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Guy Higgins
Terry College of Business

Alan Dennis
Terry College of Business

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Guy M. Higgins, Jr. (ghiggins@blaze.cba.uga.edu),
Alan R. Dennis (adennis@blaze.cba.uga.edu)
Terry College of Business, Department of Management, Athens, GA 30602,
(706) 542-1294; fax (706) 542-3743

Introduction

The importance of knowledge has long been recognized. Long ago, Sir Francis Bacon (1597) wrote, "*Knowledge is power*." More recently there has been an increasing recognition that 'knowledge,' as opposed to 'data' or even 'information,' is the most critical organizational resource (Drucker, 1993). All knowledge acquisition takes place inside individuals (Simon, 1945), but for knowledge to become 'organizational knowledge,' it must be shared throughout the organization (Lipshitz, *et al*. 1996; Nonaka and Takeuchi, 1995; Levitt and March, 1988)

Most organizations already have a basic form of knowledge base in their standard operating procedures (SOPs), company policies, transaction records, *etc*. But organizational knowledge also includes the combined experience of all of the organization's employees – the human capital of the firm (Penrose 1959). This type of knowledge, diffused throughout the organization, is called "*migratory knowledge*" (Badaracco, 1991) in that it is only 'on loan' to the organization as long as the individual that holds it remains an employee. It is the combination of the diffused and migratory nature of this knowledge, along with its continual creation, that makes the sharing of this knowledge both difficult and imperative. Unfortunately, much of an organization's newly created 'knowledge' is never captured or shared; it never moves beyond those who actually experienced its creation. Thus, this non-collected, non-shared knowledge is continually being lost as employees simply forget their experience or leave the organization.

Knowledge Management Systems and the Learning Organization

Nonaka proposed the knowledge-creating company, or one involved in 'knowledge management,' as an example of organizational learning (Nonaka and Takeuchi, 1995). Lipshitz, *et al.* (1996) extended the Nonaka definition as the "*process through which organization members develop shared values and knowledge based on past experience of themselves and others.*" This definition not only emphasizes that the creation of knowledge is a human process, but that this knowledge becomes organizational as it is shared with others and the effects of its use materialize at the organizational level (Levitt and March, 1988).

Discussion about 'learning organizations' has become quite popular in both the academic and popular management presses (Senge, 1990; Fiol and Lyles, 1985), yet the organizational learning literature does not clearly address 'how' an organization 'learns'. While the idea of organizational learning is not new (Chandler, 1962; March and Simon, 1958), it has apparently been difficult to develop a clear definition of organizational learning (Garvin, 1993). Simon and others, extending Bernard's (1938) view of the organization as a cooperative system designed to expand capacity beyond the limitations of its individual members, see the organization as an "*information-processing machine*" extending the bounded rationality of its human decision makers (Nonaka and Takeuchi, 1995; March and Simon, 1958; Simon, 1945). Organizations may be conceptualized as institutions for integrating knowledge (Grant, 1996); this definition seems particularly apt for a 'learning organization.' Thus, there is a tradition, going back to Bernard, of a biological model for the information/knowledge-processing component of organizations.

To address the need to manage their 'knowledge,' many organizations have adopted a variety of technologies under the general aegis of 'knowledge management systems.' What is a knowledge management system? That is still an open question, but, for the purposes of this paper, we assume the ability of the organization to continually create new knowledge and focus our definition of a knowledge management system as the processes by which organizations identify, capture, systematize, categorize, and disseminate knowledge from and to members of the organization.

We believe that the development of a successful knowledge management system is the crucial factor in being a learning organization. The processes of a knowledge management system are the same processes that individuals engage in as they learn and manage knowledge. Therefore, we propose a biological/cognitive metaphor for the structure and functioning of an effective organizational knowledge management system. Specifically, we propose that the information processing of the human cognitive system, as modeled by the Adaptive Character of Thought – Revised (ACT-R) model (Anderson, 1996), is an appropriate metaphor for the categorization and dissemination processes that must be utilized by knowledge management systems within learning organizations.

The Human Neurological System

Human cognition may be defined as the collection of mental processes and activities used in perceiving, re-

membering, thinking, and understanding. This cognitive system has both a set of biological/neurological components (the brain/nervous system) and a production-system architecture (the 'thinking' component as described by the ACT-R model). The basic biological/neurological components of the human cognitive system are: (1) sensory registers, (2) executive control processes, (3) short-term/working memory, and (4) long-term memory.

The 'sensory registers' are the points of initial contact with the environment, where interceptions of external stimuli occur (sight, hearing, touch, *etc.*). These stimuli produce a volume of potential informational input well beyond the capacity of the neurological/cognitive system to capture, identify, and systematize. However, processing of incoming information from each register begins immediately upon interception, and information is 'selected' for further processing. Information not selected is retained for a very short period, but eventually is permanently lost in a process known as decay (Kolb and Whishaw, 1995).

The 'executive control processes' are the set of components that allocate resources to the processing system. This allocation is necessary because our ability to perform mental work is limited by the degree of utilization of these cognitive resources. One important cognitive resource is 'attention,' the mental energy used to perceive, think, and understand (Bruning, *et al.*, 1995). Attention can be further subdivided into 'focal attention' and 'cognitive attention.'

Focal attention selects information for additional processing and typically is not a conscious process (*e.g.*, when your eyes focus on movement) (Bruning, *et al.*, 1995; Kolb and Whishaw, 1995). Cognitive attention is the internal processing that connects newly selected information with the existing knowledge base, and is what we normally identify as thinking.

'Short-term' or 'working' memory is where conscious, cognitive activity takes place. It has both limited capacity and limited storage time; a specific 'memory' that has been selected for further processing can still be permanently lost if either the capacity (interference) or storage time (decay) of working memory is exceeded before the information is transferred to long-term.

'Long-term memory' theoretically has both unlimited capacity and permanence; however, access to long-term memory requires both time and effort (additional cognitive resources, although these are expended within working memory). Forgetting information stored in long-term memory is not believed to be a permanent loss of that memory, but rather a failure of retrieval. The retrieval of information from long-term memory is, in part, a product of its representation (Bruning, *et al.*, 1995; Kolb and Whishaw, 1995), and this is addressed in the ACT-R model.

The biological/neurological components of the human memory system are shown in Figure 1, below. The model shows that there are several levels of processing prior to adding information to long-term memory. These processing levels allow for the identification of information that is considered worthy of further processing (selective attention), the capture and systemization of this information (cognitive attention, rehearsal/ maintenance elaboration), and its dissemination (retrieval/reconstruction). However, the dissemination process is more fully described by the cognitive system. The model also shows how information may be lost along these stages.

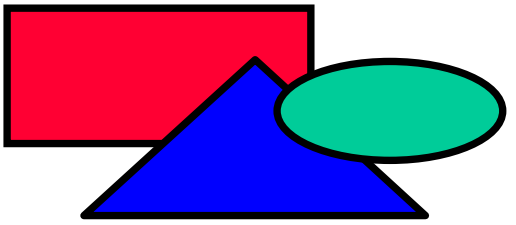

Figure 1: The Human Memory System

The Human Cognitive System

Long-term memory stores both declarative knowledge (facts) and procedural knowledge (how to use those facts). The ACT-R model represents declarative knowledge in schema-like structures or 'chunks' that encode the category and contents of information. Procedural knowledge is represented by productions. Production rules specify the conditions and actions of productions, that is the conditions under which the action will take place and the outcome of the production, which can include creating new declarative knowledge. In the ACT-R model, declarative and procedural knowledge are intimately related. Production rules specify how chunks are transformed and apply only when a rule's conditions are satisfied by the declarative knowledge in memory. Thus, declarative knowledge provides the context in which cognitive processes, as represented by production rules, take place (Anderson, 1983).

The concept of "*spreading activation*" is a key feature of the ACT-R model. Spreading activation is seen as determining the level of activity in long-term memory. This activation must begin somewhere, and the points where activation begins are called "*focus units*." Once focus units are activated, activation spreads through associated

elements, which can be wildly dissimilar; for instance, the word 'bridge' is associated with a structure spanning a river or road, a card game, and a component of a computer network, among many others. Each of these meanings is appropriate in a particular context, and it is through the context that we assign meaning. The evidence suggests that we consider all possible meanings before settling on the one appropriate meaning. Any element's activation is a function of prior experience, the extent to which that element has been useful in the past, and the odds that it will be useful in the current context (Anderson, 1983).

The Human System as a Metaphor for a Knowledge Management System

Just as in the human system sensory registers interface with the external environment, employees function as an organization's sensory registers to its external environment. The first information processing challenge in the human system is that of sorting through the multitude of sensory inputs to identify and select those that warrant further processing. An organization faces a similar problem; each of its employees can be considered as an analogue for an individual sensory modality, and each employee will potentially produce information/knowledge to be processed. While there is not an obvious priority for the processing of input from the human senses, there is a priority in an organization. The probability of significant knowledge is likely higher from the organization's managers and knowledge workers than from employees lower in the hierarchy.

The larger issue, however, is how to sort through all of the potential inputs to identify the important inputs. As a practical matter, only the employee that has had the experience is capable of the initial selection of that knowledge for input into the system. Any potential input not selected at this initial level is eventually lost. Thus, an effective knowledge management system must provide adequate incentives to encourage this reflection and input.

Once input is proposed for the knowledge management system, it must be processed to determine whether and how it should be incorporated into the organizational knowledge base. As in the human system, this can be done in several stages. The early part of this processing could be done by middle management; however, the ultimate decision must rest with reviewers capable of seeing the broad strategic picture.

While the identification, capture, and systemization of knowledge is an essential part of any knowledge management system, it is the sharing of the knowledge that is crucial. Organizations have been developing and refining methods of categorizing and disseminating their knowledge since their inception. Standard operating procedures, company policies, *etc*., are all ways to disseminate knowledge. While these methods may be effective in disseminating templates of procedures, not all knowledge can be templated. How does an employee faced with a situation identify strategies in the organization's knowledge base that can help?

Some companies have adopted a library approach to their knowledge bases. The contents of the knowledge base are catalogued, and indices are developed to assist in finding a specific element of the knowledge base. However, like using a dictionary to find the spelling of an unknown word, the indexing system may not be helpful to all users. It is here that the production-system architecture of the ACT-R model and its use of the concept of spreading activation should prove valuable.

As discussed earlier, in the human cognitive system, nodes of declarative knowledge are linked by procedural knowledge. These linkages provide the context of the knowledge stored. The strength of these linkages is based on either the depth of the processing that occurred when the nodes were stored in long-term memory or the number of times that the specific linkage since has been called upon ('fired'). The stronger the linkage between the nodes, the greater the association between the nodes. Any of these nodes can become a focal unit (the beginning point of a "spread" to associated nodes), simply by the declarative knowledge in that node being fired. An obvious linkage for any element of an organizational knowledge base is its functional area, its knowledge 'silo.' However, while a specific silo can provide access, other linkages will also be appropriate for proper cataloguing. An expansive key word system that catalogues knowledge multi-dimensionally is needed. The comprehensiveness of this multi-dimensional catalogue is analogous to the strength of the linkages in the human system. Access is then a browsing function with appropriate filters to quickly cull inappropriate information. Just as the ACT-R model and spreading activation allow for the identification of the appropriate portions of the human knowledge base with a minimum of cognitive resource expenditure, a corporate knowledge base should be similarly user friendly.

Conclusion

The human cognitive system is proposed as a metaphor for a knowledge management system; it is not intended to provide a model for such a system, rather it provides a cognitive framework from which to analyze the system. As an example, how the human system identifies the important stimulus among all of its competing stimuli is not important, but the need of the organization to address its knowledge identification problem is important. Thus, this cognitive framework does not provide the answers to all of the questions; instead it provides an indication of what the questions ought to be.

References available from the first author and at http://www.cba.uga.edu/~ghiggins/AMCIS_Citations.htm