

Evans, P. (1994). Investigating the use of interactive hypermedia systems. In K. Beattie, C. McNaught, & S. Wills (Eds.), Proceedings of the IFIP TC3/WG3.2 International Working Conference on the design, Implementation and Evaluation of Interactive Multimedia in University Settings. Melbourne, Australia 6-8 July 1994. Elsevier Science Publishers Amsterdam, The Netherlands.

# Investigating the use of interactive hypermedia systems

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## Abstract

There have been innumerable glowing reports of the way hypermedia systems allow users to explore and use vast amounts of information in ways not possible using traditional information systems, such as books or libraries. However, these reports are often based on anecdotal data or data collected in small contrived experimental settings.

There are several reasons for this lack of strong research evidence on hypermedia use including the relatively recent development of such systems. More substantive difficulties arise from the very characteristics which make hypermedia systems so powerful and versatile. In addition, hypermedia systems are "enabling" technologies and for this reason any investigation of their use is also an investigation of interactions between at least four sets of factors: features of the users, the tasks they are doing, the content in the system and the tools provided by the system.

It is suggested that more complete understanding of the use of hypermedia systems will only be achieved through triangulation among data derived from multiple qualitative and quantitative data collection and analysis methods. Research methods will be examined in the context of a study of the use of the Perseus hypermedia system in an undergraduate course. Data collection methods included interaction logging, observation, questionnaire, interview and exam results. Of particular interest is the InterLogger(TM) set of tools which assists in the collection and annotation of the interaction log data. Examples are presented demonstrating the way in which fine grained interaction log data was analysed, interpreted and used as a quantitative backdrop to interpret the qualitative data.

The paper concludes by highlighting applications and implications for interaction logging for researchers, users, and developers of hypermedia systems.

Keyword Codes:

H.5.1; H.3.3; K.3.1

Keywords:

Multimedia Information Systems; Information Search and Retrieval; Computer Uses in Education

# 1. Hypermedia and Multimedia

Two fundamental concepts shared by all hypermedia systems are those of links and nodes. A node is a fragment of information which might contain different data types such as text, sound, drawings, images, or video. A link is a relationship or connection between nodes and users of the hypermedia system can use these links to move among the nodes. However, information systems containing a network of interlinked nodes are not new, with a common example being the inter-linking of articles and books in scientific literature. What is new is the computational nature of hypermedia systems made possible by modern computers allowing the system to provide a more active and supportive interface for interaction not possible in non-computer based systems.

While the terms "multimedia" and "hypermedia" are sometimes used interchangeably, these systems generally have a differing focus. Hypermedia systems traditionally have provided users with high levels of user-control, for example, allowing users to search for relevant information through large information spaces. On the other hand multimedia systems may contain expository sequences guiding the user through materials designed to teach particular concepts or skills. While the distinction is a matter of degree of user-control, the ways in which people interact with these systems are quite different and research on these interactions must consider the different design goals. The system investigated in this study emphasised higher levels of user-control and thus a major focus of the study was the way users moved around the system.

Proponents of hypermedia systems suggest that such systems provide the user with enhanced intellectual and physical access to a wealth of contextualised information. This increased access can empower users to engage in authentic and situated research activities previously only possible for subject experts with access to a pool of research assistants and well-stocked libraries or other information stores. However, these hypermedia environments require users to be strategic consumers of information capable of high levels of self-directed learning. Without these skills, users are reduced to wandering aimlessly through a forest of disconnected materials and participating in shallow and fragmentary fact collection and unintegrated learning.

## 2. The research question

This paper reports on methodology used to study the ways in which students used a hypermedia system called Perseus to support information seeking and use in an undergraduate course on Greek and Roman religions.

A primary goal of the Perseus Project was to collect and provide access to a large amount of primary information about ancient Greek culture within a hypermedia

environment. The underlying rationale being that by providing scholars with a rich information environment they will be empowered to ask a wider variety of questions related to ancient Greek culture.

Perseus 1.0 was released by Yale University Press in April 1993 (Crane, 1992) and consists of a CD-ROM disk readable on a Macintosh computer. In addition to many other things, the Perseus 1.0 CD-ROM contains over 50 volumes of Greek literature including English translations, and over 5,000 colour images and textual descriptions of about 1,500 objects including sculpture, coins, vases and buildings. Future versions of Perseus will include a larger quantity of materials and a more complete description of Perseus can be found in Mylonas (1992).

### **3. The research methodology**

Research methodologies used to investigate the way students use a complex and large hypermedia system such as Perseus should have several characteristics. First, they should be based on the triangulation of findings from several data sources using different collection and analysis methods (Marchionini, 1990). Second, they should incorporate elements of ethnographic and naturalistic methods sensitive to the perceptions of the participants (Grudin, 1990; Neuman, 1989). Third, they should be conducted over significant amounts of time in authentic settings while participants are performing real tasks.

Data collection and analysis methodologies are often described as being either quantitative or qualitative and there is often reluctance to combine these in a single study. While the positivist and naturalist research paradigms are based on different assumptions about the world and research, it is possible to use the unique strengths of each within a single study. In fact, doing so often reveals insights and concepts not visible if either methodology is used in isolation.

Grudin (1990) suggests another reason for the importance of multiple data collection and analysis methods. He positing the existence of five stages of computer research. The focus of the first and second stage was on development of basic hardware and software and research methods were largely informal tests of speed, capacity and reliability. The wide spread use of interactive end-user computing resulted in a research focus on usability, interface and human computer interaction in the third stage. The remaining stages focus on the impact of computer based environments on the way individuals (stage four) and later groups (stage five) relate to the world. Each of these stages has its own preferred set of research methodologies with the earlier stages focusing on quantitative methods employed in relatively short term, contrived experiments in laboratory settings. In the later stages there is more use of longer term studies using a variety of qualitative methods in naturalistic settings and disciplines such as social and organisational psychology and ethnography. While some hypermedia research is being done in relation to stages 1 and 2, the focus of most research is on issues pertinent to stages 3, 4 and 5. Thus, we should be using appropriate and multifaceted research tools.

In the Evans (1993a) Perseus study, data was collected from participants using the following methods:

- focused and opportunistic observations of people using Perseus;
- interviews with groups of students and individual students;
- questionnaires;
- student performance on examinations and in the course; and
- recording a log of all interactions between users and Perseus.

The overriding goal, when selecting data collection and analysis methods, was to be able to triangulate between data points. For a detailed description of the triangulation and integration process see Evans (1993a). If confirming evidence could be found using different methods then more confidence could be placed in the conclusions.

The remainder of this paper will focus on the use of interaction logging or transcript analysis (Siochi & Ehrich, 1991) in the Perseus study, and the methods used to represent and analyse data derived from the interaction log. In addition, two examples of triangulation between other methods and the interaction log will be briefly described.

### **3.1. Interaction logging as a methodology**

Interaction logging has many advantages as a research method. First, the data is collected unobtrusively in the user's natural environment while performing authentic tasks. Second, vast amounts of data can be collected relatively cheaply without the direct involvement of the researcher. However, interaction logging also suffers from disadvantages. As the user is using the system in their natural setting, it is sometimes difficult to infer what they are trying to do, and interaction logging, like other data collection methods, is subject to specific biases. For example, while information is displayed on the screen there is no guarantee that the participant is attending to that information. Another problem with the method is imposed by the interaction logging software which must be integrated into the experimental system, thus its operation imposes some computational load on the system.

The InterLogger (Evans, 1993b) suite of HyperCard stacks was developed as a general purpose tool for assisting the researcher to collect and process interaction logs. InterLogger contains the following stacks: InterLog Installer, InterLogger, InterLog Listener, and InterLog Coder. The function of each stack is briefly described below and more details are provided in Evans (1993a).

The InterLog Installer stack was used to insert code into the experimental stacks to record the interaction events. In addition to the automatically inserted modifications, some modifications were also done by hand.

Each time Perseus was used the InterLogger stack recorded a time stamped log of events each containing the stack and card name, and the mouse action or menu selection used to move between these. Throughout the study over 7 megabytes of interaction log data was collected corresponding to 363 sessions or more than 310 hours of Perseus usage. Users were also asked to provide contextualising information in the form of their name and goals before using Perseus. At the end of the session users were asked if they achieved their goal and also to comment on good or bad

aspects of Perseus. Further contextualising information was also provided because users were able to press a function key at any time and enter an on-line comment.

One difficulty with the interpretation of interaction logs is that it is sometimes difficult to deduce what task the person is doing during the session. For this reason other data collection methods (eg observation and field notes or perhaps video) are often used and then synchronised with the interaction log. However, this synchronisation is often time consuming and inaccurate.

InterLogger addressed this problem by sending the interaction log to a second Macintosh which was used to annotate the interaction log in real time (see figure 1). This combined data collection methodology is better than the sum of the two individual mechanisms (observation and interaction logging) because the observer is freed from recording the mechanical aspects of what was going on (eg the screen the subject is looking at, or how long they looked at it) and is able to record the more qualitative data (eg the user's goals and intentions, their interactions, comments and other gestures.) Thus each collection instrument (the computer and the researcher) is used to collect data most suited to their abilities.

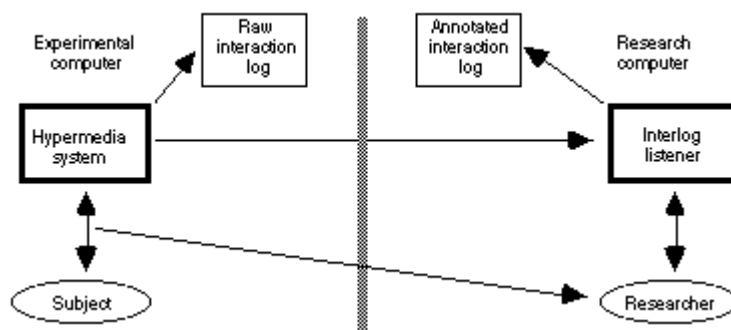


Figure 1: Showing the subject's computer recording the raw interaction log and also sending a copy to the researcher's computer where it is annotated (based on observations) in real time.

The InterLog Coder stack quantified the raw interaction log into a format which could be imported into a standard statistical package. Briefly this involved removing redundant data from the interaction log and coding each of the interaction events into a location state and a move state.

## 3.2. Display and analysis of the interaction data

Quantitative data from the interaction log were displayed and analysed in four main ways. Taken together these analyses provide ways of visualising and identifying patterns in the large amount of quantitative data that was collected. Examples of these displays are given below.

### 3.2.1. Frequencies, totals and averages

First, descriptive statistics based on the interaction log data were computed to describe the number of sessions, the blocks of time different people used Perseus, and

the amounts of time they used different parts of the Perseus system. Figure 2 demonstrates that even though students were assigned to do the same tasks, there was a large range in the number of hours different students used Perseus.

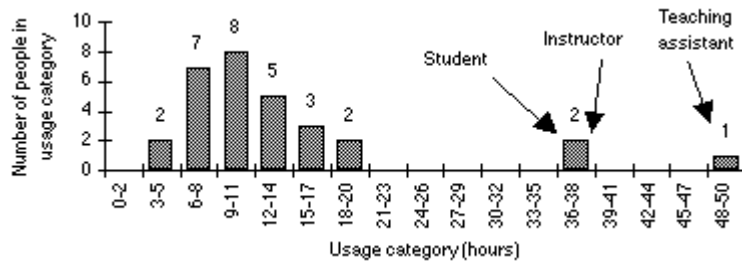


Figure 2: Frequency of users in by number of hours of Perseus usage.

Figure 3 shows the number of discrete visits to each state. The large number of visits to the Travel Path and the Images states reflects the importance of images and paths to people involved in the course.

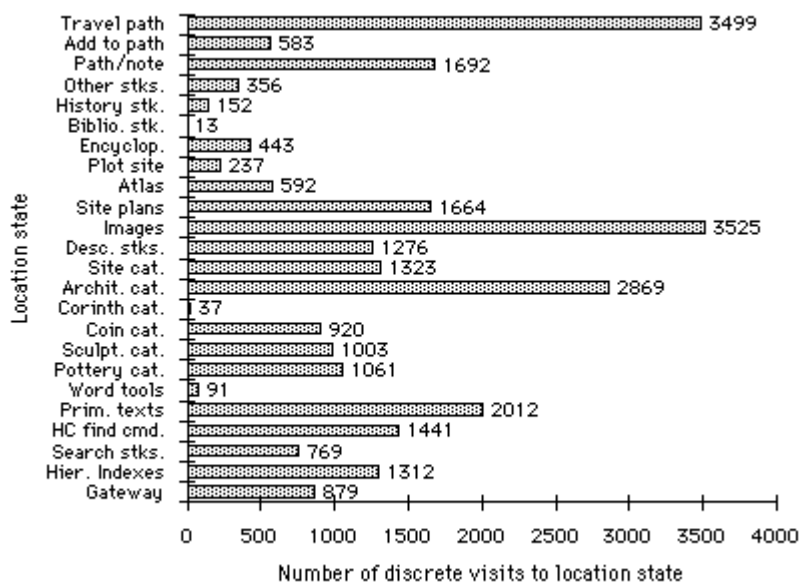


Figure 3: Number of visits to each Perseus location states.

### 3.2.2. Interaction Plots

Lin, Liebscher, and Marchionini (1991) have suggested that state-by-time plots showing movement across different states over time will represent the dynamic nature of the interaction between the user and the system.

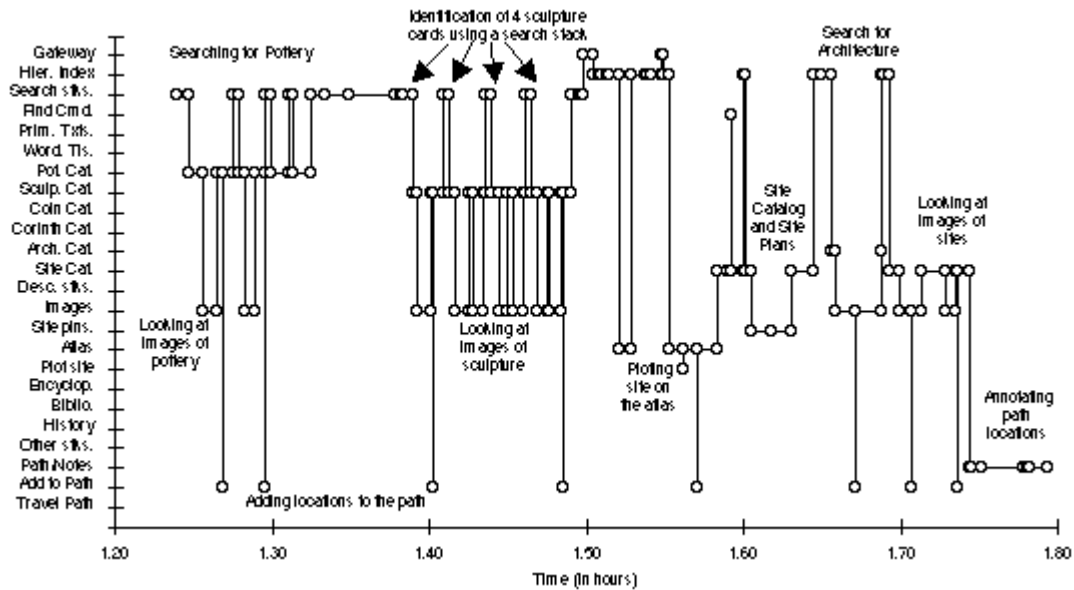


Figure 4: Half hour section of an interaction plot showing a group of students finding information, adding locations to their path and then annotating this path

Figure 4 shows a half hour portion (from 1.5 to 1.75 hours) of a session which clearly shows that a group first searched in the Pottery Catalog and then the Sculpture Catalog. While searching in the Pottery Catalog, the group engaged in four separate search cycles in which they used a Search stack to identify four Pottery Catalog cards. They looked at two images on the first two Pottery Catalog cards and added both to their path. The next two Pottery Catalog cards were not relevant and they returned to the Search stack. While looking for sculpture, they identified four Catalog cards and added two locations to their path. They then plotted a site on the Atlas and added it to their path--then they looked at information in the Site catalog, Site plans, Architecture Catalog, and at several images. Near the end of the excerpt they annotated the locations on their path.

While these state-by-time interaction plots vividly represent the dynamic nature of the interaction within an individual session they do not provide a way of summarising across a number of sessions.

### 3.2.3. Transition matrices and diagrams

Transition matrices were computed to allow examination of the way groups of people moved through Perseus in a number of sessions. Each cell in such a matrix represents the number of times the user moves from one state to the other. Thus the cell [Gateway, Index] gives the number of times the group moved from the "gateway" to the "index" state. Table 1 is a transition matrix based on all moves and all sessions. For example, it shows that on 305 occasions people went from the Gateway to an Index stack and on 60 occasions they went from the Gateway to a Search stack.

Table 1: Transition matrix showing frequency of moves from one state (rows) to another (columns).

	p	q	a	b	c	d	e	f	j	k	l	o
a-Gate	7	2		305	60	25		15	4			3
b-index	122	69	82		104	174	3	584	25	2	7	107
c-Search	33	11	41	68		168	9	357	75	14	1	
d-PrimT	80	3	121	95	154		72	7	3		1	10
e-Word	3		7	5	8	63			1			
f-Cat.	9	2	89	407	336	7			728	2638	570	21
j-Desc	5	8	24	91	63	4	2	634		3	3	1
k-Images	42	8	1	2				2795	28		652	
l-Plans	1		15	37	7	2		405	54	644		4
o-Atlas	258	125	33	61	8	6	1	16				
p-Encyc.	292		14	92	28	100	4	5	3	42	2	2
q-Hist.	1		10	53	10			1	6	8		2
x-Plot	258				90				1			257
Total	302	104	437	1216	778	549	91	4819	928	3351	1236	407

Such transition matrices could be based on subsets of the interaction log database to show certain types of behaviours. For example, the transition diagram in Figure 5 is based on sessions where the subjects declared they were looking for information and where "retreat" moves (returning to a previous location) have been removed. This vividly illustrates the flow of activity through the Perseus data base. Each transition is tagged with the number of times that transition occurred as a percentage of the total number of transitions. Thus the transition from Search Stacks to Descriptions Stacks occurred 1.0% of the time while that from Search Stacks to Catalog Stacks occurred 5.3% of the total number of transitions.

One cluster or island of connected information is centred around the Catalog Stacks. The number of lines moving into and out of the Catalog Stack state represent over 52% of all transitions and reflects the importance of the Catalog Cards to the organisation of Perseus. Of these transitions 32% correspond to the display of images from Catalog Stacks.

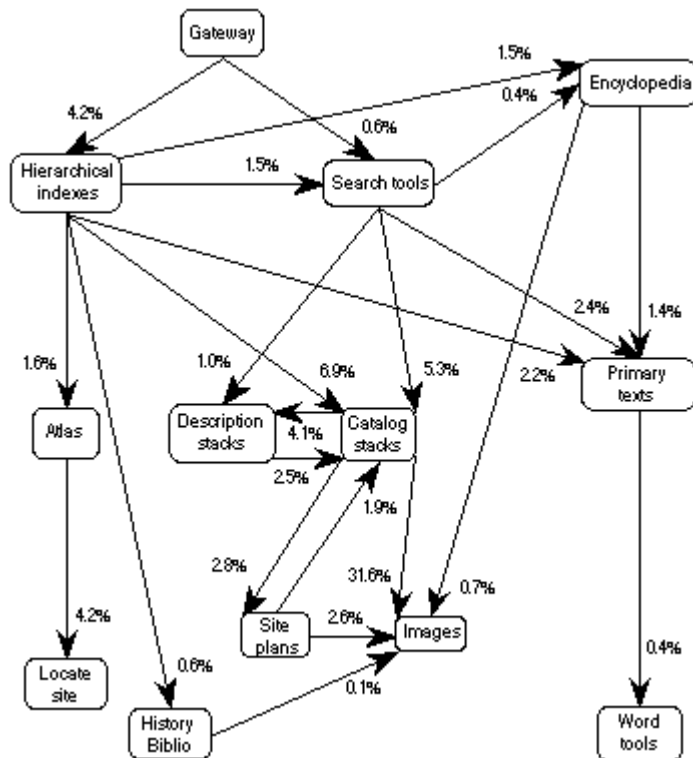


Figure 5: Transition diagram based on the filtered transition matrix.

### 3.2.4. Sequential analysis

Sequential analyses were computed to examine the sequences of events which occur before an event of interest. Sequences of events prior to relevant locations being added to a student path were computed to examine how people located relevant information. Table 2 shows the 13 most common sequences of length four--185 unique sequences occurred. Sequences of four locations include the shortest sequences in which a person uses a search tool to find an image, that is, from a search stack, to a Catalog Card, to an image, and then to Add to Path (ATP). The relatively small percentage of such events in Table 2 (2.1%) might be used to argue that the Perseus search stacks were not very effective. An alternative interpretation is that the Perseus search tools identified relevant objects, but multiple images were inspected before the best image was added to the path.

### 3.2.5. Summary

Each of the four different methods of displaying the interaction data emphasises a different aspect of the way in which people interacted with the Perseus database. More advanced tools offering three dimensional displays, colour or movies, will further increase the ways researchers are able to visualise patterns in the mass of data which can be collected through interaction logging.

## 4. Example of triangulated analysis

This section gives an example of the way data from different sources can be supported by evidence collected through interaction logging.

## 4.1. Fingertip access to information

Undoubtedly one of the most applauded features of Perseus was the ease with which it provided access to visual images. One student commented:

*At least we found something without having to dig through books. I mean it's easier to sit down there and find all the information you needed instead of running all over the place.*

Another said:

*You can access it on one computer as opposed to flipping through six books. I mean, you can at least try to find it. It takes a little less effort. [Perseus is] better than going around the stacks carrying huge books.*

Table 2: Frequency of length 4 sequences ending in the ATP state.

Sequences of states	Freq.	Perc.
ATP -> Pot. cat -> Images -> Pot. cat	28	4.8%
ATP -> Images -> Arch. cat. -> Images	23	3.9%
ATP -> Atlas -> Plot site -> Atlas	22	3.8%
ATP -> Prim. texts -> HC find -> Prim. texts	22	3.8%
ATP -> Images -> Coin cat. -> HC find	20	3.4%
ATP -> Prim. texts -> ATP -> Prim. texts	20	3.4%
ATP -> Images -> Pot. cat -> Images	19	3.3%
ATP -> Coin cat. -> Images -> Coin cat.	16	2.7%
ATP -> Sculp. cat. -> Images -> Sculp. cat.	15	2.6%
ATP -> Images -> Sculp. cat. -> Images	14	2.4%
ATP -> Site cat. -> Images -> Site cat.	12	2.1%
ATP -> Arch. cat. -> Images -> Arch. cat.	12	2.1%
ATP -> Images -> Pot. cat -> Search stks.	12	2.1%
ATP -> other states	348	59.7%
Total	583	100.0%

The interaction log data supports the ease with which students were able to gain access to information by recording the speed with which students were able to move around the system. This is shown not only by how rapidly students were able to move from a search tool, to a catalog card, then to an image of an object, but also by the interaction plots showing the ways in which students were able to systematically navigate around Perseus finding, storing and annotating locations.

## 4.2. Movement between representations

Students also commented that they valued the way Perseus allowed them to move among different representations of the information--the images, textual descriptions, site plans etc.

*Texts come to life with pictures and maps. I like the way that Perseus allows you to compare different types of information together (i.e., photos with texts and definitions) without having to go to different parts of the library.*

*Perseus is more interactive than a book. If you had to look up a plan [in a book] ... you would have to go and find the description of the plan and you would have to dig for descriptions of a certain area of the plan, whereas in Perseus they have the hot-spots that you can just click on and it will give you the description of what that place is in relation to the rest of the plan. So it made it faster to do; it was just more "point and go" than searching through pages and pages of text from a book.*

Information from the questionnaires also supported the importance of these links with the majority of students believing that Perseus was either "useful" or "very useful" in helping them to find thematic connections across different types of information. Further questioning suggests that students were mainly talking about the links between images, texts, and plans.

The movement between different representations of information is also supported by data derived from the interaction log. For example, the frequencies for the different sequences or the percentages for the transitions shown in the transition diagram (figure 5).

## **5. Conclusions and implications**

Triangulation between data collected and analysed using different methods greatly added to the value of this study. In particular the mass of data provided by interaction logging provided a valuable backdrop from which to test the views and attitudes of the participants.

Below are a set of recommendations related to the use of interaction logging for researchers, educators and developers of hypermedia systems.

### **5.1. For the researcher**

As the experience and theory base in the use of hypermedia systems grows, it should be possible to conduct more focused studies however qualitative methods should not be supplanted by purely quantitative ones. Research in a domain such as hypermedia use, which involves the interaction of humans with technology, must use both qualitative and quantitative methods in a synergistic fashion when and where they are most suited to the research problem.

Interaction logging allows the researcher to build a detailed picture of how users are using hypermedia systems over long periods of time and at different locations. The information can be collected relatively cheaply and unobtrusively (with permission) and increasingly capable tools for scientific visualisation will allow the researcher more flexibility and power in exploring the mass of data which interaction logging can collect. (For example, Marchionini is working on using movies for presenting this data.) Path algebras also suggest ways in which this data may be represented and analysed.

In addition to providing an object for research, large, highly interactive hypermedia systems provide a research environment which can be used in many domains. Careful

examination of the interactions between the user and the system can provide a depth of insight into the ways that users find, select, use and understand information that is not possible to collect in non-computational environments. Unobtrusive interaction logging is one such data collection method with a potential usefulness that has just begun to be recognised and explored.

## **5.2. For the developer**

Interaction logging provides a tool which allows developers to conduct usability testing at a level of detail that is difficult to achieve in non-automated environment. In addition the analysis and representations of interaction logs using path algebras, may make it possible for a system to identify and assist users who have become disorientated within the system.

As hypermedia systems become more mature there will be an increasing push towards standards and transportability. These standards should include the provision of "hooks" which can be used to log the interaction between the user and the system. These hooks could also be used to implement tools for use by the reader as they are using the hypermedia system.

## **5.3. For the user**

Hypermedia environments are enabling systems and their impact depends on factors other than the content or the tools provided by the system. In the model discussed earlier, the way a system is used also depends on features of the user, and the tasks which are undertaken. To effectively interact with a hypermedia system requires the user to be self-directed and metacognitively aware of their information needs and their navigation through the system. Interaction logging may be potentially helpful to the user for strategically managing their use of the hypermedia system. ReadingTools (Evans, 1992) is an example of a set of tools which assist the user by recording an annotated history and allowing the user to retrace this history or plot their progress through a database.

# **6. The Future**

The future will undoubtedly be bright with promise and opportunity. Kay claims that "in the near future, all the representations that human beings have invented will be instantly accessible anywhere in the world on intimate, notebook-size computers" (Kay, 1991, p. 138). While the technologies underpinning such systems will develop rapidly, it is critical to remember that the ways in which these systems will be used will always depend on the interaction among features of the content, the tools embedded in the system, the tasks that are being performed, and the user. Only with careful research of these intricate interactions, will complex hypermedia systems be utilised to their potential.

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