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Task and Activity Models in Hypertext Usage

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Abstract

In this chapter we examine hypertext usage from the point of view of the information processing tasks performed by hypertext users. Our main purpose is to provide a general framework to identify the tasks which may be effectively supported by hypertext environments. First we present different approaches to the analysis of information processing tasks, as they appear in hypertext and information retrieval literature: Formal, user-centered and integrated. Then we review empirical studies focusing on the cognitive processes involved in hypertext usage. We examine two general types of tasks: Information search tasks and learning/exploration tasks. Based on these studies we suggest that hypertext usage requires the user to build up a task representation and a task management strategy. These two processes are influenced by individual as well as situational factors. Finally we propose a general framework to represent the task and activity levels involved in using hypertext. The framework includes three levels of analysis: The rational or formal level, the cognitive task representation level and cognitive task management level. The latter is further analyzed as a cycle that includes goal evaluation, selection and processing of goal-relevant information. We briefly discuss the implications of this framework for hypertext design and assessment.

1. Introduction

A major requirement for electronic information systems is to provide effective support to the users' information processing activities. By information processing activities we mean activities in which people need to access, read and understand information structures (e.g., texts and documents). Although early hypertext research and development efforts have mainly focused on technical aspects such as data representation and information retrieval algorithms, system usability has now become a key issue (Wright, 1991).

Efforts to improve hypertext usability may be based on several strategies, such as domain modelling (e.g. Nanard & Nanard, 1991) or design aids (Marshall & al.,

1991) which can improve the coherence and visibility of the hypertext structure and the meaning of nodes and links. Interface tools (e.g. Nielsen, 1990) also aim at facilitating navigation and user information about the system (contents, menus, relations, organization). However, these approaches are often limited or difficult to apply. For instance, domain modelling doesn't guarantee system usability; design aids are difficult to define (Marshall & Rogers, 1992); interface tools increase the system complexity and their efficiency is rarely evaluated.

So far, hypertext research has paid little attention to the cognitive analysis of information processing tasks. Most hypertext systems available today were primarily designed as general purpose systems, aimed at supporting users' interactions with information structures regardless of the purpose or task. Another problem is that many of the proposed systems have seldom received any empirical assessment, which makes it difficult to evaluate their effectiveness.

In this chapter we suggest that a closer analysis of information processing tasks may provide useful insights for the design of usable hypertexts. In our perspective task analysis consists in describing the different types of knowledge and skills involved in the performance of a given information processing task. In addition, task analysis involves modelling the goals and subgoals, the plan (subgoal organization), procedures (subgoal execution), strategies (conditions of execution of a group of procedures), objects and actions. This type of approach is widespread in the area of ergonomics applied to design (Diaper, 1989; Hammouche, 1993; Johnson, 1991; Johnson & Nicolsi, 1992).

Some authors (e.g. Wright, 1990) consider that task analysis has direct implications on decisions regarding hypertext structure (e.g., linking) and design (interface). According to McKnight, Richardson & Dillon (1988),

"In order to determine the optimum links, the author needs to anticipate the uses to which the reader will put the text (...) If the author can foresee a range of tasks and provide 'templates' to support these tasks, then the reader is more likely to interact successfully with the document". (p. 339)

A serious problem however is that a cognitive theory of information processing tasks is yet to be proposed. It is our contention that such a theory may be partly induced from empirical studies of how real users perform those tasks, and what factors affect their performance. The purpose of this chapter is to contribute to that aim.

In section 2 we present different approaches to the analysis of information processing tasks, as they appear in hypertext and information retrieval literature. We have identified three types of approaches: Formal, user-centered and integrated. In section 3 we focus more directly on the cognitive processes involved in using hypertext. We review empirical studies on using hypertext for two types of tasks: Information search tasks and learning/exploring tasks. For each of these types of tasks we examine how presentation format affects the user's strategies and representations. Based on these findings, we propose a general framework to represent the task and activity levels involved in using hypertext.

2. Task analysis in hypertext research

The tasks or activity domains for which hypertext may be useful or efficient

have been subject to much debate. Bernstein (1993) defined three types of information-based activities he called information mining, manufacturing or farming. Bernstein pointed out that these activities may call for different support environments. For example, "information mining" may be best supported by information retrieval systems, and less well supported by hypertext systems.

The issue of what information processing tasks may or may not be supported by hypertext calls for a detailed analysis of these tasks, which may be conducted from several points of views: A "system-centered" or formal point of view consists in defining formal criteria to characterize information processing tasks. A "user-centered" point of view focuses on how the user represents and performs these tasks. In this section we illustrate these two approaches in the case of information retrieval tasks, which have been most extensively studied in the literature.

2.1. Formal approaches to information retrieval

From a formal point of view, the main purpose of information retrieval is to select relevant information units (recall), while ignoring irrelevant units (precision; see Salton & McGill, 1983). Research on information retrieval has focused mainly on problems such as document indexing, database structuring, search algorithms and query languages.

In this area of research, the term "hypertext" is often used metaphorically to indicate some form of linking between database items. Database linking may be based on several techniques, such as fuzzy logic (Frei & Stieger, 1992; Croft, & Turtle, 1993), neural networks (Biener, Guivarch & Pinon, 1990; Lelu et François, 1992) or Petri nets (Stotts & Furuta, 1991).

In some systems hypertext linking was included as one of several tools (e.g., Girill & Luk, 1992). The rationale is that users may need different tools at different stages of their information retrieval activity. For instance, hypertext may be most useful in the early phases of the activity, when the user's goal is not yet completely specified.

Traditional information retrieval methods or systems have sometimes overlooked the needs of human information retrievers (Thompson & Croft; 1989). Many systems suffer from poor interface design, complex query syntax, and the need to specify target contents in advance. Using hypertext for information retrieval may alleviate these problems: The user does not have to specify target information in advance interaction with the system is made easier, and finally the user receives an immediate feedback on the relevance of his or her selections (see Agosti, 1992; van Rijsbergen & Agosti, 1992).

2.2. User-centered analysis of information search tasks

A few authors have examined information search tasks as they may be performed by a hypertext user. For instance, Wright (1990, p.176-178) has defined several categories of information search activities based on characteristics of the "target", i.e. the searched information. Search target may be simple and fully known in advance, or it may be more complex and interactively specified as part of the search activity itself.

In addition, Wright pointed out the diversity of the sub-activities involved in information search: Reading, note taking, comparing information from several sources, etc. Each particular sub-activity may call for specific interface tools, for

instance a note taking facility, multiple windowing, cross referencing and footprints.

Other authors have identified situational and individual factors that may render the search task more or less difficult: expertise in the content area, reading skills, familiarity with the system (McKnight & al.;1990). Wright (1991) indicated that memory demands of the task can be increased by some interface characteristics (e.g., a small screen). However the cognitive cost generated by interface characteristics are not necessarily uniform across tasks.

2.3. Integrated approaches: The case of co-operative design systems

Although most studies focus either on systems or on users, in some cases system designers have integrated cognitive or human factor considerations in their work.

Conklin and Begeman (1989) introduced gIBIS, a computerized tool aimed at supporting cooperative design. gIBIS is based on the observation that design problems involve conversations where the participants raise issues, state positions and provide pro- or con- arguments. In gIBIS a problem is represented as a network where nodes are issues, positions or arguments whereas links are typed relations between these entities. Similarly Streitz et al. (1989) have proposed to use a rhetorical model of argumentation, along with a cognitive model of writing, as a basis for the design of SEPIA, a system to support authoring and argumentation (see also Schuler & Smith, 1990).

These examples suggest that system design may benefit from an explicit definition of the type of activities supported. However there are indications that even systems designed after a general task model may still face usability problems. In some cases informal field tests have shown that users tend to structure information in ways unforeseen by the designer (Marshall & Rogers, 1992). In other cases, some of the proposed system's features appeared to increase the user's cognitive load. For instance the constraint of representing one's ideas in the form of nodes and links may not be compatible with the way people go through a complex reasoning task (Conklin and Begeman, 1989)

The studies reported in this section indicate that information search tasks may be defined according to several points of view. On the one hand, what is to be done, on the other hand, what the subject actually does. What has to be done may be defined as a goal to achieve and the goal implementation in the system. What the subject actually does depends on his or her knowledge about the domain, the system and its interface, and his or her representation of what needs to be done.

Electronic information systems must comply with the specificity and limitations inherent to human information processing. In particular the way information is displayed by the system (e.g., idea networks) should be as close as possible to the representations users normally generate as part of the design process (e.g., paper and pencil sketches). However this is just one of the many problems people may face when using information systems. Empirical studies of hypertext usage in various contexts may help build up a more comprehensive model of the actual needs of information users.

3. Empirical studies of hypertext usage: The role of task representation and

management

In his now classic review on hypertext, Conklin (1987) pointed out two potential problems hypertext users may face, disorientation and cognitive overhead. The concept of disorientation relies on an analogy of hypertext as a "semantic space" (see Dillon, McKnight & Richardson, 1993, for a discussion of the semantic space analogy). In order to make sense of a hypertext the user must acquire a mental representation of its layout ("mental map"). Following this analogy, disorientation may be defined as not knowing where you are, where to go and/or how to go there.

Cognitive overhead may be defined as an excessive burden on subjects' processes of reading and navigating the hypertext. For instance, cognitive overhead may arise when the subject cannot remember the areas of the hypertext network he or she has previously visited (see also Wright, 1991).

Disorientation and cognitive overhead may be related to the subject's representation of the reading task and of how to manage it. Foss (1989, experiment 2) asked 10 adults to use a geographical hypertext database in order to perform a task involving the display and comparison of several cards. Foss reported two main types of problems: First, some subjects made too few comparisons and tended to lose track of their hypotheses or to forget how they had come to a conclusion. This was interpreted as a "search strategy" problem, or not having a good representation of the task requirements. Second, some subjects opened too few or too many cards at the same time, and/or positioned the cards in a way that did not allow easy comparison. This was interpreted as a "task management" problem, or not knowing how to perform the task.

Task representation and task management are tightly interrelated. For instance, poor task management (e.g., opening too many cards) may prevent subjects from applying a good task representation (e.g., reasoning by elimination). In other terms, a coherent representation of the environment (what information is available and how to access it) is essential for effective access to the information of interest.

Given the huge diversity of text-related activities, it is difficult to consider the cognitive processes of task representation and management in general (Wright, 1991). Instead the various task domains where hypertext may be used must be considered on a case by case basis. In the next two sections we will take a closer look at two general task domains: Information retrieval tasks and general learning tasks.

3.1. Managing information retrieval in hypertext

Experiments comparing hypertext and paper for information retrieval tasks have elicited two important factors which influence subjects' performance: Information search skills and strategies, and top-level structuring of information.

The role of information search skills and strategies

Searching large and complex information systems requires specific cognitive skills which may not be well mastered by novice information searchers. In a study by Weyer (1982) sixteen high school students used a computerized information system ("Dynamic Book") in order to answer different types of questions about history. Weyer noted that dealing with complex questions (e.g., comparison questions) was difficult for many of his students. Moreover the students had trouble using the system's most advanced search tools (e.g. interactive cross-reference table).

McKnight, Dillon and Richardson (1990) came to similar conclusions after asking a group of 16 adults to answer a series of questions by searching a 40-unit document presented using either print or hypertext. In the hypertext conditions the subjects spent a greater proportion of time searching the menus, and they seldom used the direct links between cards. The results suggested that the search facilities provided in hypertext may not be immediately mastered by novice users. McKnight et al. also noted that task requirements may interfere with presentation formats. For instance, subjects may be more willing to use direct links between related units if asked to summarize the document.

There is some evidence that users' performance may improve as they become familiar with the system. Gray and Shasha (1989) asked college students to answer a series of questions by searching either a printed or two computerized versions (with/without hypertext links) of a sociology chapter. The paper group answered more questions than the two computer groups, and did so faster in four out of five questions. However, in the two computer groups, search time decreased with question rank, suggesting a training effect. Finally, in the hypertext group, the effective use of direct links varied across subjects and questions, which suggests an interaction of task representation and search strategy (see also Wang & Liebscher, 1988; Marchionini & Shneiderman, 1988).

Rouet (1994) also observed an improvement of search strategies in novice hypertext users. In the first study, sixty 12 to 14 year-old students participated in four experimental sessions. At each session the subjects were asked to search the hypertext in order to answer four questions. Search effectiveness increased over experimental sessions, especially for the more complex questions. Moreover the subjects used different search strategies as a function of question complexity, but only after some practice. Rouet suggested that practice improved students' representation of the hypertext organization and task requirements. In the second study, thirty nine 16 to 18 year-old students searched two hierarchical hypertexts in order to answer simple, complex-explicit and complex-implicit questions. Search time decreased from first to last question in a series and also from first to second exposure to the same hypertext. Again, the selection strategy varied as a function of question characteristics: For simple questions the subjects selected mostly target hypertext units; for complex questions the subjects selected a larger proportion of superordinate and/or irrelevant hypertext units.

Improvement of search efficiency with training was also reported by Tombaugh, Lickorish and Wright (1987). Tombaugh et al. asked novice computer users to read a lengthy text on screen using either a single or a multiple window format. Subjects' task was to locate the answer to 10 factual questions, after having read the whole text once. In experiment 1 subjects received minimal training and there was no advantage for multi-window presentation. In experiment 2 subjects were trained more carefully to manipulate the pointing device and to read in multiple windows. Multiple windows resulted in significantly faster responses once subjects were familiar with the procedure.

These observations are compatible with our claim that both a task representation and a task management strategy are needed to perform hypertext search tasks. Representing the task means understanding the information needs

given a task or request, e.g., making a difference between a fact retrieval and a comparison question. A task management strategy relates the available information and search tool to the task representation in order to access and process the required information.

Effects of top level structure on information retrieval

Several studies have demonstrated that structured representations of the top-level structure of a hypertext (e.g., a hierarchical index) facilitate user navigation and improve search effectiveness.

Simpson & McKnight (1990) evaluated the effects of structural cues on subjects' representation a 24-unit hypertext database on house plants. They used three types of structural cues: Hierarchical versus alphabetic table of contents, presence or absence of a "footprint" (marking the last opened card in the table of contents), and a typographical cue (signalling major units in capital letters). Twenty four experienced computer users read the hypertext once and then searched the hypertext to answer 10 factual questions.

Subjects in the hierarchical condition opened the table of contents more often. They also opened a smaller number of cards both during the initial reading and question-answering periods. Finally they were able to reconstruct the organisation of the hypertext more accurately. Footprints reduced the number of cards opened during initial reading but not when answering questions. The authors concluded that structural cues usually found in paper documents are also helpful in hypertext environments. However different structural cues may be more or less efficient depending on task demands.

The top-level structure may have a qualitative influence on subjects' content representation. Edwards & Hardman (1989) asked 27 undergraduate students to answer a series of 20 factual questions about the city of Edinburgh using a 50-card hypertext. The subjects were assigned to one of three presentation formats: Hierarchical (cards were linked through embedded keywords), index (card headings were listed in an alphabetic index) or mixed (hierarchy and index). Search time decreased with from first to last question and the decrease was faster in the hierarchical format than in the two other formats, suggesting that hierarchical organization resulted in more en-route learning of the content. The representations drawn by subjects after using the hypertext varied as a function of presentation format. The hierarchical presentation resulted in more hierarchical layouts. The authors suggested that hierarchical presentation may help subjects build a "cognitive map" of the hypertext.

As pointed out earlier, novice users may not readily take advantage of unfamiliar navigation tools. Mohageg (1992) asked 64 adult paid volunteers to use a hypertext geographical database to answer a series of questions. The subjects were assigned to one of four presentation formats: Linear, hierarchical, network or mixed (hierarchical + network). Subjects in the hierarchical and mixed conditions needed less time to locate the answers than subjects in the network condition. Also the subjects did not use all the features of the system. For instance, in the hierarchical format, 44% of subjects failed to use the home key to return to the superordinate card. Instead they backtracked their way to the top of hierarchy.

Finally, navigation tools may be profitable only for some tasks. Wright &

Lickorish (1990) observed that the effectiveness of two navigation systems (index versus paging) varied as a function of hypertext content and task requirements. For a book-like hypertext on house plants the index mode tended to be easier to use and preferred by subjects. For a table-like hypertext and for complex questions the paging mode was more efficient. The authors concluded that different navigation systems may fit different activities.

Egan et al. (1989) found that the Superbook system was more efficient than a paper version for questions that matched words in relevant sections of the book. The system was less efficient (with respect to search time) for questions whose words did not match any word in the book. The same result was obtained in a study by Mynatt et al. (1992). Subjects using an online encyclopaedia with a string search tool were more efficient at answering text-based questions than subjects using a paper version of the encyclopaedia.

In the two studies the authors were careful to provide detailed explanations and training to the subjects before completing the experimental task. Pre-training may have helped the subjects plan task management strategies based on system characteristics.

The empirical evidence confirms that searching complex information systems requires adequate information processing skills. First, the subject must be able to build up a relevant task representation. For instance, when asked a question, the subject must represent the information needed to answer that question (a single fact, a relation between facts, etc.). Second, the subject must manage the task of searching that information. Hypertext environments might facilitate information search to some extent, especially when target information cannot be easily located on the basis of structural cues (e.g., headings). However, using a hypertext system requires the user to adjust his or her existing strategies to the functioning of the proposed tools, or even to create new strategies. There is consistent evidence that repeated use of a system plays an important role in this process.

3.2. Managing learning tasks in hypertext

In the studies presented above, the phrase "information search" was often used in the sense of "locating a piece of information". However, in many cases the target information is not precisely defined in advance. The user's purpose may be to explore the system so as to acquire a representation of its content (which may in turn enable the user to define more specific targets).

The task of selecting relevant pieces of information, and building up coherent study sequence may become more difficult as the task requirements and/or the amount of information to be studied increases. It has been suggested that hypertext may facilitate this process by allowing students to sequence the document sections according to their needs, and by providing her with different representations or "views" of complex study materials (Spiro et al., 1991). Different representations and/or access structures (indexes, graphical browsers, embedded links...) may help the reader select and navigate relevant portions of the materials, and build up a mental representation of the high-level relationships among topics.

However, it must be pointed out that this hypothesis has received little empirical support so far (Rouet, 1992). As Charney (in press) pointed out, predefined sequences play an important role in text comprehension processes: Readers tend to

consider early information as important, and they rely on referential continuity to build up high level content representations.

Thus, there are really two issues involved in learning with hypertext: One is to find out whether hypertext can effectively support text-based learning (given subjects' regular learning strategies). Another one is to find out what specific skills subjects must use or acquire in order to become efficient hypertext users.

Interactions between learning task and presentation formats

In the previous section we have illustrated the diversity of information search tasks. Similarly, learning from text can take many different forms. It is an issue to find out for what type of learning activities hypertext is best suited.

First, it appears that hypertext may support only tasks where a thorough examination of the materials is necessary. Gordon, Gustavel, Moore and Hankey (1988) asked 24 university students to read either general interest texts with no learning requirements ("casual reading"), or technical texts with a comprehension requirement ("technical reading"). In each group, the subjects read two texts presented in linear format, or in hierarchical hypertext format. The study period was followed by a free recall task and comprehension questions.

In the casual reading situation, linear presentation resulted in better free recall of important information (no difference was found in the technical reading situation). Linear subjects answered a slightly larger proportion of questions than hypertext subjects. The "casual reading" subjects also found the hypertext format more effortful and preferred linear text. Gordon et al. concluded that hypertext may not be well suited for reading situations that do not explicitly aim at learning.

A problem for hypertext subjects was that they did not have a good sense of the contents of the subordinate units. Some subjects reported that they didn't know "what was behind the door", that is, what information they would get when selecting a highlighted word. Consequently, the poor effectiveness of hypertext in this study may be partly due to interface design problems. Moreover, in this study the task and text factors were confounded, which makes it hard to find out which was responsible for the observed results.

Dee Lucas and Larkin (in press) hypothesized that hypertext presentation may facilitate the reviewing a document after reading it once by providing direct access to the relevant sections. They compared three presentation formats of a 9-unit expository document on electricity: Linear, unstructured hypertext (with an alphabetic index), and structured hypertext (with a hierarchical content map).

In the first experiment, 45 college students read the document in one of the three formats with a general reading task (i.e., to be prepared for a comprehension test). The subjects first read the document in a fixed order and then were allowed to review it. Compared to linear presentation, the two hypertext formats resulted in a larger "breadth" of recall: The subjects recalled unit titles and ideas from more text units. Furthermore, the structured hypertext condition resulted in better memory for title locations in the index.

In the second experiment, 63 college students read the same text in one of the same three conditions. However they were given a specific reading task (i.e., be prepared to summarize the document). The subjects reviewed more units than in experiment 1, and the differences between situations were greatly reduced. The

authors concluded that reading for specific purposes can override the benefits or drawbacks of different presentation formats.

These empirical studies suggest that the effectiveness of hypertext depends on three types of parameters: How the learning task is defined, how the document structure is represented, how the subjects are trained.

Presentation format can influence learners' strategies

Other studies have found that subjects can adjust to some extent their reading strategies to the characteristics of the presentation format. Black et al. (1992) found that the presentation format of online definitions influenced subjects' willingness to access those definitions. Rouet (1990) found that leaving previous selections unmarked increased subjects' disorientation, as evidenced by the looping rate (i.e., accidentally revisiting previously studied nodes).

The influence of presentation format on subjects' strategies may also depend on their study skills. Students are not equally able to cope with complex information processing tasks (Lodewijks, 1982; Wagner & Sternberg, 1987). Britt, Rouet & Perfetti (in press) observed different strategies of college students when studying a set of documents presented as hypertext. Some students tended to follow the index presentation order whereas other students selected the documents in a different order. Likewise, only some of the students were willing to review the documents after reading them once. Thus, all the students did not take equally advantage of the opportunities offered by hypertext presentation.

3.3. Conclusions

We have pointed out that using a hypertext poses two types of task related problems: task representation problems and task management problems. Having a good task representation means knowing how to obtain the best result with minimal time and effort given tasks requirements. Efficiently managing the task means knowing how to cope with the affordances and constraints of the environment (e.g., screen size, availability of search tools).

We have illustrated these two problems through a review of the empirical literature. Problems associated with task representation and task management were evidenced through "on-line" data (e.g., navigation patterns) and through "off-line" measures (e.g., subjects' memory for hypertext structure and/or content, their ability to answer questions, etc.).

The empirical studies conducted so far have evidenced usability problems and some of them have suggested how these problems may be solved.

In several cases, poor effectiveness of hypertext could be attributed to users' lack of training. Conversely, training may allow users to master advanced tools (Weyer, 1982, McKnight et al., 1990; Mohageg, 1992, Rouet, 1994). It is likely that training improves the integration of task management and search strategy. An advanced search strategy may take into account the qualities and limitations of the information environment (see Wright's (1993) "environmental affordances").

A constant finding across many experiments is subjects' need for overview structure information. Structured tables of contents seem to allow the acquisition of structured representations of the hypertext, which in turn facilitates navigation. Designers should be careful in deciding how to represent structure. There are indications that many different structural cues may interfere (Edwards and Hardman,

1988; Tripp & Roby, 1990).

Wright (1991, 1993) showed that interface characteristics (how information is made accessible to the user) strongly influence subjects' strategies for a given task.

In order to provide an analytic approach to the problem of task management in hypertext, we have distinguished two task domains: information retrieval and general learning. Although such a broad distinction is a convenient starting point, we are aware that it may not be theoretically relevant.

First, there is no clear-cut distinction between the two task domains. Searching for high level information may be very close to learning about a subset of the hypertext domain. Second, learning tasks may involve exploring as well as information retrieval subtasks. Recent studies have suggested that users may access a hypertext database with very different purposes and strategies in the course of a single session (de Vries, 1993).

In fact, learning defines an outcome rather than a particular type of activity. Different interactions with information structures may result in different learning outcomes. However mere exposition to hypertext is no guarantee of effective learning, even though the hypertext structure may have been designed after expert knowledge representations (Jonassen, 1993).

Finally, the studies presented in this section have used many different criteria to assess user performance: navigation patterns (number of cards opened, etc.), memory for hypertext content, ability to reconstruct the hypertext structure, etc.). In the absence of a thorough analysis of the task requirements, it is sometimes difficult to decide if those criteria are the most relevant ones. This points out the need for a general definition of tasks in hypertext research.

4. From task analysis to activity models

In this section we propose some elements to describe task and task management in hypertext. First we propose a three-layer framework to describe the users' task and activity. Then we examine in more detail the evaluation, selection and processing mechanisms involved in using hypertext.

4.1 A general framework for hypertext-supported tasks

In the traditional human factors perspective, a task model is often an abstract description of what should be done and the most efficient way to do it, regardless of the specific characteristics of the user. In recent years there has been an increased consideration for the users' actual representation and execution of the task, and how to take them into account in system design (Anderson, 1990; Mahling & Croft, 1993; Wright, 1993;).

A comprehensive model of information usage tasks should establish a set of relations between a rational model of the task, the user's cognitive representation and the user's activity. Based on these principles, Table 1 presents a general categorization framework for task analysis. Three possible layers of task analysis are considered: The rational task model layer, the cognitive task model layer, and the cognitive activity layer. At each layer three main entities are defined: A goal, a set of means and an environment.

	Goal	Means	Environment
Rational task model	Formal goal definition Optimal goal structure	Rational method Optimal plan + procedures	Information database Interface
Cognitive task model	Cognitive goal representation	Actual plan Cognitive strategy	System representation (application domain, tools, interface)
Cognitive activity	Action regulation	Action execution	Currently displayed information

Table 1: A three-level analysis of hypertext usage

A rational task model describes the most efficient way to achieve a goal in a given environment. The cost of achieving a goal may be estimated as a function of time and effort. The rational model can be formulated independently from the characteristics of a particular cognitive system (e.g., knowledge, purposes, skill, strategies). In a rational model, the *goal* is defined formally, as the desired state to be reached. The *means* consist in an optimal plan and set of actions. The *environment* consists in an information database (e.g. a hypertext database) and an interface that allows access and navigation in the database. There may be several rational models for a given task (Simon, 1991).

The cognitive task model also consists in a representation of the goal, a representation of the environment, and possibly adequate means. The cognitive task representation plays a role in organizing (planning, monitoring) the subject's activity. It also provides criteria to evaluate and terminate the activity (Chatillon & Baldy, 1994). The cognitive goal representation is influenced by a particular subject's expertise and interpretation of the task. Consequently, there may be several cognitive representations of a given rational model. For instance, pre-questions or reading directions may receive different interpretations across readers. Similarly the cognitive plan or strategy is related to, but not isomorphic to the rational method. It may vary as a function of the subject's goal representation, and can be updated as a function of incoming information (see “cognitive activity”). The *environment* of the cognitive task model is the information system as represented (i.e., learned, mastered) by the user. System representation may vary as a function of subjects' domain expertise, previous experience, and so on.

Cognitive activity results from the application of a cognitive task model in a particular situation. At this level the goal is represented as a regulation mechanism. The cognitive strategy results in a series of actions (e.g., selecting and reading hypertext units). The environment consists of the information currently displayed and the navigation tools currently available. *En route* feedback may lead to revision of the cognitive strategy in an opportunistic fashion (Hayes Roth & Hayes Roth, 1979).

The relations between the three layers are as important as the entities defined at each level. When analyzing a particular task, it is especially important to identify the

possible discrepancies between a rational task model and the corresponding cognitive representation(s).

Within this general framework, we suggest that information usage tasks may be defined according to at least two dimensions: The specificity of the goal (which may be more or less precise) and how the goal is implemented in the system (unique or multiple implementations). The combination of these two dimensions results in four typical information usage tasks.

- "Locating" corresponds to cases where the user has to deal with an explicit request about a unique piece of information.
- "Exploring": The user doesn't have an explicit request but he or she looks for a relevant (and unique) piece of information.
- "Searching": The user has an explicit query which corresponds to a set of units in the hypertext. The set of relevant units may be grouped or distributed.
- "Aggregating": The user doesn't have a precise query but he or she thinks that he may find several relevant units in the hypertext.

A particular situation is "re-aggregating" where the user has previously acquired information from the hypertext and is updating his or her knowledge through a further consultation. This type of task may increase the "functionality" of knowledge by showing the user how previous knowledge can be inserted in a new context (see Spiro et al.'s (1991) concept of criss-crossing).

During a session several of these strategies may be used in turn. For instance exploration may become aggregating if it is extended to several areas of the hypertext.

4.2. Reading hypertext: Evaluation, selection and processing

In this section we examine the relations of task representation to the activity of using a hypertext. As shown in Figure 1 using a hypertext may be represented as a processing cycle including three main stages: Goal evaluation, topic selection, content processing. This view is compatible with other cognitive models of computer-supported tasks (Guthrie, 1988; Norman, 1984).

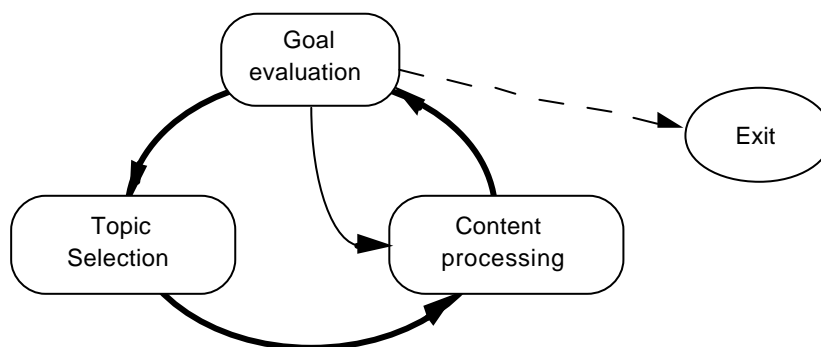


Figure 1: Global hypertext processing cycle.

Goal evaluation. As suggested in section 4.1., the subject's task model includes

a goal representation which may be modified dynamically as a function of the subject's progress in the system. Goal evaluation is the process by which the subject compares the current state of affairs with his or her goal representation. Goal evaluation first takes place at the very beginning of the activity: When confronted with a problem or question, the reader has first to determine whether a solution or answer can be produced, and what means should be devoted to that end. Then goal evaluation may take place each time the subject acquires information that may contribute to goal achievement.

Maintaining an active goal representation in working memory may interfere with the cognitive cost of selecting and locally processing hypertext units, due to the limited working memory capacity (Britton, Glynn & Smith, 1985). Subjects may reduce this load by taking notes while selecting and studying documents. The issue of whether hypertext offers new means to support goal maintenance has hardly been studied so far. However, it has been showed that including a note taking facility in an electronic text environment does not result in any decrease in comprehension performance (van Oostendorp, in press). Moreover, there is evidence that providing an explicit representation of a required information search goal (e.g., a pre-question) facilitates the search process.

When searching for specific facts in a hypertext, inexperienced readers often need to re-activate their goal representation. In a series of experiments, Rouet (1991) used a prototype hypertext system to study 12 to 14 year-old students' information search strategies. The task consisted in searching a seven-unit hypertext to answer questions. The first version of the experimental system did not include any option to display the question after the search process had been initiated. This turned out to make the task very difficult for many subjects. Some subjects would typically initiate the selection process before they had a stable representation of the search goal. After a few selections, they would stop and ask the experimenter for another presentation of the question.

When question display was made available in a later version of system, it was actually used by one subject out of three on average. This percentage rose to 40% for the most complex type of questions.

Even under general study objectives, readers may need to check the problem statement while reading the hypertext. Rouet, Favart, Britt & Perfetti (1994) used a simple hypertext system as a research tool to examine college students' learning from historical documents. College students were asked to use the system to study a series of historical controversies. Each controversy was stated in a pop-up frame that could be opened from any document page. Rouet et al. observed that on average 68% of the subjects opened the pop-up option at least once while studying the documents. Interestingly enough, question lookbacks did not occur at random locations in the study sequences. About 75% took place either at the beginning or at the end of the sequence. A possible interpretation is that subjects were monitoring their own study activity, recalling the question either to plan document selection, or to their understanding. This finding supports the hypothesis that task representation has both an organizing role and an evaluation role (see above, section 4.1).

In the previous examples the "goal" is a representation of the information to

acquire. In other situations, the goal may be defined in terms of treatment to apply to the information. For instance, general knowledge acquisition or text summarization. In these cases goals are defined at a more abstract level, and the subject has to infer the nature of goal-relevant information. For instance, when given "general learning" directions, the subject may focus on general domain organization. In a summary task the subject may look for main points.

There is no empirical evidence that such procedural goals may be difficult to maintain in memory (e.g., that a subject may fail to remember that her task is to *summarize* the hypertext). However the influence of presentation format (e.g., linear text vs. hypertext) may vary as a function of task requirements (Dee Lucas & Larkin, in press).

Topic selection

Selection in hypertext is made through menus or embedded buttons. A user may have to make several selections before he or she reaches a passage of interest. In order to make selections the subject must have correct expectations about where the selectable items may lead. Not knowing where a link leads can be a serious problem when exploring a hypertext (Gordon et al., 1988). With paper documents the reader may not know where a specific information is located, but the whole document is visible and it can be manipulated with no restriction. It is a central issue to provide hypertext readers with such a sense of global visibility (Lai and Mamber, 1991).

In some particular hypertext applications, knowing the destination of links is not a problem. For instance Britt, Rouet, Georgi & Perfetti (1994) used hypertext to present multiple history documents. The use of links was limited to connecting related documents using a "refers to" criterion, i.e., two documents were linked if one referred to the other. In this particular case the destination of links was unambiguous.

In any case, navigation requires a goal, a plan to achieve the goal, and the ability to evaluate intermediate results and to revise the plan accordingly. A correct representation of the hypertext organization (which may be partly analogous to a cognitive map, Dillon et al. 1993) is a powerful help for orientation and hence, navigation. Conversely, the analysis of subjects' navigation patterns may reflect cognitive orientation (Foss, 1989, Rouet, 1990). However, the observable part of navigation may not reflect accurately the subject's orientation. Some orientation processes may not result in explicit decisions (e.g. mentally reviewing the pages read), and some decisions may not be interpretable in terms of orientation.

Content processing

During the content processing stage the subject acquires a cognitive representation of the meaning of the selected passage. Understanding a passage of text involves a hierarchy of processing levels. At the local level, the reader has to comprehend the meaning of the text, i.e. to extract its macrostructure and to integrate the content with her previous knowledge (van Dijk & Kintsch, 1983). At the global level, the reader has to evaluate whether the passage contributes to the goal, and to integrate the information with that of previously read information (i.e. the result of previous cycles, see Guthrie, 1988; Rouet, 1990). Goal evaluation may have an impact on the low level processing of a passage. For instance, the user may decide to stop reading a passage if a certain relevance threshold is not reached. Shifting between

local and global levels of processing may result in some disruption of the comprehension process (Charney, in press).

In sum, when reading a hypertext, basic text processing is embedded in an elaborate cycle that includes selection of relevant passage and evaluation of goal achievement. Although such a high level management of the reading activity may be observed with conventional text, it is important to notice that in hypertext it is compulsory. There is no predefined organization which the reader might follow passively. Instead the user has to play an active part in building up a coherent sequence of text units. This necessity of a strategic control may explain the difficulties encountered by novice hypertext users.

The cycle of evaluation, selection and processing proposed here does not account for all the specific cognitive operations that take place during hypertext usage. However, it provides a general cognitive interpretation for the concepts of task representation and task management introduced in the first part of this chapter.

5. General discussion and conclusions

In this chapter we have examined hypertext usage with an emphasis on the user's task representation and management. We have stressed the need for explicit models of information processing tasks and activities. In the studies conducted so far, task analysis was often incomplete, and there is a large heterogeneity in the authors' definition of "task". In sections 2 and 3 we have reviewed several approaches to the problem of analyzing information processing tasks involving hypertext. We have showed that tasks can be analyzed from the machine or the user point of view. The latter approach demonstrates that managing navigation in hypertext is a complex cognitive activity, that may be responsible for some of the usability problems evidenced in the hypertext literature (disorientation, preference for traditional formats, familiarity effects, etc.).

Our task analysis suggests that these problems have to do with building task representation and task management strategies. This is only possible if users are able to identify goals, to maintain and to evaluate them throughout the activity. Also users must have at least some knowledge of the properties of the environment (e.g., top-level organization, search tools etc.) in order to build up effective action plans.

How should hypertext be designed in order to provide effective support to information usage tasks? Although we cannot offer a general answer to this question, results from empirical studies as well as our general task analysis framework provide at least some hints.

First, information should be structured according to some categorization principle that the user can identify. The overall organization should be made explicit, if possible in a hierarchical way. However, the user should be able to visualize all the available layers at a glance. A clear, explicit top-level structure is what will allow users to make informed selections based on their goal representation.

Then the user should be able to mark, select or extract the intermediate results of the search process. This can decrease the burden of remembering and integrating partial results from search cycles. Online notetaking facilities may contribute to that aim.

Finally, the need for training and practice should not be overlooked. It is

unrealistic to expect a new, unfamiliar environment to generate immediate benefits. Instead, the users need to identify the type of information structures involved, to understand the functioning of navigation and orientation tools, and to build or adjust adequate management strategies.

Hypertext has potential for many applications in education, research and business. However, the usability, effectiveness and desirability of hypertext applications in these areas will depend in a large part on how well system design integrates a correct model of the task as it is represented and managed by the user.

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