Mental Models and their Role in the Interaction between User and Information Retrieval Systems (Narrative Review)

Nakhoda M., Kazempour Z., Naghshineh N.

1 Assistant Professor, Library and Information Science, University of Tehran; Tehran, Iran.
2 Ph.D. Student, Library and Information Science, University of Tehran; Tehran, Iran and Faculty Member, Payame Noor University, Tehran, Iran.

Abstract

Searchers in retrieval data systems, affected by various factors, used different approaches and methods. So, with proper knowledge and control of these factors can lead to identified and targeted paths Information seeking behavior. In this system, it is important to be appropriate bed for interaction between users and systems that one of them is mental model. So, aim of this study is to familiarity with mental models of users and interacts with information retrieval systems, such as web. This narrative review was conducted in 2015, searching the literature using the term of “mental model” and “information searching behavior” in databases, including PubMed, WOS, Science Direct, Emerald, Oxford, Magiran, and Scientific Information Database (SID) and Springer. After that, the relevant abstracts were reviewed and their full texts were extracted and classified using content analysis. Results showed that mental models have capability of being identified and extracted. Many users may have weak or incorrect mental models and mental models may affect the function of users and there are variety techniques to extract mental models and they should be used combined in order to reach better conclusion. Research done in the field of information retrieval showed the importance of this subject and since many users has defective mental models that cause to faint function, so the study of these models is essential in order to create and develop better information retrieval systems.

Keywords: Mental models, information retrieval systems, human interaction with computers.

*Corresponding author: Ph.D. Student, Library and Information Science, University of Tehran; Tehran, Iran and Faculty Member, Payame Noor University, Tehran, Iran.
Introduction

Research showed that use of new information technology has positive impact in the process of learning and study (Chatanash and Miaji, 2014). It is important to create the perfect condition in the information retrieval system for efficient interaction between user and system. To establish an efficient communication, the information system must be understandable for users and is designed in a way to express information needs of user and help in search. For greater efficiency of information systems, designers must realize that what potential user think during an effective or ineffective use of their products. If they understand the mental process of users when they interact with systems gain more success in their work. In recent years, the professional designer of information systems, have more attention to people who interact with system.

In some cases they tend to explain and predict the user’s behavior such as psychologist. They also interest in perception of mental imaginary of users. In Norman’s idea the way of using system is not just important and studies has exceeded of usage and have reached a level that even consider the process of user thought (Norman, 2012). Today, with the development of computer applications in all areas of life and in particular its presence in the field of information retrieval, the relationship between humans and computers, has become inevitable. This has led to the emergence of a new field called "human-computer interaction". This field that is the intersection of computer science field, cognitive science and human factor engineering, often talk about how to design systems.

This interdisciplinary areas, try to understand structures and paradigms that define how people use technology. Cognitive science provides more accurate knowledge about perception and recall information by individuals. Human-computer interaction field apply this knowledge to predict how the use of electronic systems and thereby optimizing the system (Carroll, 2013).

Part of the research in this area, will examine this problem that how it is possible to adjust knowledge of user and knowledge used in information system design effectively, so that the user does not confuse of system function (Entezarian, Fattahi, 2010). So, one of the important research fields in the study of human interaction with computers is the study of man and his knowledge such as his/her mental models. So, aim of this study is to familiarity with mental models of users and interacts with information retrieval systems, such as web.

Materials and Methods

This narrative review was conducted in 2015, searching the literature using the term of “mental model” and “information searching behavior” in databases, including PubMed, WO S, Science Direct, Emerald, Oxford, Magiran, and Scientific Information Database (SID) and Springer. After that, the relevant abstracts were reviewed and their full texts were extracted and classified using descriptive statistics and content analysis.

Mind and Mental Models

Mental models in general, simplified representations of reality in the minds of people and to help understand and predict phenomenon in the interaction with the environment Guthrie, 2008). Accordingly, a range of cognitive structures in the mind of every human person makes his model of the world: A model that includes expectations, perceptions and experience of human. These structures has been created , in the processing of sensory data, potential information and knowledge of individual, and lead to their imagination and human understanding of the world and himself/herself. Sternberg knows the mental models as a knowledge structures that allow people to understand and explain their experiences (Sternberg, 2012).mental model term, was first proposed by Craik in 1943. He stated that mental model is internal representations of external objects and phenomena and include words, numbers and other signs. Johnson Laird in 1983 in his book “mental models” expand the structure of mental model and raised it as theory to explain deductive reasoning of human and his errors that occur in the argument (Sinkinson, et al., 2012).mental model theory is a Psychological theory that is used widely for individuals’ cognitive processes when using mechanical or computer systems (Zhang, 2009). In the 90s, the theory of mental models proposed in the area of human interaction with the computer and then in various fields including the field of library and information science, particularly been used it h in connection with information retrieval system.

Mental Models in the Field of Human Interaction with Computers

In the field of human interaction with computers, mental models are knowledge of how a system works? What are its components? How the components relate to one another? What are the internal process components? And how the components interact with each other (Li, 2007)?

In other words, mental model is an image of mind that user makes from a system and its function for better usage. Rouse and Morris (1986) defined mental
models as mechanisms that enable human to define goal, shape, function and prediction of system’s future (Savage-Kneipshild, 2001). These model shows belief systems of users. These models show belief systems of users. They are dynamic and they gradually are formed when people gain experience in working with a system. Thus, this model is created according to observation of a user and his prediction about the function of system. Users create an imaginary in conclusion of work with system or education of system and with each experience, their mental models will develop. Sometimes people are not informed of development of this mental model in their mind. When user do not have any experience about a system, may use their former experience about some other similar system that they have used before and transform it to a system that they face now. Some times because of some different between two systems, users can not perceive definition and failure of their perception during of transformation of their experience from previous system to new system and so make some defective mental models from new system and experience a level of failure (Holman, 2009). Also accepted that mental models help people in understand a system work with it and predict the behavior of the system. Various studies have shown that better mental models of people, leading to a more efficient performance. Perhaps one of the reasons is that a mental model, consist a deep knowledge of the structure of a system and enable user to contend about function of a system. So, mental models are as a basis to do sensible thing while interacting with system and their use is beneficial in practice.

Mental Models in the Field of Information Retrieval

Retrieval information is one of the most fundamental concepts in the field of information science, because finding documents and information related to the needs of users, is the most important activity in this area. And increased ease of access to electronic information resources that are witnessing today is an achievement that has come from the progress of ICT, especially the Internet, the Web and information retrieval systems. This progress provide the possibility of easier and faster access of user to information and on the other hand give rise to a variety of fields associated with the user’s data retrieval system.

The most important features of web-based information retrieval systems, is that they are interactive, allowing faster access for end-users to provide information, often suggest various search strategies and have mechanisms for better interaction with user. Despite the many possibilities that these systems provide, the results of some studies show that users still face difficulties in using them and in many cases has been seen that they meet fail in searching for information (Ahmed, McKnight, Oppenheim, 2009). However, the use of electronic information resources steadily increased, but we do not have enough information about cognitive processes that users employ during search and use these. We do not know precisely, how they imagine this space when users search for information in the online environment? What is their decision when they work with system? What is their ideas and perception from this environment and its search? In other words, what is users’ mental model when searching in a retrieval system? In the past, research which was conducted in the field of information retrieval systems often focused on technical aspects of the system. Gradually this research observed users and their function. But until recent years, was discussed less the cognitive processes and the reasons they joined in the search for information, especially electronic information. While studies show that one of the factors that affects user search function, are their mental models. Users during search, apply mental models, based on them use specific search strategies and show a variety of information-seeking behavior (McNally, 2005). In general, the study of mental models in information retrieval systems, follow two objectives (Zhang, 2009):

Understanding the cognitive process of user behavior when using these systems.

Use this understanding to design more efficient systems and materials more efficiently.

In this regard Dimitroff researched and examined the relationship between mental models of user about an online catalog of library and their success in using it. He found that complete mental models of user have significant impact on the performance of user. Users with more complete mental models have fewer errors significantly and retrieved more relevant documents (Dimitroff, 1992). Holman in his doctoral thesis showed that poor mental models or incomplete, had a negative impact on user performance during retrieval information. For example, people with the wrong mental model of search engines, do not check retrieval results beyond first page of search results and in case of lack of evidence, discontinue and begin a new search (Holman, 2009). Slone during the observation of user when work with net and web-based index of library, found out that mental models of users impact their search solutions, website observed and resources used(Slone, 2002). It should be noted that in some cases there were not significant differences in search performance groups with different mental model of the web: Including Zhang’s research on the impact of mental models on their search behavior on the web, there is no significant difference (Zhang, 2008a). The
researchers in the field of human interaction with computers believe that for effective use of the system, the user’s mental model must be compatible with "conceptual model" of designer as much as possible (Grudge, Johnson, 2004). Norman has created clear distinction between mental models and conceptual models. Mental models are what something that user has in his mind and it is not visible; while the conceptual model is something that is presented by a designer or teacher, as a description of a system to user. In his view, the conceptual model can be the basis for the creation of user mental models (Borgman, 1999). accordingly, mental models must also play a role in the development of conceptual models because studies have shown that when users' mental model is different from the conceptual model of a system, so users are in trouble about interact with the system. So the importance of identifying the user mental models to remove defects or coordination with conceptual model of the system becomes apparent. By studying users' mental models, behavior and their performance in the information retrieval systems are deeper and better conceived. In addition, by identifying users' mental models can explain diversify of their performance and the reasons for their success or failure in dealing with an information retrieval system and understand the cognitive processes underlying their behavior when using the information retrieval systems.

So one of the reasons of mental model study is that user' function and his/her interaction with information retrieval systems would be guided by his mental model. People use mental model to facilitate their interaction with the system. These models enable them to understand the system and use it to predict its function (Li, 2007). Accordingly with study of mental model, view of user to system would be clear and it can be useful for the design or reform.

Features of Mental Model

In this section a number of features mental models are considered:

Incompleteness is one of the inherent features of mental models. Because mental model represent a comparative of environment. But this feature is not a defect for mental model, because it is rooted in man’s limited memory and processing power.

Mental models are often raw and simple. In a sense, these models are often inconsistent with the conceptual model. When using a system based on their observations, they guess the main mechanism of the system. As long as the system acts according to the expectation of user, user considers the mental model valid. Mental models often have misconceptions as well. For instance in various studies, misconceptions of users from Internet and processing mechanisms questions on web search engines have been seen.

Mental models are dynamic because people change them according to the change in environment.

Mental models of people in one area may affect their mental models related to other area (Zhang, 2009). For example, Marchionini (1989) in his study found that some students are able to use mental models of their printed encyclopedia and based on that mental models create more advanced use of electronic encyclopedias (Marchionini, 1989).

Norman also refers to 3 characteristics of mental models (Norman, 1983):

Mental models show the beliefs of user about a system.

Parameters and fashion of mental model coincide with the situation of a system that user see

Mental model make possible the understanding and prediction of the behavior of a system.

Mental models despite all the positive and negative characteristics, always is foundation of user behavior in interaction with various systems and be aware of these features are useful in identifying them.

The Need for Research on Mental Models of Users

It is important to create favorable conditions for efficient interaction between users and systems in the information retrieval system. To establish an effective communication, information systems must be designed to help in expression the needs of the users and performance of a search and retrieve. Therefore, the success of information systems depends on provision of suitable facilities during work, and to enable users to effectively interact with the system (Entezarian, Fattahi, 2010). In this context, Borgman believes that understanding the behavior, structure, functioning and expectations of the users is necessary to improve the efficiency of information systems (Borgman, 2003).

Marchionini and Shneiderman in their study about interaction of user with hypertext system showed that the first step to understanding the status of retrieval information in an electronic media is promoting the understanding of cognitive process (Marchionini, Shneiderman, 1988). One of the important factors in this context is mental models, because users' mental model of information retrieval systems affects the formation of their information seeking behavior and the efficient use of those systems. Identifying these models enable us to understand what people think during search for information how they think, how their thought affect their decision and how these solutions may limit their search. So it is essential that researchers in the field of library and information science in the study
identify mental models of users. The results of the identification of these models and their impact on information search behavior can be important in several ways:

With research in this area can be deepened their understanding of the process of searching for information by the user. Thus, when a root of certain attitude is studied, it can be corrected better.

Since so many costs, time and energy is spent to create information retrieval system, so it is important that people know how to use them; with recognition of user’s mental models can achieve this fact and even attempt to predict the behavior of users.

This makes it possible for designers of information retrieval system to provide the user interface and create systems that are close as possible to users’ mental models.

Because studies have shown if systems are designed in such a way that is close to the natural processes of the human mind, it would be more efficient. In other words, a system that as far as possible consistent with user mental models or can help to make the correct mental models, would be used more easily and make more user satisfaction. So the results of this research can be a road map for designers and providers of information retrieval system, in correcting or designing user interface, search mechanisms and guidelines of a system.

Since the user’s mental model of an information retrieval system may be incomplete or inaccurate, so with identifying and study can determine that what level of training for user is needed. The results of these studies affect the importance of information literacy as well and cause to accommodate the education provided by librarians and information professionals with skills and needs of the present and future users.

Identify the mental model can be used to modify the information-seeking behaviors and with this study we can justified the variety of user performance with differences in mental models. Accordingly, it can be said that information retrieval system designers, service providers and information literacy educators can use the research results in the field of design information retrieval system and improve and develop teaching strategies.

**Framework of Research in the Field of Mental Models of Information Retrieval**

The shape show the current situation of research related to mental models in the field of information retrieval.

As shown in the figure, individual difference and environmental factors are on the left hand while behavior pattern and function of research are on the right hand. During the study we found out that the main part of existing studies on information retrieval system have focused on the direct effect of individual differences and environmental factors on information seeking behavior (Flashes 1, 2). When the theory of mental models in this area was taken into account, the researchers looked deeply into the study of the structure and observed it as a mediator and the underlying factors affecting user searching behavior. In the other word, researcher gravitated on the study of cognitive mechanism in the use of information retrieval systems. Because they found some individual differences or environmental factors that affect the behavior and performance of the information retrieval systems May be due to the fact that they may affect
user’s mental model. In this step asked this question "how individual differences and environmental factors affect their performance" instead of this question "Is seeking individual differences and environmental factors contribute to the performance of the system is different (Zhang, 2009)?

The number of these studies is including merely identifying the model of the interaction of the user with the information retrieval systems like:

Westbrook, 2006; Naughton, Agosto, 2012; Makri, 2007; Mlilo, 2010.

A number of studies, in addition to the extraction of these models, review their impact on user behavior and their performance (the part that has been shown by flash 3 in the shape) like:

Holman, 2009; Zhang, 2008b; Khoo, Hall, 2012; Dinet, Kitajima, 2011.

Another group of researchers also have investigated the influenced by a number of individual differences and environmental factors on mental models of users (the part that has been shown by flash 4&5 in the shape). Like: Zhang, 2013; Li, 2007; Zhang, Chignell, 2001.

Researchers in the field, tried to identify mental models users in interaction with different types of information retrieval system, including continuous list of libraries, online and offline databases, search engines, web and so on.

Tools and Methods of Eliciting Users’ Mental Model

Mental models are not directly visible and just can be detected via their effect on the user and his behavior. So it is difficult to extract and identify them. it is not enough that the researcher directly or in the form of closed questions, ask people about their mental models. Because people often are not aware of their cognitive structures which determine their behavior. And if you ask people speak directly about their perceptions, it is likely that they will move from their unconscious to the conscious and do not reveal their true perceptions. Therefore it is necessary to use research techniques in order to access to the unconscious mind of users and examine them also in the context of an actual performance (Makri, et al., 2007). Accordingly, Young suggested that in order to extract mental models, researchers will examine the following (Young, 1983):

Method of use of a system by user:

Description of user about a system (the cause of specific event or reason of specific function of system in part of the work).

Prediction of user about the behavior of system (A prediction about what happens in a continuous process or how the change of one part of system affect other part).

Learning about system by user (it means that user teach other how to work with system and during this teaching some part of his mental models would be revealed).

In this context, researchers used different methods to detect mental models and they are considered in this section:

Semi-Structured Interview

In many studies, the interview is used to examine the mental models of people of different computer systems. In addition, in the field of psychology and behavioral sciences accepted that the verbal report, are relatively good tool to show mental activities. In the meantime, one of the interview methods that are more applicable in this field is semi-structured interview. In this interview, people speak about their idea and thought in the framework that is created by interview question. In addition, researchers can modify the order of questions based on the responses of individuals to express freely their subjective perceptions and ideas (Zhang, 2009). In this regard, Li said semi-structured interviews have the flexibility to find the nature of the knowledge and concepts of people (Li, 2007). In these interviews, questions are begun with "why", "how" and "what if" and can be very useful for the extraction of mental model. By these question can access to some part of user belief (Holman, 2009).

Thinking-Aloud Protocol

This has been used repeatedly in order to achieve those verbal reports of people’s mental model. For example in the research of Makri, et al., 2007; Katzeff, 1990; Chen, Dhar, 1990; Li, 2007.

In this protocol, users will be asked, to talk about their thoughts during the interaction with the system. In other words, orally express their thought process. This method cause minimum interface of researcher. Another type of thinking aloud protocol, is the technique of repeated taught, that is used in the research of mental model field. In this way, the participants will be asked how to use the system by using their knowledge about the system, in order to teach another person. So the lecturer’s mental model of the system becomes apparent (Sasse, 1991).

The use of interviews and think-aloud protocols may have limited the power of speech of people. And it is likely that users do not find words adequate to express their perceptions. So the use of a complementary tool can be very useful here. Use of drawing can be complementary and sufficient method in showing mental models (Thatcher, Greyling, 1998). This issue has been fixed in a lot of research in this area.
Drawing and Drawing Concept Mapping

Many researchers believe that the drawing can be used to extract users' mental models. So they used drawing method as a means to show the mental model of information retrieval systems. For example, Zhang used the Drawing and Interview method in his study. He asked users to draw a graph or a picture of their perception about the web. He found that data collected by both interview and drawing, are complementary and fairly provide complete representation of mental models (Zhang, 2009). Efthimiadis and Hendry asked users to draw the function of search engine in order to search user's perception of web search engine (Efthimiadis, Hendry, 2005). Other researchers like: Gray, 1990; Papastergiou, 2005 used these tools in their study as well. Drawing Concept Mapping has been defined as a method of showing (representation) of people knowledge in the form of graph with lines that show the relation between concepts. This way is used, as an intuitive and efficient way to indicate the individual's understanding of a concept or set of concepts. For example Holman used this method in his study in order to extract users' mental models. This method is similar to the Drawing method, except that users must draw the relationships between concepts (Holman, 2009).

Observation

Observation is another way to identify mental models when users interact with the system at the time of the search. In this way, usually errors and common patterns of behavior as a means to extract users' mental models are analyzed. For example, Huang research into the behavior of users when they pause during in the dialogue system, so that he revealed their mental models (Huang, 1992). Chen and Dhar detected thought and incorrect understanding of users about information retrieval system via the observation of 30 users were searching in a library online catalog. And thereby, the gap between users' mental model of the system became apparent (Chen, Dhar, 1990). Data collected by observation than verbal reports of users, are more objective and reliable. But the imagery obtained through observation does not reveal more information about the user's cognitive model. In this way, researchers can see what users are doing, but they do not have any information about why they do so. Researchers had to extract users' mental models based on observed behavior, which it is challenging; because researchers with different backgrounds have different interpretations of their behavior. Due to the limitations of this approach, there is little research that has used just observation methods to show mental models of users. In contrast, this method in studies of mental models, were used in order to complete such thinking out loud verbal reports and interviews (Zhang, 2009).

Contextual Inquiry

In this method the researchers observed and interviewed their subjects while doing a real search. This method has 3 features:
  
  - Researcher collects data in the context of the work.
  - Researcher and participants are involved with each other in the search.
  - Search focuses on the set of defined issues and not focuses on the list of questions.

This method is useful for the study of a production or new process and enables researcher to observe apparent behavior of user and does not focus on the report of user from their behavior (Holman, 2009). In addition to these, there are other ways to extract the mental models that they have rarely been used in the field of information retrieval: so in this study we do not assess them. As you see in each method of identify mental model, there is some limitation. Verbal reports (interviews, thinking aloud) depend on the ability of users to express their perceptions and ideas. Drawing and concept mapping, lets people show their ideas in a comprehensive manner. But the interpretation of this drawing function is understood by researchers. Also these methods are not efficiency in reveal abstract concepts. Observation and Contextual inquiry allow researchers to examine the actual behavior of users. But deduction cognitive mechanisms that are base of a manner are difficult in this method. So researcher uses the combined of all methods in order to defeat weak point of each one.

Conclusion

Study of papers related to mental models reveals some points that are:
  
  - Mental models have capability of being identified and extracted.
  - Many users may have weak or incorrect mental models.
  - Mental models may affect the function of users.

There are variety techniques to extract mental models and they should be used combined in order to reach better conclusion.

Studies done in the field of information retrieval show the importance of this subject and since many users have defective mental models that cause to faint function, so the study of these models is essential in order to create better mental models.

Finally it can be said that research in the field of mental models identification can reveal some part of
reasons related to user's manner during the search and use of the conclusions can be suitable for designing the better information systems. So we should say that such study is essential to create web-oriented information systems.

References


Milo S (2010). " Mental Models: Have users ' mental models of search engines improved in the last ten years?" MA Dissertation, Organizational Psychology in the Faculty of Humanities, University of the Witwatersrand, Johannesburg.


Norman DA (1983). "Some observations on mental models". In Gentner D & Stevens AL (Eds.),
Mental Models (pp. 7-14). Hillsdale, NJ: Erlbaum.


