>11</td>
</tr>
<tr>
<td>6 Edit a Field Object</td>
<td>0 1</td>
<td>0 0</td>
<td>1 0</td>
<td>1 0</td>
<td>0 0</td>
<td>3</td>
</tr>
<tr>
<td>7 Draw a Box</td>
<td>1 0</td>
<td>0 1</td>
<td>4 0</td>
<td>0 1</td>
<td>0 0</td>
<td>7</td>
</tr>
<tr>
<td>8 Draw a Bar</td>
<td>0 0</td>
<td>1 0</td>
<td>0 0</td>
<td>0 0</td>
<td>0 0</td>
<td>1</td>
</tr>
<tr>
<td>9 Move/Resize an Object</td>
<td>1 0</td>
<td>1 0</td>
<td>0 1</td>
<td>1 0</td>
<td>0 0</td>
<td>3</td>
</tr>
<tr>
<td>10 Edit a GoTo Button</td>
<td>3 3</td>
<td>0 0</td>
<td>0 0</td>
<td>1 0</td>
<td>0 0</td>
<td>8</td>
</tr>
<tr>
<td>11 Edit a Picture Object</td>
<td>2 0</td>
<td>1 0</td>
<td>0 0</td>
<td>3 0</td>
<td>0 0</td>
<td>6</td>
</tr>
<tr>
<td>12 Edit a GoTo Button</td>
<td>0 0</td>
<td>0 0</td>
<td>0 0</td>
<td>0 1</td>
<td>1 0</td>
<td>2</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>12 9</strong></td>
<td><strong>10 1</strong></td>
<td><strong>8 7</strong></td>
<td><strong>8 5</strong></td>
<td><strong>0 2</strong></td>
<td><strong>62</strong></td>
</tr>
</tbody>
</table>
The following sections discuss each of the five problem areas in greater detail. For each problem area, representative verbalizations from participants are presented. These data are used as illustrative examples of problems common to either the text-only or highly graphic group. In some instances, both groups experienced similar problems. When this occurred, the most information rich data were selected irrespective of help system type.

4.2.1 Forgetting. For study purposes, forgetting is defined as an instance, upon returning to the task environment, a could not remember a sub-goal presented in help. Text-only and highly graphic participants had similar forgetting experiences, therefore, the verbalizations presented in this section are representative of both groups.

Overall, participants experienced more forgetting problems with copying an object (task 5) and editing the appearance of a goto button (task 10). Copying an object was one of the longest tasks and editing the appearance of a goto button was one of the more complex of the twelve tasks. In over ninety percent of all forgetting instances participants were unable to recall the first step of the sub-goal and had to immediately return to help as the following verbalizations revealed:

I always have a hard time when I read all this stuff remembering where to start. [Glenn, task 10]
It’s so many steps I forget what I’m supposed to do. [Gabriel, task 10]
I have to go back because this all makes sense but I never pay attention to exactly what I’m supposed to choose from the menu. [Gloria, task 3]
The comment “choose from the menu” in the last verbalization refers to the first step of many of the sub-goals in which participants had to click on an object then select from the pull down menu an operation such as cut.

Once participants began a task, Linkway Live!™ automatically displayed a series of sub-tasks to be completed toward final completion of the task goal. For instance, the task goal creating a field object (task 1) consisted of six sub-tasks, each with a varying number of required steps. Each sub-task is automatically triggered and displayed on screen by the preceding sub-task. The extra burden on short-term memory resulting from the display of sub-tasks most likely attributed to forgetting as Tyra’s comment indicated:

You know what? I forget all these instructions. I have to go one by one. The problem is if I do step one it doesn’t stay in memory and then I have to go back and I will not remember. See, I forgot already. [Tyra, task 7]

4.2.2 Problems manipulating graphical elements. As is true with a growing number of software programs, the Linkway Live!™ interface includes graphical elements such as dialogue boxes and pull down menus. These elements are the primary means of communicating with the program to execute commands. The Linkway Live!™ interface utilizes four different graphical elements to communicate: dialogue boxes, objects (such as buttons and text fields), pull down menus, and cursors. As an example, participants encountered a total of thirteen different dialogue boxes. All but one dialogue box contained verbal (textual) prompts in which participants had to either click on a desired option (e.g., click anywhere outside box to close) or type a response (e.g., name an
object). The remaining dialogue box contained only graphical components in which participants selected the desired color of an object.

Problems in manipulating graphical elements specifically refer to a participant’s inability to recall the necessary procedural step(s) to accomplish an action (i.e., sub-goal) such as closing a dialogue box or naming an object. In the text-only help system graphical elements, and how to manipulate them to complete tasks, were described verbally. To illustrate, one of the steps in editing a button object read:

(GoTo dialogue box appears)
(a) Click on small box next to desired destination
(b) Click anywhere outside box to close

As indicated, text-only participants were first informed that a dialogue box would appear; procedural instructions on how to communicate with the dialogue box followed.

The highly graphic help system provided a nearly identical verbal description which was accompanied by representations of graphical elements and directives of how to manipulate these elements as illustrated in Figure 5.
Figure 5. Example of Highly Graphic Help System for Editing an Object

The number of problem instances for text-only and highly graphic participants, 10 and 1, respectively, suggest the explicit graphical representations facilitated the latter group’s ability to communicate with the graphical elements of Linkway Live!™. To illustrate, the manipulation problems encountered when creating a field object (task 1) and copying an object (task 5) are discussed. Tyra, Tammy, Tanya, and Tina’s experiences with these tasks will be used as illustrative cases. When creating a field object in Linkway Live!™, it is necessary to first define the size and location of the object. This is done by placing the cursor (which changes from an arrow to a dotted box) in the upper leftmost corner of the location to start the object, then moving the mouse outward and downward until the desired size is reached. Once the location is defined, one must click inside the
box to begin typing characters. Tyra and Tammy’s verbalizations will be used to illustrate the problems text-only participants experienced with manipulating two specific types of graphical elements, dialogue and cursor boxes.

After reading all help steps for creating a field object and after returning to the task environment, Tyra was initially confused about where, and how to type the word “vowels” as her comments below indicated:

I have to type the word vowels? Where? Here in the box? How?
[At this point, Tyra returns to the high level help screen]
Well, it doesn’t say anything about typing text over there. It says to select the object and says, oh, I haven’t done this. Oh, yeah, I have done this. Ah!

Tyra remarks “ah” upon realizing that she had not attempted the last sub-goal which is to type “vowels” in the field text box. The procedure for this sub-goal read:

(dotted box will appear around field in the location previously defined)
(a) Click mouse where you would like to begin typing text. Click once more. (cursor will change to left bracket symbol)
(b) Type text
(c) Click anywhere outside box to close

Tyra returned to the task environment and began typing without clicking the mouse in the desired location and commented, “So, it’s not typing anywhere. Am I dumb?” She then returned to help, this time specifically to the sub-goal of how to type text, and read aloud, “Click where you would like to begin edit.” She then commented, “I didn’t see anything.” She read further, “Click once more to open bracket.” Then remarked, “Where is the open bracket?” Upon returning to the task environment, she correctly clicked inside the field box and typed “vowels”.

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Manipulation problems also surfaced when several text-only participants attempted to close dialogue boxes. For instance, when creating a field object (task 1), Tammy was unsure if she had successfully accomplished the sub-goal of selecting a field object. Tammy correctly selected “Field” from the Object Type dialogue box (by clicking on a box to the left of the word “Field”), but instead of closing the box (by clicking outside) continued to click on “Field”. Tammy’s comment below indicated she was unsure whether the field had been created:

Okay, or maybe I will just be able to do it now. I’m trying to figure out if [clicking on “field”] just allowed me to make my field. You know like if that will give me a field or if that is just giving me [pause].

Tammy was still confused when completing task 5 as the comment below illustrated:

Now, I’m trying to decide if I close [the dialogue box] if it’s going to do it, or if I click out here [outside the dialogue box] will it just do it?

This verbalization revealed that Tammy perceived closing a box and clicking outside the box as resulting in different outcomes. She did not understand that to close the box one simply had to click outside the box.

Text-only manipulation problems also occurred when participants attempted to name an object. Participants were required to name a cut object when copying an object (task 5), and were given the option of naming for cutting an object (task 3). When cutting an object, three of the five text-only and three of the six highly graphic participants were unsure of how to name the object so decided to use the default name. In Linkway Live!™
a default name "scrap" automatically appears in both the object name section of the Cut and Paste Dialogue boxes. By ignoring the naming step, these participants selected "scrap" as the default name for the cut object. Before copying an object (task 5), all participants were informed of how the default function worked in Linkway Live!™ and were told not to use the default name but to name the cut object for this task. None of the highly graphic participants who initially experienced naming problems encountered problems by task 5. Tina and Tanya, however, still experienced difficulty in naming an object with task 5.

Several other manipulation problems of text-only participants revealed deeper misunderstandings of the Linkway Live!™ interface. Tanya and Tina's experiences are used to illustrate. When naming an object in task 5, Tanya mistakenly concluded that an object name somehow embodied the object with certain properties. She commented:

I'm trying to paste the piano keys so I don't know whether I'm calling it "pianokey" or "firstpage" [which is the page she believed she was on].

Tanya also seemed confused that once named an object could be referenced by this name throughout the program. When copying an object, Tanya named the cut object "pianokeys" which was a descriptive name for the object. Upon pasting this cut object to the next page, instead of selecting "pianokeys" from a list of object names in the Paste Object dialogue box, Tanya typed a new name "nextpage" which was descriptive in that she was now on the next page in the Linkway Live!™ folder, but clearly incorrect.
Although Tanya was one of the more experienced computer users, she did not grasp the concept of naming an object.

Similarly, Tina did not understand why an object had to be named before the object could be copied (cut and pasted) to another page. While on the Cut Object dialogue box she made the following comment:

That’s kind of strange, strange to type the name for the cut object. Will all the screens tell you what the object is if I call things differently from what you would call things? If I typed in “piano” [Linkway Live! ™] would not give me what I was looking for. It’s odd that [Linkway Live! ™] must recognize the name of something before you can move it. The directions are odd. If you type the name of something maybe it seems as though [Linkway Live! ™] is asking if by typing a name that’s the direction of what [Linkway Live! ™] is going to look for which is strange for a computer to ask. Okay, skip this part.

Tina’s hypothesis that Linkway Live! ™ would not recognize “piano” if she so named the object was incorrect. Her following hypothesis, however, was correct. The purpose of naming an object is so Linkway Live! ™ can access the object at some later point in the program. Tina ultimately decided naming an object was not necessary so ignored this part of the task. Tina was one of the more inexpert computer users having only prior wordprocessing experience.

4.2.3 Transfer of learning. Participants transferred knowledge both from earlier tasks in the Linkway Live! ™ environment and other computer platforms (i.e., Macintosh or Windows). Overall, the number of transfer problems were quite similar for both groups. A further analysis, however, revealed differences between the two groups. Of
the fifteen total problem instances encountered, six (or 40%) were a result of confusion with earlier tasks. Text-only participants were responsible for all of these problem instances. Nine (or 60%) of total transfer problems were a result of prior experience with either the Macintosh or Windows platform. Text-only participants were only responsible for two of these problem instances.

4.2.3.1 Transfer problems related to earlier tasks. In total, four text-only participants and none of the highly graphic participants experienced transfer problems related to earlier tasks. These instances are important because they suggest how either help system facilitated or impeded participants’ ability to “understand” the Linkway Live!™ interface. Tammy and Tom’s experiences with copying an object (task 5) and drawing a box (task 7) will be used as representative cases to illustrate transfer problems encountered by the text-only group.

Copying an object (task 5) consists of two phases, cutting and pasting the object. Having cut an object previously (task 3), Tammy went directly to paste and commented:

I just want to copy this [object] onto the next page. Okay, we already did that [referring to the three cut steps which are a part of the first phase of copying an object].

Tammy confused cutting an object in task 3 with the object to be cut in task 5. That is, Tammy recalled cutting an object previously but incorrectly transferred this knowledge to the current task goal. Object similarity did not contribute to her transfer problems—in one task the object was a book, in the other piano keys.
Text-only participants also experienced transfer problems when changing the color of a box which was the first sub-goal in drawing a box (task 7). Tammy, Tina, and Tom confused this sub-goal with the sub-goal of selecting the color of text (from task 1). To change the color of a box, participants had to access the color option from the “Options” pull-down menu. This action invoked the Color dialogue box. Similarly, when creating a field object (task 1), participants were required to select a color for the object also using the Color dialogue box. Text-only participants transferred their prior learning and instead changing the color of the box as required by the task, they attempted to change the color of text as they had done when creating a field object (task 1). To illustrate, after reading all sub-goals and steps in help, Tom commented:

Now, this is what confused me cause I was thinking we were going to change the colors of those words first the way that we did [when creating a field object].

4.2.3.2 Transfer problems related to prior platform experience. Transfer of learning problems across computer platforms were independent of the text-only or highly graphic help conditions, but provide valuable insights of how participants prior knowledge can affect current performance. The most prevalent problem instances occurred when participants attempted to “click and drag” an object in Linkway Live!™, a feature not permitted in DOS based applications. As an example, Gloria, a DOS and Windows user, attempted to click and drag an object during a move operation (task 2). She realized she was carrying over skills from the Windows platform as the following comment revealed:
I’m trying to move the object from here (points to correct location). But do I click? Maybe, I’m trying to hold the button down, maybe that’s the problem. Oh, I just click there to place. I’m carrying over from other programs. I’m trying to drag, that is specifically what I was doing. I see that now.

Several participants misinterpreted the Linkway Live!™ “Tool” option for the Windows “toolbar”, a graphical interface which facilitates the execution of simple and complex commands. Also, one Macintosh user, Tanya, was confused by the location of the “cut” and “paste” operators. These operators are located under the “Edit” menu on the Macintosh while in Linkway Live!™ they are located under the “Object” menu.

4.2.4 Referent representation. In this study, referent representation problems refer to instances in which participants experienced difficulty with how an object or element referenced in the help system environment was actually depicted in the task environment. Although collectively text-only and highly graphic participants experienced referent problems for five tasks, the only tasks for which both groups experienced problems were copying an object (task 5) and editing a goto button (task 12). Verbal reports from editing a field object (task 6), editing a picture object (task 11), and editing a goto button (task 12) will be used to illustrate referent problems for both text-only and highly graphic participants. Tyra, Tina, Gina, and Gabriel’s verbal reports provide the richest examples of referent problems encountered by the two groups; therefore their reports are used as illustrations throughout this section.
When editing a field object (task 6), participants were required to select the field (by clicking on the object) before editing one or more of its' properties. The help steps for the sub-goal of selecting the field read:

(a) Click on field
(dotted box will appear)
(b) Click ‘Object’ then click ‘Edit’

After reading these help steps, Tyra did not recognize the field object as referenced in help once she returned to the task screen as her comments revealed:

Click field, that’s the thing there is nothing here that says field (at this point she is searching the pull down menus) and it says click on field. That is weird. That would be the field? [she correctly identifies the field]. But, it doesn’t say anywhere that that is the field.

Tyra was expecting the word “field”, not a collection of textual characters.

The same method for selecting an object was required when editing a picture object (task 11). After selecting the object, participants had to choose a particular picture file to edit. This sub-goal read:

(‘Picture File’ dialogue box appears)
(a) Scroll filenames by clicking up and down arrows until desired filename is reached
(b) Click on filename
(c) Click anywhere outside dialogue box to close

The “filename” above referenced a verbal list of names. Tina, however, bypassed the list entirely because she was expecting explicit graphical images from which to choose.

Several text-only participants were also confused by the reference to “arrows” above and the depiction of arrows in the task environment. This was true for the sub-goal
above and one of the sub-goals associated with editing the destination of a goto button (task 12). As an example, one of the sub-goals when editing a goto button was to edit the button appearance. One must select, from a dialogue box, the desired icon (graphical representation for the button) from a listing of available icons. A variety of arrows are available as icons. Similarly, left and right arrows are used to scroll the available icon list.

The reference used in the help steps read,

“Click arrow keys to scroll available icons”, was problematic for several text-only participants as Tina’s comments indicated:

What is the difference between this arrow [used to scroll] and those arrows [available icons]? Did it say what the difference was in help? I didn’t think so.

This verbalization revealed Tina’s unable to distinguish the arrow icons from the arrows used to scroll the icon list.

Referent problems of the highly graphic group differed from those of the text-only participants just discussed. Highly graphic participants did not have difficulty recognizing particular referents, but rather were: 1) confused when certain graphical elements appeared in more than one location, and 2) misunderstood that elements referenced in help were used for illustrative purposes only. Confusion with graphical elements were limited to attempts to move objects from one location to another and occurred when moving an object (task 2) and moving and resizing an object (task 9). Figure 6 is an example of the highly graphic representation of the sub-goal for moving an object (the second sub-goal for task 2).
When moving an object in Linkway Live!™, the dotted box around the object to be moved remains on screen and a second, empty box is used to define the new location for the object. This means that during the move operation, two dotted boxes are simultaneously on screen. Once the mouse is clicked in this new location, the original object (enclosed in the dotted box) now appears in the new location. Due to screen size and design limitations, specifically the inability to simulate movement, the second box was not shown in help. Gina was surprised by the appearance of the second box in the task environment and commented, “I didn’t know it was going to give me the second box.”
One highly-graphic participant did not understand the function of element names as used in help sequences. When copying an object and editing the appearance and destination of goto buttons, participants were presented with name dialogue boxes as depicted in Figure 7.

![Example of Referent Name Used As Illustrative Example in Highly Graphic Help](image)

(a) Without clicking mouse, type new name for button

(b) Click mouse once ( will reappear)

(c) Click anywhere outside box to close

Figure 7. Example of Referent Name Used As Illustrative Example in Highly Graphic Help

The object and button names were intended as illustrative examples; not as required names once participants were back in the task environment. The explicit representation of names in help confused Gabriel who diligently used the names specified in the help sequences. At one point when editing the appearance of a goto button (task 10), she could not recall the name of the button used in the help example. Instead of choosing a
name of her own, she remarked, “I’m trying to think of what was the button name.” She returned to the sub-goal in help to locate the name.

4.2.5 Spatial arrangement of help steps. In the text-only help system, help steps were presented one following the other; preceded by alphabetic characters to indicate sequence. Given the physical screen limitations and the desire to represent highly graphic help content as participants would experience them in the task environment, highly graphic help steps were not always presented in the same space-order as text-only help. Gloria was the only participant who experienced difficulty of this kind. Her confusion is summed up with the following comment:

When I’m looking at this the way we read left to right and so on. I read what’s uppermost. I read [select action from Object menu] first and then went down here to [click object] and then I looked again and thought no that’s not going to work. I need to click the object first and then I noticed it was a’s and b’s.

4.2.6 Problem Analysis Summary. This section described the problem areas participants experienced when translating help procedures into executable actions. In general, findings revealed the highly graphic group experienced slightly fewer problem instances for forgetting, transfer of learning, and referent representation, and substantially fewer problem instances for manipulating graphical elements. Unlike the highly graphic group, however, the text-only group experienced no difficulty with the spatial arrangement of help steps.
The next section summarizes findings from the information content analysis of the physical and verbal behaviors of participants.

4.3 Information Content Analysis

To compensate for the possibility of sparse verbalizations, an information content analysis was performed. This analysis focused primarily on the non-verbal actions (i.e., physical actions) of participants. Since the analysis was derived from actual errors, it identified the more critical problems from which participants were unable to recover.

First, an error analysis was performed to uncover any errors committed. For purposes of this study an error was any instance in which a participant omitted or added a step not included in the help instructions, or attempted to perform a step or series of steps included in help instructions but attempted the step out of order. Second, a taxonomy of information content was designed. This taxonomy was adapted from the research of Bieger and Glock (1981). In an attempt to describe the relevant characteristics of text and pictures, these researchers developed a taxonomy of information categories to classify the content of textual and highly pictorial procedural information. Table 4 shows the five categories of the most essential information content for completing the twelve study tasks.
Table 4

Taxonomy of Essential Information Content for Task Completion

<table>
<thead>
<tr>
<th>Information Category</th>
<th>Definition</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operational</td>
<td>Information that directs participants to engage in a specific action.</td>
<td>Click object.</td>
</tr>
<tr>
<td>Element</td>
<td>Information which specifies which objects or elements of the system to act upon.</td>
<td>Click 'Page' from menu then click 'Box'</td>
</tr>
<tr>
<td>Qualifying</td>
<td>Information which modifies other information by specifying the manner or limits of the information.</td>
<td>Move cursor outward and downward until desired size is reached</td>
</tr>
<tr>
<td>Spatial</td>
<td>Information which specifies the position, orientation, or location of an object or element in space in relation to another object, element or fixed point of reference.</td>
<td>Move cursor to upper leftmost position of desired location for box</td>
</tr>
<tr>
<td>Higher Order Operational</td>
<td>Information which is not attributable to any of the other four categories and which results in the non-execution of an entire task or sub-goal. Because these errors signal more pervasive misunderstandings than the others, they often result in one or more additional errors.</td>
<td>Not cutting an object before trying to paste the object</td>
</tr>
</tbody>
</table>

Adapted from Bieger and Glock (1981)

Although the primary focus of this study is qualitative, it is useful to discuss several quantitative measures derived from the error analysis. A total of ninety-five errors were committed. As shown in Table 5, fifty-two (or 54.7%) of the errors were committed by text-only participants; forty-three or (45.3%) were committed by highly graphic participants.
Table 5

Frequency and Mean Errors by Help Type

<table>
<thead>
<tr>
<th>Help Type</th>
<th>Frequency (%)</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Text-Only</td>
<td>52 (54.7%)</td>
<td>10.4</td>
</tr>
<tr>
<td>Highly Graphic</td>
<td>43 (45.3%)</td>
<td>7.2</td>
</tr>
<tr>
<td>Totals</td>
<td>95 (100.0%)</td>
<td>8.6</td>
</tr>
</tbody>
</table>

These errors were further analyzed to determine the specific content participants either did not understand or misinterpreted. This content was then placed in one of the five content categories. Overall, least number of errors was attributed to spatial information and the largest number of errors was attributed to element information as shown in Table 6. Text-only participants committed more element, qualifying, and higher order operational errors (14, 12, and 11 respectively) and highly graphic participants committed more operational and element errors (11 and 10 respectively).
### Table 6

**Task Goal and Frequency of Errors by Information Type**

<table>
<thead>
<tr>
<th>Task Goal</th>
<th>Operational</th>
<th>Element</th>
<th>Qualifying</th>
<th>Spatial</th>
<th>Higher Order</th>
<th>Operational</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TO HG TO HG</td>
<td>TO HG TO HG</td>
<td>TO HG TO HG</td>
<td>TO HG TO HG</td>
<td>TO HG TO HG</td>
<td>TO HG TO HG</td>
<td></td>
</tr>
<tr>
<td>1 Create a Field Object</td>
<td>0 0 0 0 5 4</td>
<td>4 3 0 0</td>
<td>16</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Move an Object</td>
<td>1 3 0 0 0 0</td>
<td>0 2 0 0</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 Cut an Object</td>
<td>1 2 0 0 0 0</td>
<td>0 2 0 0</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 Delete an Object</td>
<td>1 0 1 0 0 0</td>
<td>0 0 0 0</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 Copy an Object</td>
<td>2 0 8 3 0 0</td>
<td>0 0 3 3 19</td>
<td>19</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 Edit a Field Object</td>
<td>1 1 1 0 1 0</td>
<td>0 0 1 0</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 Draw a Box</td>
<td>0 0 1 2 1 1</td>
<td>0 2 6 1 14</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 Draw a Bar</td>
<td>0 0 0 1 1 1</td>
<td>0 0 0 0</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 Move/Resize an Object</td>
<td>1 4 0 0 4 3</td>
<td>1 1 0 0</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 Edit a Button (appearance)</td>
<td>0 0 0 2 0 0</td>
<td>1 0 0 1</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11 Edit a Picture Object</td>
<td>0 0 3 1 0 0</td>
<td>0 0 1 0</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 Edit a Button (destination)</td>
<td>1 1 0 1 0 0</td>
<td>0 0 0 0</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>9 11 14 10 12 9</strong></td>
<td><strong>6 8 11 5</strong></td>
<td><strong>95</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The following sections discuss each of the five information content areas in greater detail. For each information type, representative physical actions by participants are described. These data are used as illustrative examples of errors common to either the text-only or highly graphic group. In some instances, the errors of both groups were similar. When this occurred, the most information rich data were selected irrespective of help system type.

4.3.1 Operational Information Content. Operational errors for both groups were quite similar which the majority (75%) occurring because participants did not select an object (by clicking on it) before attempting to perform an operation such as cut or move. Similar to the forgetting problems discussed earlier, operational errors generally occurred when participants initially left the help screen and returned to the task environment. The large number of errors of this type (21 or 21.1%) is somewhat surprising since Linkway Live!™ automatically displays the message “no object selected” each time an operation is attempted for which an object has not been selected.

4.3.2 Element Information Content. Element information specifies which Linkway Live!™ objects or elements are depicted and should be acted upon. Collectively the two groups committed element errors on eight tasks, but the only tasks for which both groups committed errors were copying an object (task 5), drawing an object (task 7), and editing a picture object (task 11). In addition to these task differences, there were also differences in the nature of errors for the two groups. For instance, more of the element errors of the highly graphic groups resulted from participants selecting an
incorrect option from the pull down menu (i.e., selecting ‘New’ from the Object menu rather than ‘Edit’). Six of the ten highly graphic errors were of this type and involved Grace, Gloria, and Glenn.

Text-only participants committed more element errors which involved the physical manipulation of objects. Nearly forty percent of the text-only errors occurred when participants either moved to an incorrect page or tried to paste an object to an incorrect page. For instance, Tina and Tyra both incorrectly moved to the last page (e.g., screen) of the folder when the task required that they move to the ‘next’ page. These participants also attempted to paste to the same page instead of the next page of the folder.

4.3.3 Qualifying Information Content. Qualifying information modifies other information by specifying manner, attributes, or limits of that information. Qualifying errors were closely tied to the transfer of learning problems discussed in the preceding section. The primary way qualifying information was used in the design of the help systems was to specify how much to move an object. For example, several tasks instructed participants to move the mouse in a particular direction until the desired size of the object was reached. The errors across help system type were quite similar so the remaining discussion in this section is relevant to both text-only and highly graphic participants. Creating a field object (task 1) will be used to illustrate the nature of qualifying errors. When creating a field, participants had to define the location and size of the field. To do so required participants to click the mouse at the location to begin the
field, pull the mouse outward and downward until desired field size was reached, then
click the mouse to complete the operation.

Gabriel and Glenn committed the four highly graphic errors for this task and their
experiences were representative of the entire group. Although both moved the cursor in
the right direction, both repeatedly attempted to click and drag the mouse instead of
clicking then moving the mouse.

4.3.4 Spatial Information Content. Spatial information specifies the position,
orIENTATION, or location of an object or element. Location describes the position of an
object in space in relation to another object or fixed point of reference. For instance,
creating a field object required participants to click \textit{inside} a field object before typing the
contents of the field. Similarly, orientation refers to the alignment of an object in some
specified way. As an example, several tasks required participants to move the mouse
\textit{outward} and \textit{downward} to define the size and location of the object. Highly graphic
participants committed sixty percent of the spatial errors.

Twelve of the fourteen (or 85.7\%) spatial errors occurred because participants
either did not: 1) select the proper location to perform an action (generally either inside or
outside a graphical element) as required, or 2) correctly align cursors to perform goals
such as drawing a box. Text-only participants experienced more difficulty with the former
(5 of 6 instances or 83.3\%) and highly graphic participants experienced more difficulty
the latter (4 of 8 instances or 50\%).
To illustrate the latter, when drawing a box (task 7), participants were to place one large box around a two fields of information, a title and four menu items located directly underneath the title. To do so, participants had to first position the cursor in the upper leftmost position of the desired location for the box; in this instance just to the left of the first letter in the title.

4.3.6 Higher Order Operational Information Content. This error category included instances not directly attributable to a single content source as previously discussed. These errors were more complex in that they involved an entire sub-goal (e.g., cut an object). In several instances participants omitted a sub-goal completely and in others they replaced one sub-goal for another. Nearly 70% of the total higher order operational errors. Since thirteen (or 81.3%) of higher order errors occurred when participants were either copying an object (task 5) or drawing a box (task 7), these two tasks are discussed.

A total of six errors occurred when copying an object. These errors were committed by two participants, Tammy and Grace. Copying an object consisted of two sub-goals, cutting then pasting the object. Each of these sub-goal contained several steps. Higher order errors initially occurred when both participants omitted the cut object sub-goal. The length of steps for this task most likely contributed to participants’ problems. Grace’s confusion with what object to paste and where to paste it may have demanded so many attentional resources that she forgot the cut object sub-goal. To illustrate, after
reading the help steps for cutting and pasting (and upon returning to the task screen)

Grace remarked:

Now, I can’t remember where to move it, to the what page? Okay, then I
go to paste? What do I want to paste?

Once on the task screen, Grace was confused about which object to select. Once
she determined the correct object, she immediately commented, “I need to go to the next
page”. She struggled a bit before returning to help, but once on the help screen quickly
recognized that she had not yet cut the object.

Tammy seemed confused by the term “copy” which was used in the task
instructions and as the title of the help goal for this task. After reading all help methods
for both cutting and pasting, Tammy clicked on the object and instead of accomplishing
the cut sub-goal moved directly to the next page. At this point she realizes something is
wrong and asked, “Oh, is it going to copy it?” While still on the next page she asked, “Is
copy the same as paste? I’m looking for copy. Can you paste a copy?” She returned to
help, noticed “Copy an Object” (which is the title of the help goal for this task) and
remarked, “See, there’s that copy. I think all I have to do is highlight it” Without reading
any of the help steps for either the cut or paste sub-goal, Tammy returned to the task
environment but ultimately never completed the task.

Another set of interesting higher order errors were discovered when participants
attempted to draw a box (task 7). Text-only participants committed six (or 85.7%) of the
seven errors for this task. All errors were similar, therefore, Tom’s example will be used
as a representative case. The first step to draw a box was to select the color of the box to
be drawn. The steps for this sub-goal read:

(a) Click ‘Option’ from menu then click ‘Fg Color’
(foreground color box appears)
(dot indicates current color)
(b) Click on desired color (if other than current color)
(c) Click anywhere outside box to close

The task goal was to place a light blue box around a title and four menu items
located underneath the title. Instead of accomplishing this goal, Tom attempted to create
a field object (task 1) which has as a sub-goal changing the color of text to be used in the
field as the high level goal for task 1 shows below:

Select object type
Select field location and size
Select text size
Define field attributes
Select text color
Type text

Tom confused changing the color of text with changing the color of a box. He attempted
to execute a correct procedure (sub-goal) in an inappropriate instance.

4.3.6 Information Content Summary. This section discussed the information
content of errors participants committed as they accomplished the twelve study tasks.
The information content analysis revealed, in general, the number and types of errors
were similar. Text-only participants committed slightly more element, qualifying, and
higher order operational errors when compared to highly graphic participants, and highly
graphic participants committed more operational and spatial errors when compared to the text-only group. The next section discusses participants reactions to the debriefing instrument each was asked at the end of the data collection session.

4.4 Responses to Debrief Instrument

Participants were asked to reflect upon their experiences after each session. These reflections were captured using a debriefing instrument (See Appendix C).

4.4.1 Overall Impressions. When asked to give their impression of the help system, nine of the eleven (81.8%) participants were quite positive. Two participants (one text-only and one highly graphic) had a less than favorable experience with the help system. These two participants (Tyra and Gabriel) felt the help instructions were too lengthy and that in some instances they were unclear. Tyra felt there were “too many instructions to follow” She commented, “I kept forgetting [the instructions]. I lost a lot of time in going back to help.” Similarly, Gabriel responded: felt, “some areas were unclear, and there seemed to be so many steps.”

Several other participants also mentioned the wordiness of instructions or the number of steps associated with a particular task, but overall described their overall impressions positively. For instance, the remaining eleven participants reported the help systems as easy to use and understand., clear, and at the right level of detail. The following comments reflect these participants overall impressions with the help system:

Although, I’m always hesitant to use help systems, I was pleasantly surprised at how easy this help system was to use. [Geri]
I think the help system did an excellent job of providing support to a user of Linkway. [Tanya]

Easy to use. Easy to understand, though some lengthy explanations take a few looks (more familiarity would eliminate). [Tina]

4.4.2 Comparison To Other Help Systems. Overall, both text-only and highly graphic participants felt the help system compared favorably to other help systems they had encountered. Six of the eleven participants specifically commented on the goals and sub-goals hierarchy design used. The follow comment best expressed participant’s views:

This help system let’s you utilize it at the level you are at. Some help systems end to assume that you know certain things. This help system allows you to click into the part of the process you need help with. [Glenn]

Two of the highly graphic participants felt graphics increased the utility of the help system. Gina commented, “This help system was much easier to use due to graphics. Tammy responded, “Visually help functions that I have used don’t have enough detail and actually don’t have graphics to lead you.”

4.4.3 Most Liked Aspects. Participants most liked the organization of the help system. Both help systems were developed using a GOMS analysis which focused on the goals of Linkway Live!™. Instead of presenting only the lowest level goals (i.e., the actual steps to be performed) as has been done in previous GOMS work, the help systems used in the present study presented help goals at two levels. Higher level goals represented general methods for accomplishing tasks and lower level goals represented the
actual steps to be performed to accomplish the task at hand. This dual level goal format was designed to accommodate varying needs and facilitate learning the Linkway Live!™ interface. As illustrated below, responses to the debrief suggest participants found this organization format useful:

I loved the set-up. The wording along the right side of the screen was very helpful.. [Gina]

I like the way the help steps were listed systematically and the “yellow” information. As a user I liked having control over what help items I would have to (or could have to read)... [Geri]

4.4.4 Least Liked Aspects. Participants least liked the lengthy explanations, and the inability to have help present on the task screen. Grace summed up the responses regarding the lengthiness of explanations as follows: “By the time I read through all the help stages, I would sometimes forget the order of what I needed to do to complete the task”.

4.4.5 Aspects Participants Found Confusing. There were several aspects of the help system which participants found confusing—using alphabetic labeling, naming files, copying objects, and the length of some help instructions. Gina found the labeling of the details steps somewhat confusing, and commented:

It threw me off when they used letters (exp a,b) instead of numbers to show the order that I needed to take.

Several participants (text-only and highly graphic) mentioned copying an object as being confusing. This finding corroborates findings from the problem and information
content analyses in which a large number of problems and errors were identified for this task.

4.4.6 Graphics. Unsolicited responses concerning graphics suggest that overall participants found them useful as indicated below:

I think it is better than any other help system. Visually, help functions that I have used don’t have enough detail and actually don’t have graphics to lead you. [Glenn]

In fact several highly graphic participants expressed a need for even more graphics and one text-only participant suggested that graphics be added to improve utility. There were specific tasks, however, for which highly graphic participants had difficulty interpreting graphics. For instance, Gabriel commented:

Various pictures, for example the pencil on the screen when the task asked me to place an object in the box. This was somewhat unclear.

Similarly, Glenn had the following reaction:

“Most of the time [instructions] were clear. Several times (like changing the color of the box) instructions were confusing about which box they were talking about.”.

4.4.7 Debrief Questionnaire Summary. This section discussed participants reactions on the debrief instrument. Overall, participants found the help system useful and easy to understand. Tyra and Gabriel were the exceptions who commented on the length and clarity of instructions. Participants found the goal structure organization of the help system quite useful. They especially liked being able to view both sub-goals and specific procedures. Participants would have liked to have help resident on the screen
which was one of the design limitations of the study. Several participants made specific reference to the utility of graphics. While these responses were generally positive, specific instances in which graphics impeded task execution were also mentioned.

This chapter presented the findings of the study. Chapter 5 discusses the implications of these findings, conclusions, and recommendations for further study.
CHAPTER 5

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

This study described the experiences of participants as they completed tasks using either a text or highly graphic help system. This chapter begins with a summary of the findings. Next, conclusions based on these findings are discussed. This chapter concludes with recommendations for future study.

5.1 Summary of Findings

This section discusses each of the research questions posed by the study. It summarizes findings from the problem, information content, and debrief questionnaire analyses. Findings from these three analyses addressed the first three research questions. Once summarized, these findings are used to address the last research question.

5.1.1 Problem Analysis Summary. The first research question asked, "What problems/obstacles do participants experience in translating text-only and highly graphic representations of help content into executable actions. What are the similarities and differences encountered between the two help groups?"
The problem analysis identified five problem areas: forgetting, manipulating graphical elements, transfer of learning, referent representation, and spatial arrangement of help steps. The transfer of learning problem area was further divided into two sub-problem areas: problems across platforms (i.e., Windows and Macintosh), and problems related to earlier Linkway Live!™ tasks. The only problem areas for which highly graphic participants experienced more problems when compared to text-only participants were transfer problems related to prior platform experience and spatial arrangement of help.

Findings suggest the nature of problem instances differed for the two groups in all areas except forgetting. Unlike highly graphic participants who experienced little difficulty with manipulation of graphical elements, text-only participants experienced a variety of problems including general confusion with when, where, and how to communicate with graphical elements. In the transfer of learning problem area, text-only participants experienced more problems which suggested misunderstandings from earlier Linkway Live!™ tasks and highly graphic participants struggled more with adapting knowledge gained from other computer platforms to the DOS-based Linkway Live!™ environment. Where text-only participants had trouble identifying referents described in help once they returned to the task environment, highly graphic participants were either confused when elements referenced in help appeared in a different location on the task screen or they misunderstood that elements referenced in help were used for illustrative purposes only. Lastly, problems with the spatial arrangement of help content was
unique to highly graphic participants. Possible explanations for these similarities and differences between the text-only and highly graphic groups follow.

Forgetting most likely occurred because participants' suffered memory overload of both textual and graphic representations of help content. That is, the amount of help information presented was more than could be stored in working memory and recalled once on the task screen. Given the small number of participants and the more exploratory nature of this study, it is not possible to make definitive statements concerning whether findings support the models of perceptual processing, cue summation, or economy of processing. However, the similarity in the verbalizations of the two groups for forgetting seem contrary to perceptual processing theory which maintains that word processing is more cognitively demanding than picture processing. In the present study, this would suggest that if pictures provided more cognitive economy they could be processed and recalled more easily than text. Therefore, forgetting instances for text-only participants would be more prevalent than, and perhaps different from, highly graphic participants.

An alternative rationale to perceptual processing is that forgetting was exacerbated by the inherent design of Linkway Live!™ which automatically presented participants a series of sub-tasks which had to be completed to accomplish the overall task goal. Each sub-task appeared before participants could access the help screen for a given task. Once participants understood that Linkway Live!™ would automatically display each sub-task before allowing them to access help, most adopted a strategy of reading all the help steps
then attempting to accomplish the task as opposed to reading several help steps and then attempting one or more sub-tasks in iterative fashion. As a design alternative, help resident on the task screen would have greatly minimized forgetting problems. This was not possible given study design limitations, but was mentioned as a desirable capability by a number of participants both during sessions and on the debrief questionnaire.

The relative ease with which highly graphic participants were able to manipulate graphical elements suggest the explicit representations of help content facilitated task accomplishment. These findings are consistent with the picture research findings of Levie and Lentz (1987) and Dwyer (1978, 1982, 1983). The explicit graphical representations of objects and actions seemed to help highly graphic participants accomplish the detailed steps necessary to communicate with Linkway Live!™ as well as acquire a better understanding of the interface. As suggested by Shneiderman (1986), highly graphic content may have aided participants in better understanding the interface structure (i.e., the general methods to communicate with Linkway Live!™), which in turn may have assisted participants in learning and remembering how to manipulate Linkway Live!™ graphical elements. For instance, the pictorial depiction of dialogue boxes and the cues of where to type object names may have provided a context for participants that facilitated their understanding of how and where (i.e., the specific steps) to type the name as well as the function of names in Linkway Live!™ (i.e., the general methods).
Transfer of learning problems also suggested highly graphic participants may have had a better understanding of the general methods for communicating with the Linkway Live!™ interface. For instance, all of the transfer problems identified for these participants appeared to be related to prior non-DOS based experiences. Conversely, the majority of transfer problems of text-only participants occurred when these participants incorrectly applied actions or principles from earlier Linkway Live!™ tasks to inappropriate task situations.

Text-only referential representation problems occurred when elements presented textually in help were displayed graphically in the task environment. Text-only participants had difficulty "mapping" the verbal descriptions of referents to the graphical images once in the task environment. The multiple cues (text and graphics) of the highly graphic help system may have facilitated participants ability to map referents between help and task environments. This finding is consistent with cue summation theory which suggests that multiple cues are more effective than single cues for representing procedural knowledge (i.e., help content). The theory posits that information not easily understood in one form can be added to information more readily understood in the other, thus increasing the likelihood that the message is comprehended. In the present study, since highly graphic participants were presented both textual descriptions and graphical depictions of referents, they may have utilized one cue to remedy any confusions attributed to the other. Reducing confusions or ambiguities is consistent with the
economy of processing theory which states that humans continually seek information to help reduce ambiguities during problem solving.

Highly graphic participants seemed less confused with how a referent appeared once on the task screen and more confused when an element appeared more than once on the task screen but was only presented once in help. Highly graphic referent problem instances were unique to moving objects and likely resulted from the inability to animate the movement of an object from its' current to desired location on a single screen.

According to Sukaviriya and Foley (1990), the graphical images as used in the present study (to portray a sense of animation) should have been sufficient to provide utility over text-only help content. It is this researchers’ belief that animation would have produced more favorable findings.

Prior to data collection sessions, the inability to show movement was identified as one of the limitations of the study. Design options were to add another help screen showing elements in another location to simulate movement or using a single screen with an arrow pointing from the elements’ beginning location to its’ ending location. The latter option was selected because it was consistent with the general methods (i.e., high level help goals) associated with sub-goals for the tasks and it reduced the number of screens participants had to access before returning to the task environment.

Highly graphic participants also misunderstood that specific names used in help were intended for illustrative purposes only and were not required names to be used in the task. Research on referential representation of verbal and pictorial images may help
explain highly graphic participants confusion. Words, in the absence of modifiers
generally evoke very broad concepts (i.e., book), while pictures usually evoke very
narrow concepts (i.e., a picture of “Gone With The Wind” will not be as effective in
conveying the general concept of a book). If participants viewed the highly graphic
representations more as pictures, they may have been reluctant to type a name other than
the one expressed in help. It is reasonable that they would attempt to “replicate” the
picture by typing in the exact name used in help. To emphasize the generic function of
names in help illustrations, names such as “myfilename” were used. In several instances,
however, this was not a strong enough cue for highly graphic participants.

Better design may have eliminated the few spatial arrangement problems of highly
graphic participants. For instance, using either numbers or more distinguishable letters to
show sequence may have resulted in greater utility.

5.1.2 Information Content Analysis Summary. The second research question
asked, “Which categories of information content impede task accomplishment? What are
the particular problems participants experience with different categories of information
content? Do these categories differ for highly graphic and text-only help participants?”
The information content analysis identified five error categories: operational, element,
qualifying, spatial, and higher order operational. The smaller number of errors of the
highly graphic group are support prior findings which suggest highly pictorial illustrations
may provide greater utility than purely textual descriptions (Booher, 1979; Stone &
Glock, 1981; Dwyer, 1983).
Overall, information content findings were more similar for the two groups than the problem analysis findings. Therefore, it is difficult to make any definitive statements concerning if and how information content was impacted by text-only or highly graphic representations. There are several notable observations, however, from this analysis.

Many of the forgetting problems manifested themselves as operational errors. The higher percentage of operational errors for highly graphic participants is somewhat surprising given participants received feedback after each error occurrence (e.g., Linkway Live!™ displays a dialogue box with the message “No object selected”).

The major difference (aside from the number of errors) between element errors of the two groups was which elements were involved in the errors. Text-only participants committed more element errors involving dialogue boxes and highly graphic participants committed more element errors involving pull-down menus.

Qualifying errors, like the transfer of learning problems across platforms, were mainly a result of participant’s attempts to “click and drag” instead of “click, release, and move” as required by Linkway Live!™. As with referent representation problems, animated sequences may have been more effective in conveying the required actions than the static images used in help.

Spatial errors for the two groups differed. Text-only participants committed more location errors; highly graphic participants more orientation errors. Again, it is believed that static images of procedures may have hindered highly graphic performance.
Although higher order operational errors were similar for both groups, they were more prevalent for text-only participants. These errors most likely resulted from transfer problems related to earlier tasks and memory overload. One set of higher order operational errors was associated with copying an object which was one of the longest tasks of the study. Since this task consisted of two phases, cutting and pasting, and each phase consisted of several steps, participants may have been unable to store all steps associated with both phases into short term memory. Participants may have only been able to recall the last phase, paste, upon returning to the task environment. This is another instance where help resident on the task screen would have eliminated problems.

The other major set of higher order operational errors were a result of transfer problems related to prior tasks. While these errors, in part, reflect participants unfamiliarity with the Linkway Live!™ interface, the larger number of errors attributed to text-only participants further suggest highly graphic participants had a better understanding of the general methods required to communicate with the Linkway Live!™ interface.

5.1.3 Debrief Analysis Summary. The third research question asked, “What are participants overall impressions of the help system?” The debrief questionnaire indicated few differences between highly graphic and text-only participants. Overall participants found both help systems useful and easy to understand. Participants found the organization of help especially beneficial. Participants commented specifically on the incorporation of both high and low levels of help content (i.e., general methods and
detailed steps). Participants felt this organization gave them more control and flexibility, and helped in their understanding of how to communicate with Linkway Live!™. The GOMS model was used to design both help systems. The one variation between this study and prior GOMS work is the higher level help methods (i.e., sub-goals) were actually displayed in the help system. Although, higher level methods are generated by the GOMS model, prior efforts have only displayed the lowest level steps (Elkerton & Palmiter, 1991; Elkerton, et al., 1990). A number of researchers urge the use of goals and goal analysis in the design of online help (Black, et al, 1987; Gwei & Foxley, 1990; Aarsonson & Carroll, 1987). The findings of this study support these prior efforts.

Participants continually mentioned the need to have help resident on the task screen. This one design feature would have greatly increased help system utility.

Participants also mentioned the length of instructions as a limitation to task completion, however, the number of steps participants attempted to remember before returning to the task environment (not the length of instructions) may have actually impeded performance. Again, having help resident on screen would have minimized this problem.

5.1.4 Suggestions for Online Help Design. The final research question asked “What do these findings suggest regarding the design of online help systems?” The following design suggestions are proposed:

1. Goal analysis models, such as GOMS, should be considered in help system design.

Varying levels of goals should be user controlled to provide greater flexibility and
facilitate learning and remembering the general methods as well as the specific steps required to communicate with the help system.

2. Controlled animation, not just illustrations which portray a sense of animation, should be incorporated in help system design. Allowing users to control animated sequences or replay sequences as necessary would provide even greater utility. Ideally, help system design should move towards providing users with a “procedural demonstration”. This demonstration would simulate the current user task and the steps required to solve the users problem. This demonstration would explicitly show the steps an expert would use to accomplish the task. Think of the demonstration as an animated GOMS analysis for each goal and/or sub-goal of the system.

3. Multiple representation formats (text and graphics) are more effective than single formats (text or graphics) and should be incorporated into help system design.

4. To minimize memory overload, help should remain resident, or be easily accessible (perhaps through a hot key) on part of the task screen during task execution.

5.2 Conclusions

This study explored and described the experiences of participants as they communicated with text-only and highly graphic representations of help content. The following are the conclusions of this research effort:

1. The nature of problems encountered suggest there are differences in the utility of text and graphics in online help.
2. Although further study is needed, these preliminary findings do support the theories of cue summation and economy of processing.

3. More research is needed to determine the optimal mix of text and graphics in the design of online help.

4. The GOMS model, or similar goal structure analysis models facilitate task accomplishment.

5. Graphical representations enhanced learning and remembering of the general methods required to communicate with the computer interface.

6. The combination of graphics and animation would provide greater utility than graphics and still images.

5.3 Recommendations

Based on the findings of the present study, the author strongly encourages more research on the utility of graphics in online help. There remains a dearth of research in this area, so much so that inspiration for this effort had to be culled from the more information rich picture research literature base. And even this source uncovered few efforts dealing with the specific case of procedural tasks. To expand the knowledge base, recommended next steps follow.

This initial effort compared text-only and highly graphic help. To provide a more balanced design, one that did not intentionally favor one representation over the other, fairly strict design specifications were employed. This suggests other representations of
highly graphic help content might provide more utility than the one used in the present study. Research on alternative designs need to be explored.

The GOMS model used to design both help systems has previously only been used to design text-based help. The findings of this study suggest goal structure analysis models like GOMS provide utility in online help. Further research is required, however, to determine the flexibility of the model to accommodate graphics. Perhaps a graphics based GOMS model should differ from a text-based GOMS model to provide maximum utility.

Lastly, more research is needed on the combined effects of graphics and animation in the design of online help. Findings from this study indicate that explicit graphical representations coupled with animation which is user controlled may promote learning and remembering help knowledge.
APPENDIX A

GOMS ANALYSIS FOR CREATING A TEXT FIELD
Goal of Creating a Text Field

Pass 1: Method to accomplish goal of creating a hypermedia folder

Pass 2: Method to accomplish goal of creating text

Step 1. Get location of unit task from storyboard
Step 2. Decide: Where text should be displayed
Step 3. Accomplish goal of performing creating text

Selection rule set for goal of performing creating text
If text is permanently displayed, then accomplish goal of creating field text
If text is not permanently displayed and text appears in rectangular box, then accomplish goal of creating text pop-up
If performing creating text is not permanently displayed and text appears as full page, then accomplish goal of creating text document
Determine goal accomplished

Pass 3 Method to accomplish goal of creating a text field

Step 1 Select object type
Step 2 Select field location and size
Step 3 Select text size
Step 4 Define field attributes
Step 5 Select text color
Step 6. Type text

Pass 4 Detailed steps to accomplish goal of creating a text field

Select object type
(a) Click 'Object' then click 'New'
   (dialogue box appears)/(the 'Object Type' dialogue box appears)
(b) Click small box to left of 'Field'
(c) Click anywhere outside box to close

Select field location and size
(cursor changes to small dotted box)
(a) Move cursor to upper leftmost position of desired location for object
(b) Click mouse
(c) Move cursor outward and downward until desired size is reached
(d) Click mouse
Select text size
(dialogue box appears)/(the text size dialogue box appears)
(dot to the left of line two indicates default text size)
(a) Click on text size desired (if other than default size)
(b) Click anywhere outside box to close

Define field attributes
(dialogue box appears)/(the 'FIELD Information' dialogue box appears)
(Steps a & b are optional)
(a) Without moving mouse, type name for field
(b) Click mouse, cursor will reappear
(c) To allow others to change the contents of this field, click 'Unlocked'
Otherwise, leave 'Locked'.
(d) Click anywhere outside box to close

Select text color
(dialogue box appears)/(the color dialogue box appears)
(a) Click on desired color (if other than default)
(b) Click anywhere outside box to close

Type text
(dotted box will appear around field in the location previously defined)
(a) Click mouse where you would like to begin typing text. Click once more.
(cursor will change to left bracket symbol)/Graphics version shows [ symbol.)
(b) Type text
(c) Click anywhere outside box to close
APPENDIX B

VERBAL DESCRIPTION OF PROCEDURAL HELP STEPS DEVELOPED USING A GOMS ANALYSIS
Task #1 Create a Field

Select object type
(a) Click 'Object' then click 'New'
   (dialogue box appears)/(the 'Object Type' dialogue box appears)
(b) Click small box to left of 'Field'
(c) Click anywhere outside box to close

Select field location and size
(cursor changes to small dotted box)
(a) Move cursor to upper leftmost position of desired
    location for object
(b) Click mouse
(c) Move cursor outward and downward until desired size is reached
(d) Click mouse

Select text size
(dialogue box appears)/(the text size dialogue box appears)
(dot to the left of line two indicates default text size)
(a) Click on text size desired (if other than default size)
(b) Click anywhere outside box to close

Define field attributes
(dialogue box appears)/(the 'FIELD Information' dialogue box appears)
(Steps a & b are optional)
(a) Without moving mouse, type name for field
(b) Click mouse, cursor will reappear
(c) To allow others to change the contents of this field, click 'Unlocked'
   Otherwise, leave 'Locked'.
(d) Click anywhere outside box to close

Select text color
(dialogue box appears)/(the color dialogue box appears)
(a) Click on desired color (if other than default)
(b) Click anywhere outside box to close

Type text
(dotted box will appear around field in the location previously defined)
(a) Click mouse where you would like to begin typing text. Click
   once more.
   (cursor will change to left bracket symbol)/Graphics version shows
   [ symbol.)
(b) Type text
(c) Click anywhere outside box to close
Task #2  Move an Object

Select object to move
  (a) Click object
      (dotted box appears around object)
  (b) Click 'Object' then click 'Move'/Click 'Object' from menu then click 'Move'

Move object
  (cursor changes to dotted box the same size as object)
  (a) Move cursor to desired location for object
  (b) Click mouse
Task #3 Cut an Object

Select object to cut
   (a) Click object
      (dotted box appears around object)
   (b) Click 'Object' then click 'Cut'

Name cut object
   (Dialogue box appears)/(Cut Object dialogue box appears)
   (a) Without moving the mouse, type name for cut object
   (b) When done, click mouse and cursor will reappear
   (c) Click mouse anywhere outside dialogue box to close

Close message box
   (Message box appears)/(Cut completed message box appears)
   (a) Click anywhere outside box to close
Task #4 Delete an Object

Select object to delete
(a) Click object
(dotted box appears around object)
(b) Click 'Object' then click 'Delete'

Delete object
(dialogue box appears) ('Delete' dialogue box appears)
(a) Click 'YES'
Task #5: Copy an Object

Cut Object
Select object to cut
(a) Click object
   (dotted box appears around object)
(b) Click 'Object' then click 'Cut'

Name cut object
(Dialogue box appears)/(Cut Object dialogue box appears)
(a) Without moving the mouse, type name for cut object
(b) When done, click mouse until cursor reappears
(c) Click mouse anywhere outside dialogue box to close

Close message box
(Message box appears)/(Cut Completed message box appears)
(a) Click anywhere outside box to close

Paste Object
*Move to paste page
(a) Click 'Go to' then click appropriate destination

*Select 'Paste' from Object menu
(a) Click 'Object' then click 'Paste'

Select object name
(Dialogue box appears)/(Paste Object dialogue box appears)
(a) If necessary, click arrows to scroll dialogue box until desired filename
is found

Paste object
(Cursor will change to dotted box)
(a) Move cursor to desired location
(b) Click mouse once object is in desired location

*These two steps are combined into the subgoal "Select Paste Option" in the text version. In the graphics version, it was too confusing (from a user's perspective) to sequentially illustrate two separate pull down menu scenarios on one screen. Therefore, the steps associated with these two sub-goals were illustrated on two separate screens.
Task 6 Edit a Field Object

Select object
(a) Click on field
(dotted box will appear)
(b) Click 'Object' then click 'Edit'

If necessary, edit text size
(dialogue box appears)/(the text size dialogue box appears)
(dot to the left of line two indicates default text size)
(a) Click on text size desired (if other than default size)
(b) Click anywhere outside box to close

If necessary, edit field attributes
(dialogue box appears)/(the 'FIELD Information' dialogue box appears)
(Steps a & b are optional)
(a) Without moving mouse, type name for field
(b) Click mouse, cursor will reappear
(c) To allow others to change the contents of this field, click 'Unlocked'
   Otherwise, leave 'Locked'
(d) Click anywhere outside box to close

If necessary, edit text color
(dialogue box appears)/(the color dialogue box appears)
(a) Click on desired color (if other than default)
(b) Click anywhere outside box to close

If necessary, type new text
(a) Click mouse where you would like to begin edit. Click once more.
   (cursor changes to open bracket)/Graphics version shows [ symbol.
(b) Type new text or delete current text
(c) Click anywhere outside box to close
**Task #7 Draw a Box**

If necessary, change box color
(a) Click 'Option from menu then click 'Fg Color'
   (dialogue box appears)/(the foreground color box appears)
   (dot indicates current color)
(b) Click on desired color(if other than current color)
(c) Click anywhere outside box to close)

Move to location for box
(a) Click 'Page' from menu then click 'Box'
   (cursor changes to small box)
(b) Move cursor to upper leftmost position of desired location for box
(c) Click mouse
   (This time cursor changes to an even smaller box that looks like a dot)

Draw box
(a) Move cursor outward and downward until desired size is reached
(b) Click mouse

Move to desired location for box was combined. Initially, this subgoal was actually two separate subgoals, Select box from Page menu and Move box to location. These two subgoals were combined since they only contained one step each.
Task #8 Draw a Bar

If necessary, change bar color
   (a) Click 'Option' from menu then click 'Fg Color' /Click 'Option' from menu then click 'Fg Color'
   (dialogue box appears)/foreground color dialogue box appears
   (dot indicates current color)
   (b) Click on desired color (if other than current color)
   (c) Click anywhere outside box to close

Select 'Bar' from 'Page' menu
   Click 'Page' than click 'Bar' /Click 'Page' from menu then click 'Bar'

Move to desired location
   (cursor changes to small bar)
   (a) Move cursor to upper leftmost position of desired location for bar
   (c) Click mouse
   (This time cursor changes to an even smaller bar that looks like a dot .)

Draw Bar
   (a) Move cursor outward and downward until desired size is reached
   (b) Click mouse
Task #9  Move and Resize an Object

Select object to move and resize
(a) Click object
(dotted box appears around object)
(b) Click 'Object' then click 'Move+Size'

Move object
(Cursor changes to small dotted box)
(a) Move cursor to upper leftmost position of desired location for object
(b) Click mouse

Resize object
(a) Move cursor outward and downward until desired size for object is reached
(b) Click mouse
(resized object appears)
Task #10 Edit a GoTo Button (edit button appearance)

Select button to edit
(a) Click object
(dotted box appears around object)
(b) Click 'Object' from menu then click 'Edit'

If necessary, edit button name
(dialogue box appears)/the 'Button Name' dialogue box appears)
(a) Without clicking mouse, type new name for button
(b) Click mouse once, cursor will reappear (graphics version shows picture of arrow cursor)
(c) Click anywhere outside box to close

If necessary, edit button appearance
(button appear dialogue box appears) -- box has no specific name so same message is displayed in both graphics and text versions
(a) Click arrow keys to scroll available icons
Click on desired icon

OR

Click button labeled 'None' if invisible button is desired

OR

Click rounded rectangular button is this button type is desired
(if previously named, button name will appear inside rectangle)

(b) When done, click outside box to close

If necessary, edit button destination
(a) Click on small box next to desired destination
(b) Click anywhere outside box to close

Reference pointers were used instead of specific reference to objects in graphics version. For instance in (a) instead of 'Click button labeled 'None' if..... graphics version read 'Click here if'.... with an arrow pointing to the button object labeled 'None'. Select button to edit
Task #11 Edit a Picture Object

Select object
(a) Click object
(dotted box appears)
(b) Click 'Object' then click 'Edit'/Click 'Object from menu then click 'Edit'

If necessary, edit picture name* (put asterisk here)
(dialogue box appears)/(the 'Picture Name' dialogue box appears)
(a) *Without moving mouse, type name for picture
(b) *Click mouse, cursor will reappear

If necessary, select picture file name
(dialogue box appears)/(the 'Picture File' dialogue box appears)
(a) Scroll filenames by clicking up and down arrows until desired filename is found
(b) Click on filename
(c) Click anywhere outside dialogue box to close

If necessary, adjust picture position
(dialogue box appears)/(the 'Adjust' dialogue box appears)
(a) To adjust picture slightly, click on the appropriate direction (as needed) which is followed by '1'

OR
To adjust picture significantly click on the appropriate direction as needed which is followed by '8'

(b) Click anywhere outside box to close

Graphics version: To adjust picture slightly click on the appropriate direction as needed
**Task #12 Edit a GoTo Button Object (edit destination)**

Select button to edit

(a) Click object
(dotted box appears around object)
(b) Click 'Object' from menu then click 'Edit'

If necessary, edit button name

(dialogue box appears)/the 'Button Name' dialogue box appears)
(a) Without clicking mouse, type new name for button
(b) Click mouse once, cursor will reappear (graphics version shows picture of arrow cursor)
(c) Click anywhere outside box to close

If necessary, edit button appearance

(button icon dialogue box appears) -- box has no specific name so same message is displayed in both graphics and text versions

(a) Click arrow keys to scroll available icons
   Click on desired icon

   OR

   Click button labeled 'None' if invisible icon is desired

   OR

   Click rounded rectangular button is this icon type is desired
   (if previously named, button name will appear inside rectangle)

(b) When done, click outside box to close

If necessary, edit button destination

(dialogue box appears)/(GoTo dialogue box appears)
(a) Click on small box next to desired destination
(b) Click anywhere outside box to close

Reference pointers were used instead of specific reference to objects in graphics version. For instance in (a) instead of 'Click button labeled 'None' if...... graphics version read 'Click here if...... with an arrow pointing to the button object labeled 'None'.
APPENDIX C

SAMPLE LETTER TO PROSPECTIVE PARTICIPANTS
Hi Gloria:

Dr. Hall has probably mentioned me and the study I am conducting this quarter. I am looking for individuals with your background and experience to help make the study a success.

First, my name is Jo Thomas and I am conducting a study which explores ways of improving the usefulness of online help. If you are like me you have experienced difficulty, maybe utter frustration when trying to either locate necessary help information or make sense of help information when trying to complete computer tasks. Well, my study addresses some of the issues associated with making online help more 'helpful' for users. The study will involve working with Linkway Live!, the authoring program you will use during the second half of class this summer. I do not expect you to know how to use Linkway Live!, in fact, study results are more meaningful if you have no prior experience with the program.

Participation will require no more than 2 hours of your time and involve evaluating one of two help systems designed for the Linkway Live! program. At the conclusion of the study, you will be asked to complete a debrief of the session. You may use one of your scheduled lab sessions for the study and substitute the debrief for Appendix E in your syllabus. You will also receive a gift of appreciation for your participation.

Would 1:30-3:30 on Monday July 3 work for you? We will meet in 222a Ramseyer (right next to Dr. Halls' office). If you could e-mail me today during your lab that would be great. My address is jthomas. Also, if you have any questions or concerns about the particulars of the study, let me know or talk with Dr. Hall.

Thanks,

Jo
APPENDIX D

DEBRIEF QUESTIONNAIRE
The purpose of this debriefing questionnaire is to gather your reactions to the help system with which you were just working. Please be candid in your responses. All comments, whether positive or negative are useful to this study. When you think through your responses, try to reflect only on the help system itself, and explain how effective you feel the help system was in assisting you complete the assigned tasks.

1. Please give your general impressions of the help system:

2. Describe the steps to "Cut an Object":

3. Describe the steps to "Move and Resize an Object":

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4. Compare this help system to others you have used. How does it differ? This comparison could include a discussion of usefulness, clarity, level of detail, etc. and/or any other dimensions you feel are applicable:

5. Were the help instructions clear? In your response, try to recall specific examples of how they were either clear or unclear.

6. What did you like most about the help system?

7. What did you like least about the help system?
8. Describe any aspect(s) of the help system which you found confusing?

9. What were you major difficulties in working with the help system?

10. How do you feel the help system could be improved?

These last questions are simply a way of describing the population of individuals who agreed to participate in the study. No other identifying information will be used in the write-up of results.

Major Area of Study____________________________

___ Gender  ___ Age


Haber, R.N., & Myers, B.L. (1982). Memory for pictograms, pictures, and words separately and all mixed up. Perception, 11, 57-64.


