

A Library or Just Another Information Resource? A Case Study of Users' Mental Models of Traditional and Digital Libraries

Stephann Makri, Ann Blandford, and Jeremy Gow

*UCL Interaction Centre, University College London, Remax House, 31–32 Alfred Place,
London WC1E 7BT, United Kingdom. E-mail: S.Makri@ucl.ac.uk*

Jon Rimmer and Claire Warwick

*School of Library, Archive and Information Studies, University College London,
London WC1E 7BT, United Kingdom. E-mail: Jon.Rimmer@ucl.ac.uk*

George Buchanan

*Department of Computer Science, University of Wales Swansea, Singleton Park,
Swansea SA2 8PP, United Kingdom. E-mail: G.R.Buchanan@swan.ac.uk*

A user's understanding of the libraries they work in, and hence of what they can do in those libraries, is encapsulated in their "mental models" of those libraries. In this article, we present a focused case study of users' mental models of traditional and digital libraries based on observations and interviews with eight participants. It was found that a poor understanding of access restrictions led to risk-averse behavior, whereas a poor understanding of search algorithms and relevance ranking resulted in trial-and-error behavior. This highlights the importance of rich feedback in helping users to construct useful mental models. Although the use of concrete analogies for digital libraries was not widespread, participants used their knowledge of Internet search engines to infer how searching might work in digital libraries. Indeed, most participants did not clearly distinguish between different kinds of digital resource, viewing the electronic library catalogue, abstracting services, digital libraries, and Internet search engines as variants on a theme.

Introduction

One promising approach to thinking about the use and usability of digital libraries is to consider how users understand the libraries they work with. Do users draw on analogies from traditional libraries or from Internet searching to make sense of their interactions with digital libraries? How do they choose what to do and predict the effects of their

actions? Within Human–Computer Interaction and cognitive psychology, there is broad consensus that people form "mental models" (Gentner & Stevens, 1983; Johnson-Laird, 1983) of systems that they work with, which help them understand those systems and choose courses of action for using them. In this article, we report on a study in which we investigated people's mental models of both traditional and digital libraries in order to compare and contrast their understanding of these two kinds of information resources.

Background

There is a wealth of literature on mental models, and a growing body of literature on the usability of digital libraries. However, there is little on users' mental models of either traditional or digital libraries. In this section, we briefly review related literature on mental models and user perceptions of digital libraries (and their relationship to traditional libraries).

Mental Models

There are many definitions and descriptions of mental models; for example, as "knowledge of how the system works, what its components are, how they are related, what the internal processes are, and how they affect the components" (Caroll & Olson, 1988) or as "an internal mental representation created by system users" (Staggers & Norcio, 1993). It has been suggested (Schumacher & Czerwinski, 1992) that definitions of mental models fall into at least three classes: as collections of knowledge structures, as metaphors and analogies, and as process descriptions of how users

Received August 11, 2005; revised November 22, 2005; accepted March 17, 2006

© 2006 Wiley Periodicals, Inc. • Published online 27 December 2006 in Wiley InterScience (www.interscience.wiley.com). DOI: 10.1002/asi.20510

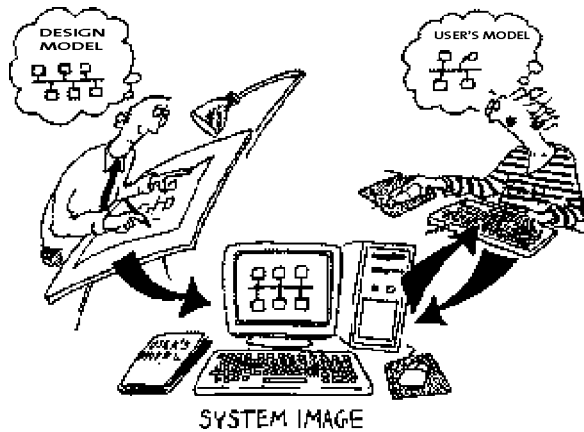


FIG. 1. Design model, user's model, and system image (adapted from Norman, 1986).

interact with complex systems. It has been proposed that mental models can be used for explaining and predicting system behavior, and hence guide much user behavior, but also that users' mental models are neither complete nor accurate (Norman, 1983).

When designing interactive systems, Norman (1986) advocates the study of mental models to drive design decisions Norman distinguishes between a "design model" and "user's model" of the same system (see Figure 1).

The *design model* is how the designer sees the system. It is not necessarily a model of what the underlying system actually looks like, but a model of how it should be presented to the user, for example, with careful use of a metaphor.

The *system image* is the implementation of the design model and consists of all the aspects of the system that the user can interact with, i.e., the actual user interface, any manuals and documentation and online help, training courses, error messages etc. The design model should be implemented consistently across all elements of the system image.

The *user's model* is the user's mental model of how the system works. The users' models are influenced by their existing knowledge and experience, and modified by their interaction with the system through this system image. So a user who is familiar with Internet Explorer and then uses Firefox for the first time will be guided by their user's model gained from the use of Explorer and their expectations of Firefox. When creating the design model, it is therefore imperative that the designer takes the intended user group's previous knowledge and experience into account in order to bridge the gap between the system image and the users' models.

In a similar vein, Newman and Lamming (1995) stress the importance of identifying the sources of users' misunderstandings about the systems they use. These are often false or inaccurate conceptions about the software's structure or functionality and provide a basis for improving designs.

As Newman and Lamming highlight, users rarely perform activities purely for the sake of interacting with a computer; they are more concerned with their own tasks and the goals

to be achieved. The concepts involved in these user activities do not necessarily translate into the terms demanded by the system. Examples of this include users file managers (e.g., Windows Explorer) who are faced with sizes of documents in bytes and not number of pages or words, or users of Web browsers having to interpret error messages such as "Error 404." These are examples of the user being confronted by concepts drawn from the designer's understanding of the system that may fail to match concepts of the user's activity. By designing user interfaces that are more obvious and self-explanatory, users are likely to be less reliant on formal training. Indeed, if formal training is proposed, a better understanding of people's (mis)conceptions can inform much of the structure of the actual training itself (Rimmer, 2004). Lewis and Norman (1995) describe the importance of providing users with a good model as it can minimise the mistakes that they are likely to make.

These ideas extend beyond the use of computer-based systems, such as digital libraries, and into the realm of the traditional library, which can also be regarded as a "system." It is widely believed that people construct and revise their mental models of systems through continuing interaction with those systems, as well as from instruction and other forms of help; in addition, people may draw on analogies and metaphors from other systems that appear in some way "similar." Senge (1992) describes mental models as "deeply ingrained assumptions, generalisations, or even pictures and images that influence how we understand the world and how we take action."

Users' mental models of devices and of concepts have been investigated within the field of Human-computer Interaction for more than twenty years. More recently, research has focused on people's understanding of networked technology and use of the Internet. Thatcher and Greyling (1998) examined users' mental models of the Internet in order to classify them against their self-reported expertise. The users with more experience presented more detailed diagrams of the Internet, which suggests that they possessed better structural mental models. Sheeran, Sasse, Rimmer and Wakeman (2000, 2002) showed how a better understanding of the Internet made network users more efficient by enhancing Web browsing software to support more appropriate user mental models.

Borgman (1986) was the first to look at mental models in the context of information retrieval (IR) in order to explain the effects of training. Within this literature, there have been several studies that have examined users' mental models as a basis from which to explain information search behavior (Dimitroff, 1992) and as a mechanism to begin to improve the user interface (Chen & Dhar, 1990; Chen & Macredie, 2002; Cole & Leide, 2003; Crudge & Johnson, 2004). These studies have focused on performance and how it is affected by characteristics of users. Such characteristics include experience with a system, academic background, age, gender, and personality (Zhang & Chigwell, 2001). However, there has been little work that contrasts the models of the electronic and real world environments: Marchionini (1989)

compared search in online and print encyclopedias and found that some online users employed print-based models, whereas others had adapted their models to the online context.

Leary (1990) focuses on the importance of metaphors and analogies in constructing mental models. Indeed the term “digital library” might well invoke the metaphor of the traditional library and suggest that one way of regarding digital libraries is as an electronic equivalent of a traditional library. However, this is a use of metaphor that others, such as Duncker (2002), challenge. The question originally motivating this research was to what extent people exploit this metaphor in understanding digital libraries; as shown below, in practice, people were found to make little use of it, relying more on their understanding of other digital systems such as Google.

The purpose of this study is to examine users’ mental representations of traditional and digital library systems. Because mental models cannot be observed directly (Sasse, 1997; Zhang & Chignell, 2001), the result of a study such as this is that the researcher forms his or her own conceptual model of the user’s mental model. Nevertheless, this notion is referred to throughout this article simply as the user’s “mental model.”

User Perceptions of Digital Libraries

Like the term mental model, the term “digital library” has been defined in different ways (Borgman, 2003). In this study, we have taken the pragmatic approach of allowing the study participants to select their own “libraries” in which to find information. In practice, our participants chose the University Science Library as their traditional library, but chose various specialist digital resources, not all of which would be strictly defined as libraries as their digital libraries.

Borgman (2003) notes that usability issues in digital libraries and other forms of information systems persist, despite the technological advances of the last two decades. Usability challenges range from the detailed (e.g., the labels on links) to the large-scale (e.g., concerning security). The study reported here focuses attention on users’ mental models of digital libraries in an attempt to go “back to basics” and to get as close to users’ underlying mental processes as possible in order to develop a better understanding of the issues facing them as they interact with digital libraries.

Although some authors (e.g., Slone, 2002) advocate designing digital libraries to help users acquire appropriate mental models of them, we are not aware of any literature that has specifically studied users’ mental models of existing libraries. Various authors have compared users’ experiences of traditional and digital libraries (e.g., Stelmaszewska & Blandford, 2004), libraries and the Internet (e.g., D’Elia et al., 2002), and traditional libraries and the Internet (e.g., Winograd, 1995).

With regard to the relationship between digital and traditional libraries, the literature highlights the difficulties associated with directly translating physical entities into the digital realm. This is closely related to the need to ensure careful use of analogies and comparisons between traditional libraries

and digital libraries or digital libraries and other digital entities. The literature does suggest, however, that there is scope to learn lessons from traditional library organization based on making the organization of the library obvious to the users and through the careful use of sign posts to avoid users becoming lost. These lessons, and their potential to inform the design of digital libraries, are discussed in our Results section.

Method

The study is based on qualitative analysis of data gathered from individuals who were performing semi-natural tasks in both traditional and digital libraries. Following a pilot study, eight students from the School of Library Archives and Information Studies and the Department of Psychology were recruited. All were working on their Masters dissertations at the time of the study, and hence all had active information needs. Four were studying for a Masters in Library and Information Studies (LIS) and the other four for a Masters in Human-Computer Interaction with Ergonomics (HCI-E). The intention in working with these groups was to have a combination of participants who could be expected to have a good understanding of libraries and of computer systems, having received advanced training in cataloguing and classification (LIS) or interaction design (HCI-E).

Participants were given the broad task of finding documents, on the same topic of interest in both the traditional and the digital library or libraries of their choice. Each participant was first asked to define a personal topic of interest and, once this was chosen, to find a document on the topic. Participants were told that their chosen topic should be narrow and related to their studies but one that they had not previously searched for. This would help ensure that their behavior was as natural as possible (Sasse, 1992). Participants were told that they would be free to navigate and use the library (whether traditional or digital) as they saw fit in order to complete their task. In order to eliminate a potential order effect, half the participants used a traditional library first and the other half a digital library, as shown in Table 1. The central cells of this table show the code names for the eight participants.

Prior to the study, each participant was asked which digital libraries they used most frequently so that the observer could ensure that he was reasonably familiar with the likely sources prior to the observation; however, it was made clear to participants that this should not constrain their choice of sources during the observation. Interestingly, some participants had a broad view of what they considered digital libraries to be. Therefore, some participants accessed digital entities,

TABLE 1. Task order for each participant.

Task order	LIS	HCI
Traditional then digital	L1, L2	H1, H2
Digital then traditional	L3, L4	H3, H4

such as indexing and abstracting databases, and Internet search engines during their search. Although this was not expected, nor was it discouraged by the observer as it had the potential to yield important mental-model related findings. This later proved to be the case.

The approach to data collection was based on Contextual Inquiry (Beyer & Holtzblatt, 1998), adapted to the context. In other words, participants were observed while working and asked to think aloud and were also probed with “what,” “how,” “why” and “what if” questions (Collins & Gentner, 1987; Payne, 1991) at appropriate times before, during, and after the observation, in order to gain an insight into users’ mental models. As the aim of the study was to examine and compare mental models of both digital and traditional libraries, the observer also asked a set of questions concerning comparisons and analogies between the two, during the contextual inquiry session. These were: (a) Did you find the digital/traditional library similar to anything you have used in the past and (b) did you notice any similarities/differences between the traditional and digital libraries?. These questions were covered during a short debriefing interview if participants had not addressed them spontaneously during the observation. These questions were not asked during observation to avoid biasing participants towards providing these types of comments non-spontaneously.

The researcher audio-recorded observations and also made notes when the verbal data alone did not provide sufficient context. An example of this was when participants used elements of the library as props, by pointing to an interface element in a digital library or particular shelf or section in a traditional library. These notes were added to the appropriate parts of the transcriptions in square brackets, for example, [User points to class mark on library shelf]. Researcher questions during observations were noted in bold. Although there was no set time limit for the tasks or observations, each participant provided about an hour of verbal data.

As noted by Posner (1989), in studies of users’ mental models, “it is necessary to infer the processes from the verbal reports that form part of the user’s mental model, rather than attempt to encode processes directly.” Therefore, a coding scheme was derived from the recurring themes identified in the verbal protocols. We identified the themes listed below. Each theme represents a different aspect of users’ mental models:

1. Similarities and differences between traditional and digital libraries
2. Access issues
3. Assessment of library content
4. Document and results organization
5. Understanding of search
6. Assessment of document relevance
7. Revising the model
8. Troubleshooting issues
9. Data for all the users were transcribed and analysed according to this coding scheme.

Results

During the traditional library search, all participants chose to use the University Science Library and electronic catalogue system, which contains details about documents held in all university libraries (referred to from now on as the “traditional library catalogue”). The traditional library catalogues were accessed from standalone computers that did not have access to the Internet. Some participants used Internet search engines to aid either their traditional or digital library searches. All the HCI-E students chose to use the ACM Digital Library and one participant also used the HCI Bibliography (HCIBib). The digital resources, used by LIS students, varied from full text libraries, such as SwetsWise and Ariadne, to abstracting services, such as Librarianship and Information Science Abstracts (LISA). All participants chose to use at least one digital library with which they were already familiar, and all libraries chosen had a strong HCI or Librarianship content.

The participants all chose to conduct information seeking tasks based on narrow topics related to their Masters theses that they had not previously covered. These topics ranged from the design of children’s libraries to voice user interfaces. All users focused on search-based information seeking, although many chose to browse documents on the shelves in the traditional library.

We present the main findings from this study according to the eight themes that were identified as aspects of users’ mental models. It should be noted that the divide between traditional and digital libraries is somewhat blurred by the use of electronic catalogues to support searching in traditional libraries and of occasional Internet searching to support finding documents in both kinds of libraries. In the presentation of results, we include quotations from participants to illustrate the findings.

Theme 1: Similarities and Differences Between Traditional and Digital Libraries

Participants regarded both traditional and digital libraries as having an element of hierarchical organization:

A digital library is organized in a similar way in that it splits things up into articles and books and things like that and I suppose a physical library splits things up into sections such as journals and books, so they’re kinda organized in a similar way. – H2

Furthermore, the broad information seeking goals of users can be satisfied in both traditional and digital libraries. However, participants highlighted differences in the process of working with traditional and digital libraries:

[You use] similar search terms, using “design,” “layout,” umm, you’re both typing search terms into a box and clicking “go,” so they both start off similar. But using the traditional library then moves over and you’re browsing through books and looking at indexes, contents pages, looking through

chapters, whereas this one just sort of stays online, and you're just looking through lists of abstracts and things. – L1

Superficial differences were identified between traditional and digital libraries:

There's a lot more of them [available documents] because they're all electronic. – H3

These differences influence how each type of library is used with regard to the ownership of documents and how users go about using them to fulfil their wider information seeking goals:

Going and looking for the book itself is a different experience as you're physically going to a floor and taking books off the shelf and I have to take it out for a set period of time and return it, whereas with a digital library I can just save an article to my hard disk. – H1

Something I do in a physical library is that I pick up a book when I think it might be useful and scan read it. You haven't got the option on a digital library and that makes me a lot more choosy about what I think might be relevant in a digital library. – L2

Although the overall goal of information seeking was deemed to be the same, participants were aware that different (but overlapping) information seeking goals could be fulfilled by each type of library:

One of the important differences would be the subject matter of what I'm looking for. In a traditional library, I'm looking for books so probably looking for searches under the title and the author because there's not a lot else that they would have entered into the library system. Whereas when I'm looking on Google, it can search through the text, and ACM, the abstract as well as the title, the full text of the papers. – H4

Participants also highlighted that traditional and digital libraries have contrasting benefits. Digital libraries can bring back seemingly irrelevant results, yet it is quicker and easier for users to assess the relevance of electronic documents than traditional library catalogue entries, because only limited metadata about each document is displayed to users. However, this is counter-balanced by the perceived quality of physical resources, which may be available exclusively offline.

Participants also noted that there are often fewer resources on the traditional library catalogue, which can lead to greater search accuracy when compared with searching in a digital library. Two LIS students, with their greater insights into cataloguing and classification, attributed this to human involvement in the cataloguing of electronic library catalogues. For example:

The standard of cataloguing and classification of books is much higher than in digital libraries. – L4

Conversely, one LIS student identified the need for more careful selection of search terms using the traditional library

catalogue which was attributed to out-of-date software and the fact that the catalogue does not support full text searching:

The library catalogue doesn't cope with three-word terms very well. You have to be more specific in the catalogue. In the digital library, you can probably use many more search terms. The [electronic catalogue] software is not as good and is probably not as up-to-date. – L2

Our findings indicate that users have a good idea of the layout and procedures in the traditional library (Kieras, 1982) terms this "how inputs become outputs." However, with digital libraries users tended to focus more on describing the common inputs (search terms) and outputs (search results) with varied levels of understanding of how search terms are turned into search results. This is further discussed below.

Users seemed to be aware of how their information seeking goals could be accomplished in the context of both types of system. They took a more search-centred approach to information seeking in digital libraries than in traditional libraries, where both searching the electronic catalogue and physically browsing the shelves were common. Users also demonstrated that they were aware of how their goals could be accomplished in both types of library, as discussed above.

There was widespread disagreement about which resources returned the most relevant results and why. As noted above, some held the view that the electronic catalogue of the traditional library returned more relevant results than the digital library due to human involvement in cataloguing. One HCI-E student (H4) assumed that the digital library would return too many results that the system would judge as relevant but the user would not. Another (H3) assumed that the electronic catalogue brought back fewer results because less thought had been put into designing the search component. This reflects the impoverished nature of subjects' mental models of the searching and relevance ranking systems they used, as discussed further below.

It is interesting to note that no comparisons between digital and traditional libraries were spontaneously given. When asked about the similarities and differences between digital libraries and "anything else used in the past," users made explicit reference to search engines and library catalogues. One participant argued that he would class digital libraries and search engines "in the same category because all you're doing is typing in words, trying to narrow down a topic which you're interested in, whether it be a paper, book or Web site, and finding it." – H1

Another participant admitted to approaching a digital library search in the same way that he would approach a Google search:

The way I used the quotation marks to separate "focus groups" and "evaluation" [in the ACM Digital Library] . . . was because of experience in using search engines like Google, where I usually use quotation marks to do that. – H4

We discuss these comparisons further in Theme 5 below. When asked about the similarities and differences between

traditional libraries and “anything else used in the past,” users were less willing to make analogies. Although some participants related the academic library to “other libraries,” no other concrete analogies were made. As one participant explained:

There probably is something . . . like in a record shop or book shop or something . . . that whole physical part of just looking for a book . . . but it’s a whole different thing in a shop. It’s a very different thing. – H1

Theme 2: Access Issues

One aspect of library use that affected participants in both types of library was that of access rights. The notion of a library card as a key to accessing documents in the traditional library was held by all participants although, because the task did not explicitly ask participants to take documents out of the library building, there were not as many comments surrounding traditional library access as might be expected.

As well as providing physical access to the library building, the library card was identified as a physical entity which holds information about the patron based on the barcode printed on the card. It was also regarded as an entity which would restrict the number of documents that could be loaned from the library at any one time:

[Whether I take an item out] depends how much space I have on my library card. If I had space I might just get a few out [. . .] But if I only have space for three books, then I’d just sit and look at them and make sure that they had stuff that I was sure was relevant. – L1

Also in the traditional library, interdisciplinary HCI-E students highlighted the physical access issues surrounding documents related to their course being “spaced around a little bit” (H4), either in different sections of a particular library or in different university libraries altogether:

Bizarrely, one of the books, “Usability Engineering” is actually in the architecture library! – H4

Although participants typically had a better understanding of access in traditional than digital libraries, physical access assumptions were sometimes found to be erroneous. For example, one participant was unaware that documents could be requested from other university sites:

It puts me off when a book is elsewhere because it’s not like I want to get the book straight away or make so much effort, I would have preferred it if there was a way to order them so that I could view them at my own leisure. – H3

In addition, physical access issues can combine with other document access restrictions in a traditional library, such as the length of loan associated with a particular copy of a document:

Oh, it says in Psychology there’s also one, but this one isn’t a one week loan like the one in Psychology, so

you could take it out and wouldn’t have to renew it every week. – H4

Access issues in digital libraries were found to pose far more of a problem than with traditional libraries. Digital library access restrictions also have the potential of creating more inconsistencies and errors in users’ mental models. Digital library users are often unsure as to why certain sections of digital libraries are restricted, whether registration/subscription is required to view certain content and whether payment is required in order to view restricted content:

It says “request document,” I’m not sure if that means I would have to pay for it. – L2

This lack of clarity in users’ mental models relating to access restrictions discouraged users from using certain sections of the digital library. More than once, users made the choice not to invest time in verifying their assumptions or answering their questions surrounding the need to register and pay for access to the library. For example:

Oh no! You’ve got to log in! That’s probably why I haven’t used [the ACM binder feature] before, because I couldn’t be bothered to set up a personal ACM account. And I think you now have to register or subscribe or something and I never know whether you have to pay or whether you don’t have to pay. – H2

Access issues surrounding digital libraries can influence the behavior of users, depending on how the user perceives the access restrictions to work. For example, users reported being discouraged from using libraries for which they did not have a clear idea of how access restrictions applied. Conversely, users reported often seeking out only information from sources that they knew they had unrestricted access to.

Sometimes, users sidestepped the issue of electronic access by reverting to traditional forms of information seeking in order to retrieve the full text of documents that might be difficult to obtain due to access restrictions in a digital library:

The access can be really slow and confusing when using different journal providers, so I’d rather use indexing services like LISA and the physical journals themselves. – L3

Some participants highlighted the confusion arising from having to access different information through different providers. This was highlighted by one electronic provider who redirected the user to other digital libraries to continue their information seeking task:

Ok, that leads me to a different digital library [. . .] Emerald [. . .] or maybe it’s just a publisher of the book. – L4

In addition, it is possible for the user to be re-directed to a site that is assumed to be another digital library but is not,

and hence hampers the search for information:

It leads me to a different database [. . .] to Kluwer [. . .]. At this point I would not look at this further. It doesn't seem to give me what I want. – L2

Although one participant (L3) did note a positive benefit of access restrictions, in terms of helping to assure document quality, the study has shown that access issues are a source of confusion and inconsistency in users' mental models, and that such issues can have a negative impact on user behavior. Users were often unwilling to invest time in verifying assumptions, instead seeking only information from sources which provide unrestricted access, or reverting to traditional forms of information seeking. This is an example of parsimony in mental planning (Norman, 1983). Participants demonstrated risk-averse, satisfying behaviors that avoided potentially time-consuming exploration. This unadventurous behavior prevented participants from developing more sophisticated mental models of access systems.

Theme 3: Assessment of Library Content

As noted above, users were sometimes unaware that they could access documents in other physical libraries and focused entirely on the University Science Library. For digital libraries, there was more explicit recognition that the user had choices. However, users reported difficulties in knowing which digital libraries contain information on certain subjects, particularly if they had accessed the Athens portal (www.athensams.net), which provides managed access to a broad range of subscription-based digital resources:

In the Athens there's lots of individual electronic libraries and some of them have got certain stuff in and some of them have got other stuff in. I find it fairly hit and miss. – H3

Even once the user has identified which digital library may be relevant to their search, problems can arise with accessing it and ascertaining which journals are available in the current library and which are not. This causes further confusion. In addition, older journals are often not carried by digital libraries, which forces users to revert to printed collections or avoid using full text digital libraries altogether:

[digital libraries] mainly only show the last two years anyway, and often you'll want to go back further than that and the access can be really slow and confusing when using different journal providers, so I'd rather use indexing services like LISA and the traditional journals themselves. – L3

Users' poor understanding of which digital libraries contain information about certain subjects might be explained by confusion arising from non-firm boundaries between users' mental models of individual digital libraries. Put another way: Users experienced difficulties in predicting which goals could be accomplished at individual libraries and how these goals could be achieved. This extends beyond

knowing what sort of information is available in each digital library to what access rights users have (and from what locations) for which journals. Our findings highlight the need to assist users in forming "bridge" between their mental models of separate digital libraries to develop a more holistic understanding of what is available here and now and how.

Theme 4: Document and Results Organization

Within a particular library, the next issue is how materials are organized. On this topic, participants were more articulate about traditional than digital libraries.

All participants described documents in a traditional library as being arranged hierarchically. In addition, two LIS students noted that, although different libraries may have different classifications systems for organizing documents, the way of finding documents in traditional libraries is broadly similar:

I've been through five or six years of universities and have used different libraries, but I usually approach it in the same broad way, I find the classmark and browse the area. – L4

Although the overall approach is common, participants reported sometimes seeking guidance from a librarian to help them understand the particular classification system within a traditional library. For finding particular documents, participants often learned where relevant sections of the library were located through a library induction or by using the signage on every floor and section of the library as guidance. Then, within a particular section, participants noted that documents are arranged in numerical order and alphabetically according to the classmark of the book.

The location of the documents also provided users with some preliminary information about their relevance:

Oh that's interesting, it's in "ENGINEERING," so maybe although the title of the book looks highly related to what I want, the title might be completely misleading. – L4

Within traditional libraries, due to their structure, much information access is achieved through browsing, which can lead to serendipitous discoveries. For example:

I was actually browsing for another book in the HCI section of this Science Library and I was reading along the titles and came across it by accident in a book by Heath and Luff. – H3

A common perception amongst users was that the act of browsing was possible only in traditional and not digital libraries:

The way I use a traditional library is I tend to find a general physical area and then browse, and you can't do that with a digital library. – L4

The participants in this study did not draw parallels between locating a particular area of the physical library

then browsing in the vicinity and issuing a search request in a digital library then browsing through the results list. However, they did describe the organization of digital resources in terms of searching and results organization.

Participants had varying levels of understanding of how searching works in a digital library and traditional library catalogue, from the rather limited . . .

I typed some search terms in and it brought me some search results back. I don't think about it any further than that. – L4

. . . to the comparatively sophisticated:

I think it's all down to the way that it does the searching, it's all down to probabilities. The top things on the list mean that, for example, they are 90% likely that they've got it right and that percentage would reduce as you go down the list. – H1

Assumptions about exactly *where* the digital library was searching for their search terms also varied, especially among HCI-E students:

Erm, my guess is it must have inclusion of those terms that I entered, I don't know, maybe in the abstract or in the citations or the references, and maybe how many times it's mentioned decides how far up the list to put them. – H2

Those participants who used the ACM digital library had the most difficulty in ascertaining how the retrieval process worked because of the apparent lack of correspondence between the search terms that were input and the results returned:

I'm not sure how exactly, whether it checks the keywords of papers or the titles or exactly how it brings back stuff that it thinks is relevant. Usually it's the case of putting in a few things and seeing what it comes back with. – H3

The symptoms of the lack of transparency between search terms and results were observable when users explained how the relevance bar in the ACM digital library works. Users distrusted the relevance bar, often ignoring it and using their own heuristics about how far they should trawl through results before they ceased the search. Surprisingly, two separate HCI-E students made the unlikely analogy of the relevance bar in the library representing a "pint of Guinness":

I think from using this system before it goes by "relevance" and it's got this thing on the right-hand side. It looks like a pint of Guinness [laughs]. The more full it is, then the more relevant it should be to your search. I largely ignore that. – H3

Several participants perceived the results returned from a search in the ACM digital library as including a lot of low relevance results. One participant attributed this to the quantity of documents held in the library database and not to the fact that the search engine might be working in a different

way to other digital libraries. As in their assessments of electronic catalogues (discussed above), some LIS students assumed that digital libraries that bring back more relevant results have their documents classified, at least in part, by humans.

Non-ACM users also displayed different levels of understanding about how search results were returned. In these cases, confusion about the relevance of search terms led to useful assumptions or discoveries about how searching actually worked. This illustrates the important role of interaction and feedback in helping users develop appropriate mental models, a topic to which we return below:

To be honest with you, I can't see why it brought up "indexing and museum." [Clicks on hyperlink]. Oh, here it is in the subject field [. . .] Because I asked it to do an "all-fields" search, so it's not just searching the title fields, it's searching the subject fields as well. – L2

Similar confusion surrounded how searching works on an electronic library catalogue within the traditional library:

It's looking for results containing "Christopher" and "Alexander" but I don't think it's recognised the author, I mean it's come out with articles with Christopher and Alexander in them, but I would have expected articles by Christopher Alexander at the top of the screen. – H3

An awareness that they had a poor understanding of how search works led many users to try searches of which they had low expectations:

So I'm typing in "pattern languages," but I know this is a real long shot. – H3

I'm not sure that word's very useful, but I'm going to do it anyway. – L3

Overall, traditional library users have built a strong knowledge of the layout of the library and how documents are organized. This is supported by physical cues such as signage and inductions run by librarians. This knowledge sometimes allows users to form assumptions about the potential relevance or utility of a document in the traditional library based on location. The lack of such depth of knowledge with regard to digital libraries suggests the need for more effective digital cues to help users understand how information is organized and presented.

The perception that browsing is not possible in a digital library may be explained as users having "incomplete models" due (Norman, 1983; Payne, 1991; Sasse, 1997), at least in part, to them focusing on search-based information seeking goals. This perception is exacerbated by the current interface designs of digital libraries, which tend to focus on search features.

With regard to how searching works and results are organized, users' varying levels of understanding might be explained by errors in the users' perceived internal structure of the system (Kieras, 1982), which in turn might be caused

by a lack of relevant feedback from the system. It may also be due to users forming their own boundaries (Norman, 1983) about what their mental model of a library should include.

An interesting symptom of this varying level of understanding is the distrust that HCIE-E students felt for the ACM relevance bar, resulting in the formation of heuristics (Collins & Gentner 1987, Norman 1983) based on personal opinions of relevance that may or may not be appropriate. Another symptom is the fact that users are often prepared to conduct searches that they anticipate are unlikely to yield valuable results, exhibiting “superstitious behavior” (Norman, 1983). Because all users employed relatively sophisticated searching strategies and indicated a sound level of competence with searching digital domains, it is likely that lack of appropriate feedback when searching is the underlying cause of “how it works” confusion with regard to searching and obtaining relevant and consistent results.

Theme 5: Understanding of Search

As noted in Theme 1, none of the participants made specific comparisons between components of the traditional and digital libraries except when asked to. However, participants spontaneously made comparisons between digital libraries and other digital entities, such as Internet search engines, e-commerce sites, and electronic library catalogues.

Some participants assumed that the search engine components of Internet search engines, e-commerce sites, and digital libraries work in a similar manner, even if surface differences exist at the interface level or in what format search terms should be entered:

I think the fundamental technology is similar but there are specific differences at the interface level in terms of options you can select [. . .] and the different ways in which they classify the things in the database. – H1

This led this participant to adopt similar searching strategies in both an Internet search engine and a digital library. Other participants used the same search terms to search digital libraries and the traditional library catalogue.

Others used the search components in different ways, although confusion was rife surrounding just how similar the searching processes of digital libraries and Internet search engines are. Some of the confusion surrounding how the search components of digital libraries and Internet search engines work might arise from the blurred distinction between them, which is itself symptomatic of the disagreement in the definition of the term “digital library” as identified in the literature. For example:

It comes back to the issue of “what is a digital library?” because some people argue that Google isn’t a digital library, it’s just a search engine. But if you look at a digital library like the ACM, well that’s just a search engine! [...] all you’re doing is typing in words, trying to narrow down a topic which you’re interested in. – H3

Any comparison between search components of digital libraries and e-commerce sites such as Amazon seemed to create less confusion amongst participants, because fewer surface similarities exist between the search engine component of the Amazon site and the search engine components of digital libraries.

Because there are more surface similarities between digital library and electronic catalogue search engine components, the confusion surrounding digital libraries and Internet search engines extends to the traditional library catalogue:

I dunno if you can do this [wildcard searching] on this [electronic catalogue] actually. Usually if you put a star [refers to ‘child*’] it just covers everything like child’s, children on the end there. I’ll put that star on it just to see, [Types in ‘child* library* and presses search button]. No: “no exact match.” I know you can do that on the Internet search engines, but whether you can do that on here, I’m not sure. – L1

One participant, when using the digital library, found a review of a book that had been found earlier in the traditional library search. The participant attributed finding the book in the traditional library catalogue and the review of the same book in the digital library to using similar search terms in both types of library:

Yeah. It had a record of the same book that is here in the library, which I initially found using the same search terms. Well not exactly, because I had to restrict my search terms for the library catalogue. – L2

Another participant displayed an understanding that it could be the underlying search technology and not just the superficial differences in required search syntax, which has an impact on the results obtained from an Internet search engine, digital library and traditional library catalogue:

A lot of better search engines will generate much more reliable results, so my expectations are that if I use one that uses a particular [searching] technique, I’d assume that others, even in a digital library might work using the same technique, and this one doesn’t. – H1

No users could clearly articulate the differences between the different search engines they worked with, indicating that users have incomplete models of search engine components. Incomplete models have a negative impact on users’ understanding of the functionality of the overall system (Payne, 1991; Sasse, 1997; Stagers & Norcio, 1993).

Where users recognized that there might be subtle differences in how search engine components work across digital media, they did not understand how this should affect their behavior, for example, in how they formulated queries. This suggests that there is scope for providing clearer information to users about how search engine components belonging to different search entities should be used.

Theme 6: Assessment of Document Relevance

Once documents have been located, the user needs to establish how useful they might be. This applies in both traditional and digital settings.

In a traditional library, participants noted that some of the potential relevance of a document can be derived from physical attributes, such as the following:

You can sort of tell [the age and relevance of the book] from the last time it was borrowed. – L3

They've got multiple copies of these, so obviously they're good books [...] and they look like general, and they're quite thick. – L1

This book looks very American because of all the glossy photos on the front. – L3

Document relevance in a traditional library was also ascertained by flicking or skimming through the entire book or reading particular sections of the book such as the contents or index pages:

I'd give it a flick. In this case I might look for authors or I might look for subject matter. – H3

As noted above, in the traditional library, potential document relevance was also judged by its location or classmark.

Participants highlighted the difficulty of judging the relevance of a document in the traditional library by using the traditional library catalogue alone, because very limited details are provided to aid users in making the judgement:

You really don't have enough information on the catalogue to determine whether they'll be useful or not, so you just take a few approximate classmarks and go and traditionally look on the shelves. – L4

This can lead users to dismiss a particular document as irrelevant purely due to the lack of metadata provided about the document in the traditional library catalogue:

Ones like this without a year showing I don't tend to bother with because they're either not catalogued properly or so ephemeral that they don't even have a year. – L4

Assessing the contents and relevance of documents is clearly harder if the document is located at another site, and some users were unaware that documents could be requested from other sites, making relevance judgements costly.

Looking up references and citations was highlighted as an important way of ascertaining document relevance in both traditional and digital libraries:

If there's a good book on this area, these two papers are likely to quote from it . . . – H3

In a digital library, where there are fewer types of cues to the user, participants placed more emphasis on reading the

titles and abstracts of documents than on skimming through the contents for assessing relevance.

Overall, users tend to ascertain relevance of traditional and digital documents in different ways, which suggests that users are aware of the appropriateness of the methods and actions that they employ (Borgman, 1986, Norman, 1983). For example, "flicking" and "scanning" paper documents is currently far easier than its electronic equivalent and is hence better suited to use in a traditional library, while the abundance of abstracts in digital libraries make scanning an abstract a feasible alternative to attempting to scan the document by scrolling through it.

Theme 7: Revising the Model

Participants often tried to clarify assumptions in their mental models by observing the feedback that resulted from them performing selected actions with the digital library. This had a positive result in many cases, helping people identify errors in their models that would allow them to use digital libraries more effectively. For example, one user reinforced his ideas about how the "citations" feature of the ACM digital library worked:

You can press "citations" and I think that when this paper is referenced in other, more recent papers, it brings up those papers. So this should give me papers written after August 2000 that cite the paper I'm looking at [presses "citing"]. Yeah, that's what happens. So now I can read through these and see if any of these are useful as well. – H3

Testing assumptions in the mental model can also have a negative result. In the case below, the participant assumes that the CrossRef search front-end to the ACM digital library finds documents written by the same author. Because this is one, but not the only, function possible using this front-end, the user's assumptions have led to the construction of a highly limited mental model of how it works, and, in this particular instance, the feedback from the system supports this limited model:

I'd be tempted to put in an author's name that I knew of to see if it brought up similar articles. Actually, let's try it, I'll type in "Drew" because she does lots of things on usability [conducts search]. This is showing me all the articles that the author's written I think, because this person is always included in the author's list. So maybe it does do what I thought it would! – H2

System feedback was also found to influence users' future searching behavior by suggesting potentially useful search terms for subsequent searches. These either described a slightly different (but relevant) aspect of the search topic or were synonyms of search terms used previously:

I'm going to go back to my original search list and put in "dialogue" and "coding" because I hadn't thought about looking for that term, but even some of the articles I found a minute ago had stuff in it about dialogue structure. – H2

These findings highlight how system feedback can play a key role in ensuring that users maximize their understanding of the system and thereby form a more complete mental model of that system (Norman, 1983; Payne, 1991; Sasse, 1997; Staggers & Norcio, 1993). Effective feedback can help users to spontaneously construct new models of unfamiliar systems or aspects of systems (Norman, 1983) and to revise their existing mental models (Kieras, 1982). A challenge for digital library developers is to design systems that promote the creation of accurate and rich mental models that are likely to support users in achieving their goals.

Theme 8: Troubleshooting Issues

Participants often had troubleshooting strategies in a traditional library to support information finding. This might involve (a) checking the surrounding area of the shelves where the document was supposed to be, (b) checking the returns trolley, and (c) checking whether the document was out on loan before either asking a librarian for help or requesting that the book be held if and when it is returned. When more detailed searching assistance was required, participants reported turning to a librarian for support. One participant also surmised that librarians could be a useful source of information if the electronic catalogue was not functioning, because they might keep a paper record of how documents are organized in the traditional library.

Participants regarded troubleshooting information seeking problems in a digital library to be far from as straightforward as with a traditional library:

Usually I just give up, it's very frustrating! [...] I've e-mailed them about it and they haven't got back to me! It is frustrating, it's awful, because you've got nowhere to go [for help]. At least in the [traditional] library, there might be something next to it that might still be relevant. You can get round it more I think with traditional things, but when it's a digital library, I just feel hopeless! – L3

Participants did, however, suggest potential avenues for exploration if a document could not be found in a particular digital library, by turning to either another digital library or a general Internet search engine. For example:

I'd probably try the Internet and that is a huge, it's not catalogued or classified, so it's not technically a library, but you might find something on the Internet. – L1

Traditional library users held detailed knowledge of library procedures. This allowed them to form well-reasoned behavior patterns (Norman, 1983) when they could not find a particular document where it was supposed to be on the shelves or encountered other problems in the library. In effect, this provided users with procedures for troubleshooting and maintenance (Staggers & Norcio, 1993).

Users recognise that some of this troubleshooting knowledge can be provided by librarians, along with other “how to

use it” and “how it works” knowledge about the library and about information seeking strategies in general. Current digital libraries do not facilitate troubleshooting of this kind, particularly with regard to searching behavior. This highlights the need for digital libraries to facilitate troubleshooting in order to avoid users taking potentially inappropriate remedial action when things go wrong, such as turning to another digital library or a general Internet search engine.

Discussion and Conclusions

In this study, we recruited participants who were relatively sophisticated users of library systems, all having a background in either librarianship or Human–Computer Interaction and all having prior familiarity with both traditional and digital libraries. We expected this user population to have a more sophisticated understanding of the systems with which they chose to work than, for example, the computer scientists who participated in some of our earlier studies (Blandford, Stelmaszewska, & Bryan-Kinns, 2001). And indeed, these users were able to achieve their chosen objectives (i.e., to find information relevant to their dissertations in both types of library) but did so inefficiently.

As discussed previously, there is rich evidence that possession of appropriate mental models leads to more effective use of systems. This study has shown that these users have formed only rudimentary mental models of the digital libraries they chose to access. For example, they have limited understanding of how documents are organized, how to tailor queries to particular search engines, how access mechanisms work, and how search results are ranked. Consequently, participants' strategies for finding information were suboptimal, and there were undoubtedly missed opportunities (e.g., because participants were reluctant to investigate access rights if it involved them entering any personal information whatsoever). Moreover, although users engaged in limited exploration, they were sometimes unwilling to explore and, at other times, unable to interpret the results of exploration in ways that would enable them to develop more sophisticated models, and hence (potentially) more sophisticated searching capabilities.

Our participants recognized that traditional and digital libraries can fulfil different but overlapping information seeking goals; indeed, these information resources were regarded as just two of a larger set of information sources that included the World Wide Web and Internet search engines. Participants were generally articulate about the differences between physical and digital information resources, but much less so about the differences between various digital information systems (including the traditional library electronic catalogue). For example, users tend to ascertain relevance of physical and digital documents in different ways, suggesting that they are aware of the appropriateness of the methods and actions that they employ when assessing document relevance in each medium.

These users had a good idea of the layout and procedures in the traditional library and therefore were better able to

articulate procedures for troubleshooting there than in the digital library. The relatively impoverished nature of their mental models of digital libraries suggests the need for improved digital cues and feedback, as well as indicating an important role for the librarian and for new forms of education on working with information. As well as addressing the issue of improving mental models, there is clearly scope for exploring new ways of supporting immediate troubleshooting in digital libraries.

The lack of detailed knowledge of “how inputs become outputs” (Kieras, 1982) in a digital library might help explain why digital library users are often prepared to conduct searches which they do not expect to yield valuable results, as discussed previously. One participant was able to use outputs from one search to suggest new terms for a subsequent search. This sophisticated probing of a library to expand the set of search terms was found in an earlier study of expert users (Fields, Keith, & Blandford, 2004). However, this behavior was the exception rather than the rule in the current study and appeared to be more serendipitous than deliberate. Participants showed very limited understanding of why the system returned the results it did or how it organized them, and hence how to formulate effective queries or to refine searches. A clear challenge for developers is to find ways of giving feedback to users that reduces the element of mystery surrounding the specifics of different search technologies.

Users’ understanding of the differences between the search components of digital libraries, Internet search engines, electronic library catalogues, and e-commerce sites were not well developed. There was a little discussion of the fact that these systems search over different data sources (titles, metadata, abstracts, full content, etc.). There was some recognition that systems might support different syntax (see, for example, the use of wild cards as presented above) and rank documents in different ways. There was no discussion on the possible effects of Boolean operators being treated differently by different search engines (e.g., is the default search an “AND” search or an “OR” one? And does the order in which search terms are entered affect the results ranking?). Nor was there any mention of stemming. Overall, participants showed limited understanding of the factors that might influence search, and even less of which systems had which features, or how to probe systems to develop a richer mental model of them. This is an important area for future research.

Access restrictions were also found to be an important part of users’ mental models of digital libraries; a poor understanding of access rights was shown to have a potentially negative impact on user behavior. One unexpected finding of this study was that users are more reluctant to engage in exploratory behavior to improve their understanding of access rights than of other aspects of digital libraries. Digital library developers need to address the potentially inhibiting effects of user caution and limited trust.

The study has highlighted areas for attention in digital library design if users of those libraries are to develop richer mental models that will make them more effective information

consumers. In our own work, we have started to explore the potential for providing search tips for users to help them develop a richer and more appropriate understanding of search engine behavior (Stelmaszewska, Blandford, & Buchanan, 2005), and we will be investigating further approaches that empower users. As discussed previously, users need better support for (a) understanding how to formulate effective queries, (b) understanding why they have got particular results, (c) assessing document relevance, (d) gaining confidence regarding access rights, (e) exploring to support the development of useful mental models, and (f) making appropriate comparisons between different systems (including search engines, e-commerce sites and electronic library catalogues). Such advances have the potential to transform users’ interactions with digital information resources.

Acknowledgment

This work is partly supported by EPSRC grant GR/S84798.

References

- Beyer, H., & Holtzblatt, K. (1998). Contextual design: Defining customer-centred systems (41–66). San Francisco: Morgan Kaufman.
- Blandford, A., Stelmaszewska, H., & Bryan-Kinns, N. (2001). Use of multiple digital libraries: A case study. In Proceedings of JCDL 2001 (pp. 179–188). ACM Press.
- Borgman, C. (1986). The user’s mental model of an information retrieval system: an experiment on a prototype online catalog. *International Journal of Man-Machine Studies*, 24(1), 47–64.
- Borgman, C. (2003). Designing digital libraries for usability. In A. Bishop, N. Van House, & P. Butterfield (Eds.), *Digital library use*. Cambridge, MA: MIT Press.
- Carroll, J. & Olson, J. (1988). Mental models in human-computer interaction. In M. Helander (Ed.), *Handbook of human-computer interaction*. B.V. (North-Holland): Elsevier Science Publishers.
- Chen, H., & Dhar, V. (1990). User misconceptions of information retrieval systems. *International Journal of Man-Machine Studies*, 32(6), 673–692.
- Chen, S.Y., & Macredie, R.D. (2002). Cognitive styles and hypermedia navigation: Development of a learning model. *Journal of the American Society for Information Science and Technology*, 53(1), 3–15.
- Cole, C., & Leide, J.E. (2003). Using the user’s mental model to guide the integration of information space into information need. *Journal of the American Society for Information Science and Technology*, 55(1), 39–46.
- Collins, A., & Gentner, D. (1987). How people construct mental models. In D. Holland (Ed.), *Cultural models of language and thought*. Hillsdale, NJ: Lawrence Erlbaum Associates.
- Crudge, S.E., & Johnson, F.C. (2004). Using the information seeker to elicit and construct models for search engine evaluation. *Journal of the American Society for Information Science and Technology*, 55(9), 794–806.
- D’Elia, G., Jörgensen, C., Woelfel, J., & Rodger, E. (2002). The impact of the Internet on public library use: An analysis of the current consumer market for library and internet services. *Journal of the American Society for Information Science and Technology*, 53(10), 802–820.
- Dimitroff, A. (1992). Mental models theory and search outcome in a bibliographic retrieval system. *Library and Information Science Research*, 14, 141–156.
- Duncker, E. (2002) Cross-cultural usability of the library metaphor. In Proceedings of the ACM-IEEE Joint Conference on Digital Libraries (pp. 223–230). New York: ACM Press.

- Fields, B., Keith, S., & Blandford, A. (2004). Designing for expert information finding strategies. In S. Fincher, P. Markopoulos, D. Moore, & R. Ruddle (Eds.), *People and computers XVIII—Design for life: Proceedings of the HCI'04* (89–102). Springer.
- Gentner, D., & Stevens, A. (Eds.). (1983). *Mental models*. Hillsdale, NJ: Lawrence Erlbaum Associates.
- Johnson-Laird, P.N. (1983). *Mental models*. Cambridge: Cambridge University Press.
- Kieras, D. (1982). What people know about electronic devices: A descriptive study (Technical Report No. 12). Ann Arbor, MI: University of Michigan.
- Leary, D. (1990). *Metaphors in the history of psychology*. Cambridge, UK: Cambridge University Press.
- Lewis, C., & Norman, D.A. (1995). Designing for error. In R.M. Baecker, J. Grudin, A.A.S. Buxton, & S. Greensberg (Eds.), *Human-Computer interaction: Towards the year 2000*. San Francisco: Morgan Kaufman.
- Marchionini, G. (1989). Making the transition from print to electronic encyclopedias: Adaptation of mental models. *International Journal of Man-Machine Studies*, 30(6), 591–618.
- Newman, W.L., & Lamming, M.G. (1995). *Interactive system design*. Wokingham: Addison-Wesley.
- Norman, D. (1983). Some observations on mental models. In D. Gentner, & A. Stevens (Eds.), *Mental models*, LEA.
- Norman, D.A. (1986). Cognitive engineering. In D.A. Norman & S.W. Draper (Eds.), *User centered system design* (31–62), Hillsdale, NJ: Lawrence Erlbaum.
- Payne, S. (1991). A descriptive study of mental models. *Behavior and Information Technology*, 10(1), 3–21.
- Posner, M. (1989). *Foundations of cognitive science*. Cambridge, MA: MIT Press.
- Rimmer, J. (2004.) *Analysing the language mismatch between system and user: The application of elicitation techniques and discourse analysis*. Unpublished doctoral dissertation, University of Sussex.
- Sasse, A. (1992). User's models of computer systems. In Y. Rodgers, A. Rutherford, & P. Bibby, (Eds.), *Models in the mind—theory, perspective, and application*. London: Academic Press.
- Sasse, A. (1997). *Eliciting and describing users' models of computer systems*. Unpublished doctoral dissertation, University of Birmingham.
- Schumacher, R., & Czerwinski, M. (1992). Mental models and the acquisition of expert knowledge. In R. Hoffman (Ed.), *The psychology of expertise: Cognitive research and empirical A.I.* New York: Springer-Verlag.
- Senge, P.M. (1992). Mental models: Putting strategic ideas into practice. *Planning Review*, 20(2), 4.
- Sheeran, L., Sasse, M.A., Rimmer, J., & Wakeman, I. (2002). How Web browsers shape users' understanding of networks. *The Electronic Library*, 20(1) 35–42.
- Sheeran, L., Sasse, M.A., Rimmer, J., & Wakeman, I. (2000, October). Back to basics: Is a better understanding of the internet a precursor for effective use of the Web? Paper presented at NordiCHI, Stockholm, Sweden.
- Slone, D. (2002). The influence of mental models and goals on search patters during Web interaction. *Journal of the American Society for Information Science and Technology*, 53(13), 1152–1169.
- Staggers, N., & Norcio, A. (1993). Mental models: Concepts for human-computer interaction research. *International Journal of Man-machine Studies*, 38, 587–605.
- Stelmaszewska, H., & Blandford, A. (2004). From physical to digital: A case study of computer scientists' behavior in traditional libraries. *Journal of Digital Libraries*, 4(2), 82–92.
- Stelmaszewska, H., Blandford, A., & Buchanan, G. (2005). Designing to change users' information seeking behavior: a case study. In S. Chen & G. Magoulas (Eds.), *Adaptable and adaptive hypermedia systems* (1–18). London: Information Science Publishing.
- Thatcher, A., & Greyling, M. (1998). Mental models of the internet—theory and application in human-factors. *International Journal of Industrial Ergonomics*, 22(4), 299–305.
- Winograd, T. (1995, July). Digital vs. libraries: Bridging the Two Cultures. Talk presented at the 18th Annual International ACM SIGIR Conference on Research and Development Information retrieval, Seattle WA.
- Zhang, X., & Chignell, M. (2001). Assessment of the effects of user characteristics on mental models of information retrieval systems. *Journal of the American Society for Information Science and Technology*, 52(6), 445–459.