Contributions of cognitive science to information science: An analytical synopsis

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Emergence of cognitive science as a distinct field of study has left an important impact on various disciplines including information science. Research questions relating to the study of thinking, intuition, and intelligence were considered unimportant for scholarly inquiry before the beginning of cognitive science; however, a greater attention has been given to these questions since the beginning of the cognitive paradigm. Cognitive science brought a different perspective to the study of a user's mental models, context surrounding a user, knowledge representation, its production, and transfer. This perspective then took roots in the discipline of information science and subsequently influenced the research. This paper is a synopsis of the various contributions of cognitive science to information science with a particular emphasis on information retrieval research. In addition to the review of various contributions, some new research avenues are discussed and the relevance of the cognitive paradigm to these avenues is presented. It would be important for information scientists to consider the application of the cognitive approach to these research areas so that the theoretical and practical scope of the discipline of information science could be enhanced.

Keywords: cognitive science, information science, information behavior, information asymmetry.

INTRODUCTION

The emergence of cognitive science (CS) as a distinct field of study can be traced to 1956 (Gardner, 1985). Many disciplines have contributed to the birth of CS. On one hand, the dissatisfaction with *behaviorism*[1] and on the other astounding mathematical advances[2] triggered the environment that was conducive to the birth of a discipline that could explore the notions of memory, perception, classification, learning, and information processing. In addition, the increasing importance of artificial intelligence (AI) and computer science necessitated the greater role of CS in studying the problems dealing with information acquisition, storage, and processing.

The beginning of the cognitive approach in information science (IS) can be traced back to 1977 (Ingwersen, 1999). The use of CS in IS remained limited, to a certain extent, to information retrieval (IR) research, which was concerned with the design of better retrieval systems. Though important advances were made in IR research, however, the use of the cognitive approach was not as widely spread in other streams of IS research as it was in IR studies. Information systems were designed using cognitive models to facilitate the interaction that takes place between a user and bibliographic records. Nonetheless, other areas within IS were not explored as extensively, using the cognitive approach, as the area of IR research. This paper reports on some of the studies that have used the cognitive approach within IS research with a special reference to IR, describes two perspectives within the cognitive approach, and finally presents some of the issues that may be examined using the cognitive paradigm.

BACKGROUND

Cognitive science, as a distinct field of study, was officially recognized in 1956; however, the foundations of this new science were laid down in 1948 at the Hixon Symposium (Gardner, 1985). Owing to increasing dissatisfaction with behaviorism, and significant advances in mathematics, information and communication theory, the need to study the inherent intricacies involved in information processing was greatly felt. Cognitive science provided the framework that had enough flexibility to allow experimentation while utilizing the advances that were made in other disciplines, particularly computer science and information/communication theory.

Cognitive science is defined as a "science that deals with the study of knowledge: i.e., what knowledge is and how it can be represented, how it can be handled by transforming it from one form to another" (De Mey, 1982, p. 3). Cognitive science deals with the study of the ontology of knowledge, its representation, production, and transfer. Due to the scope of CS, it has been used in other disciplines including computer science, AI, sociology, linguistics, and IS (Ellis, 1992).

COGNITIVE APPROACH IN INFORMATION SCIENCE

Information retrieval and cognitive science

Cognitive science started taking roots in IS around the mid-1970s (Belkin, 1990). In view of the importance of IR within IS, a need was felt to apply the cognitive approach to increase the effectiveness of the retrieval process. Two different cognitive approaches were used to study IR. The first perspective was characterized by a pure cognitive, user-centered approach,

whereas the second was characterized by a socio-cognitive perspective (Ingwersen, 1999).

User-centered approach – From the mid 1970s until the early 1990s there was a greater emphasis on user modeling, designing of IR systems using algorithms, and on developing the understanding of individual users so that a general user model could be developed. Within IR research, during the 1970s and 1980s, a significant emphasis was placed on understanding mental models. Mental models can be defined as "images that the component of a system, whether the components be people or machines, have of themselves, of each other, and of the world" (Daniels, 1986, p. 272). Various IR systems were designed by using the concept of mental models; the underlying assumption was that if we can understand the mental models of the user, the system, and of the intermediary, we can design better IR systems.

Numerous research projects used the concept of mental models to analyze the IR process. For example, Wersig (1979) used the concept of *problematic situation* to represent an individual whose internal model is not sufficient to attain his goals. Rich's (1979) system GRUNDY was designed by establishing stereotypes in the system about a user. Oddy's (1977) system THOMAS was designed to interact and proceed according to user's knowledge model. Ingwersen (1982) analyzed the verbal protocol of librarian-user interactions and concluded that librarians' search process is highly dependent on their model of a user. Researchers in IR realized that the success of an information system rests on the accurate representation of the users' needs. Oddy (1977) wrote that "The art of information system design (which I am certain, has a long future) [*sic*] is to find the form and timing of information presentation which will best aid the system user in whatever task he [*sic*] has in hand" (p. 12).

There was some criticism about the application of the user-centered cognitive approach in IS. Vickery (1997) criticized the individual cognitive approach (first used in the 1970's) because of its lack of predictability and practical investigations. Ellis (1992) objected on considering the cognitive structures in systems, information objects, and human cognition under the same model. This criticism was mainly on the use of the cognitive approach to model the users' cognitive states. However, since the early 1990's a shift occurred towards the socio-cognitive approach, which placed more importance in developing the understanding of the context that surrounds a user and an IR system. This approach addressed the preceding criticism by giving due consideration to the context in which a need develops. The importance of the context was emphasized to develop a better understanding of the user's environment.

Socio-cognitive approach – ***Context:*** A need was felt to consider the context in which information generation, processing, and organization take place. It was argued by researchers, (e.g., Jacob & Shaw, 1998) that the research in IS has ignored the social context of information processing. According to Ingwersen (1999), "the information is associated with the situation in context, not just with its general semantic value" (p. 16). Information interacts with the cognitive structures of individuals as well as of systems and then changes the knowledge structures. Knowledge structures develop with experience through various interactions in a cultural, political, social, and economic environment. It is necessary, therefore, to consider the context of users while designing IR systems.

Situation: The concept of "situation" has been used in IS sometimes as a synonym to "context" (Cool, 2001). However, a situation can be considered as a constituent of context. According to Sonnenwald (1999), "A context is somehow larger than a situation and may consist of a variety of situations; different contexts may have different possible types of situations" (p. 180). This concept of situation has an important relationship with relevance, a concept that is described later. A situation can be termed as *problematic* or *routine*; a problematic situation is one in which the cognitive state of an individual has uncertainty that may lead to information seeking (Cool, 2001), whereas a routine situation denotes a state in which there is a consistency between the user's knowledge and the current condition. The development of this concept (problematic situation) highlighted the importance of understanding the inconsistency that a user feels during a cognitive state. A change in that state, subject to the relevance of the retrieved information with the user's need, determines the efficacy of an IR system. The cognitive viewpoint assisted in examining the relationship between the IR system and the user's cognitive state during an information seeking episode. The cognitive approach was used to understand the situations where a user is uncertain, e.g., the anomalous state of knowledge (ASK) model developed by Belkin (1980) was a representation of a cognitive state of user that exists during an IR episode. Kuhlthau's (1993a, 1993b) uncertainty model is another example where different situations of users were cognitively understood (as cited in Cool, 2001).

Relevance: The concept of relevance has a prominent place in IR research. Relevance, as a concept, has been described in many ways (Saracevic, 1975); however, these varied descriptions can be narrowed down to two classes: objective or system-based relevance, and subjective or user-based relevance (Harter, 1992). Objective relevance represents the aboutness of the retrieved information; according to Harter (1992), it measures "… how well the topic of the information retrieved matches the topic of request" (p. 602). On the other hand, a piece of information is subjectively relevant if it causes a change in the cognitive state of the user (Harter, 1992). The preceding descriptions of objective and subjective relevance

present an interesting point. For instance, a document can match a query (information request) of a user but may still not be able to change the cognitive state of a user, i.e., a document can be completely relevant objectively but irrelevant subjectively. User-based (subjective) relevance represents a condition where a user arrives after having a change in current cognitive state owing to new retrieved information (Harter, 1992). According to Sperber and Wilson (1986), various cultural, social, and educational factors influence the cognitive state of a user (as cited in Harter, 1992). It can therefore be argued that by examining the users' cognitive state, a researcher implicitly concedes the importance of a context surrounding a user. Subjective relevance, by taking into consideration the users' context, provides a broader research framework that can be used to examine the relationship between a change in cognitive state and retrieved information.

Information behavior and cognitive science

Another important application of CS was in the information behavior research. Dervin and Nilan (1986) emphasized in their literature review of *information needs and uses* a focus on the cognitive viewpoint. This emphasis was reflected, later, by the use of cognitive viewpoint in the information behavior research. Hewins (1990) remarked in an ARIST review on the prevalence of the cognitive approach in information behavior research. Cognitive science was used to map the individual's models of the world. The work of Ellis (1989), Kuhlthau (1991), Yoon and Nilan (1999), and Vakkari (2000) are some of the examples that have depicted the use of the cognitive viewpoint in information behavior research.

Discussion

Cognitive science attained an important role not only in IS but also in psychology. The processes dealing with the functions of information processing, storage, and retrieval have been examined extensively within psychology. Barslou (1992) wrote that psychophysicists attempted to describe the relationship between physical information and conscious environment; gestalt psychologists explained the process involved in organization of information fields during perception, memory, and thought; and cognitive psychologists explained how humans store, process, and use information. Cognitive science became an important domain within psychology and progressed effectively as a field of research over the course of years. During its progression, various new approaches developed. For instance, since the late 1990's, approaches favoring examination of one's environment/surroundings, while studying cognitive processes, started gaining grounds and one such approach is *extended cognition* (Holland, 2006). This approach takes into consideration the tools such as pen and paper as cognitive representation of the human mind, and the ways in which a human being uses these tools as representative of cognition. The concept of extended cognition, as described above, can be useful for IS research. It is so because information scientists can analyze the cognitive states of users in greater depth by considering the various tools such as queries, language, and information systems as a representation of the cognitive states of users. The application of the cognitive approach within IS is also going through transitional phases. For instance, there is an increasing emphasis on using the socio-cognitive perspective in IS; the domain analytic approach of Hjørland and Albrechtsen (1995) is an example in this regard.

Different cognitive perspectives, e.g., user-based and socio-cognitive have left important imprints on IR research. Information retrieval has been significantly influenced by the application of various concepts and approaches developed within the domain of CS. Relevance, a notion that has paramount significance in IR, fundamentally represents the cognitive state of a user during or at the end of an information-seeking episode. According to Robertson and Hancock-Beaulieu (1992), "Relevance is the most highly debated aspect of IR research" (p. 458). Relevance, which is central to the information science, can be classified as both objective and subjective. Harter (1992) noted that objective relevance is system-oriented, whereas subjective relevance is user-oriented. A user will consider a document subjectively relevant, when that document will bring the information that would change the current cognitive state of a user (Harter, 1992).

It is therefore important to increase the subjective relevance so that the user's information need, which is represented cognitively, may be satisfied. According to scholars (e.g., Belkin, Oddy, & Brooks, 1982a, 1982b; Wilson, 1981), information need can be described as a function of the current knowledge state of a user. A knowledge state of a user may sense inconsistency between what a user has in terms of knowledge and what is required to solve an issue, thus creating an information need. Cognitive science can be pivotal in increasing the understanding of the knowledge state of users and of the nature of information, which is subjectively relevant and thus pertinent to an information need that initiated the information seeking process. This approach to information needs can enhance the overall performance of IR systems.

Besides information needs, image retrieval is another area that has pertinence with CS in the domain of IR. The importance of understanding the cognitive processes in order to facilitate image retrieval is emphasized by researchers; for instance, Greisdorf and Connor (2002) state that "To render the full strength of retrieval capabilities to a viewer, the indexing of digital images must include a self-awareness of the human mind…" (p. 6). The cognitive environment of an individual, during a particular interaction, contains in it a specific array of thoughts or ideas. According to Sperber and Wilson (1986),

"At any given time, then, the cognitive environment of an individual is the set of facts and assumptions that are manifest to him at that time" (as cited in Harter, 1992). A challenge for an information scientist is to explore this cognitive environment so that information interactions between users and organized information can be made more successful.

New horizons

There are research areas beyond IR and information seeking behavior that need consideration within the domain of IS. These areas hold important promise for the growth of IS research, and CS may be quite helpful in exploring these research problems. It would be important to consider the use of CS in understanding the phenomena of "information asymmetry, information packaging, dynamic and detail complexity, for example."

Information asymmetry is a condition where different parties in a transaction have different sets of information (Afzal, Roland, & Al-Suqri, 2009). This asymmetry can develop due to various reasons: for instance, a seller usually knows more about a product simply because of having ownership; a board director knows more about the future prospects of a company because of being an insider; and a doctor knows more about a disease due to his/her professional expertise. A buyer, owing to lack of knowledge about a product, may value a product differently from a seller who has greater information about the product. This difference in the distribution of information may effect the product valuation process. As the notion of information asymmetry may be relevant to almost any kind of transaction (economic, social, etc.), understanding of information asymmetry may greatly help the transacting parties to reduce, if not to completely eliminate, information asymmetry. Information asymmetry has already drawn a great deal of attention from researchers in the disciplines of economics and finance, and this notion warrants a careful attention in the discipline of information science. Evaluation of cognitive processes that develop during the presence of asymmetric information can enable information scientists to study the relationship between the amount of information and resulting cognitive states.

Another important research stream is the use of CS in understanding the dynamics of information packaging. Information packaging is the organization of information with an objective to increase its utilization, which in turn depends on a closer match between a user's need and an available information package. To create this match, it is important that an information professional give due consideration to various contextual factors surrounding a user and his/her information need (e.g., Aiyepeku, 1982; Dahlin, Weingart, & Hinds, 2005). Some of these factors include, for example, whether an information package is going to address an existing information need or will create a new need; what are the demographic traits of the target user population; what is the nature of the need itself, that is, is it a primary need or means to another need. A well-grounded knowledge of user traits, information attributes, nature of a need, and contextual factors would enable an information professional to choose the right form (text, visual, sound, or combination of all these), medium (print, online, popular media), and content (information) to design an effective information package. Creating a match between an information package and user's need also entails knowledge of cognitive processes associated with information processing, representation, and assimilation. Having understanding of the preceding processes may help information professionals to package information that would successfully address users' information needs.

The notions of *dynamic* and *detail* complexity represent another interesting research avenue. Senge (1990) discussed in his book "The Fifth Discipline" the concepts of dynamic and detail complexity. Dynamic complexity is involved in the issues where the effects of current actions are not clear owing to the lag of time. That is, there is a gap between cause and effect (Reigeluth, 2008) that makes it difficult to clearly see a relationship between them. On the other hand, detail complexity is present in the issues that involve many variables and therefore make the synthesis of the available information difficult. Computers can aid in resolving the issues that involve detail complexity; however, effective resolution of issues involving dynamic complexity depends on the cognitive abilities of the people involved. Depending on the nature of issues, i.e., whether they involve dynamic or detail complexity, an information professional may package the information to facilitate the resolution of a matter. In the case of an issue involving dynamic complexity, a close correspondence between the cognitive states of users and available information package(s) could be of great help in solving that matter. Cognitive viewpoint can thus help in better customization and effective information packaging.

Conclusion

The emergence of CS has benefited many disciplines including IS. Different conceptual developments within CS have influenced the nature of research within IS. For instance, the socio-cognitive perspective emphasizes the importance of context, while the user-centered approach stresses on understanding the user's mental model. Though the socio-cognitive perspective has more support in various CS as well as IS circles, the user-centered approach should not be abandoned. Instead it should be used in conjunction with the socio-cognitive approach to understand the cognitive states of a user within a broader theoretical framework. In addition, there is a need to explore the concepts such as information asymmetry, information packaging, and dynamic and detail

complexity using the cognitive approach. It is also important that the use of CS should be extended to other areas of IS research. Cognitive science may be used for the exploration of numerous processes that comes into play when information disseminates, diffuses, and transfers. This kind of stance would increase the extent of multidisciplinary research within IS and could expand the scope of subsequent research studies.

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End notes

1. The approach that called for the use of objective methods of observation in examination of behavior and for greater emphasis on behavior rather than topics such as thinking, imagination, or intention (Gardner, 1985).

2. For instance the work of Bertrand Russell and Alfred North Whitehead facilitated the reduction of arithmetic laws to propositions of elementary logic (Gardner, 1985).

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