Learning: Knowledge Representation, Organization, and Acquisition

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Knowledge acquisition is the process of absorbing and storing new information in memory, the success of which is often gauged by how well the information can later be remembered, or retrieved from memory. The process of storing and retrieving new information depends heavily on the representation and organization of this information. Moreover, the utility of knowledge can also be influenced by how the information is structured. For example, a bus schedule can be represented in the form of a map or a timetable. On the one hand, a timetable provides quick and easy access to the arrival time for each bus, but does little for finding where a particular stop is situated. On the other hand, a map provides a detailed picture of each bus stop's location, but cannot efficiently communicate bus schedules. Both forms of representation are useful, but it is important to select the representation most appropriate for the task. Similarly, knowledge acquisition can be improved by considering the purpose and function of the desired information. This article provides an overview of knowledge representation and organization, and offers five guidelines to improve knowledge acquisition and retrieval.

Knowledge Representation and Organization

There are numerous theories of how knowledge is represented and organized in the mind including rule-based production models (Anderson & Lebière, 1998), distributed networks (Rumelhart & McClelland, 1986), and propositional models (Kintsch, 1998). However, these theories are all fundamentally based on the concept of semantic networks. A semantic network

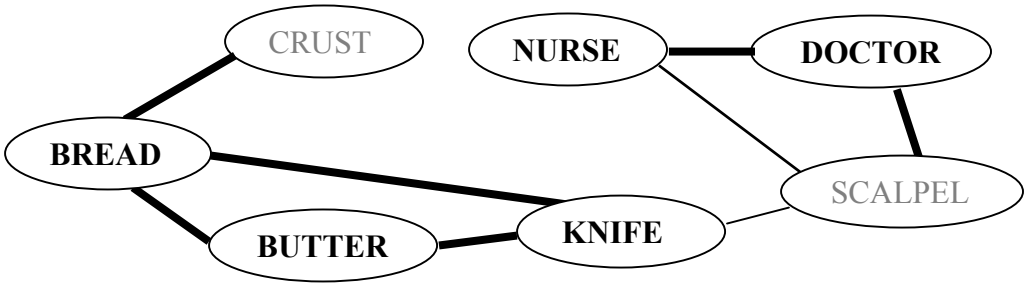

Figure 1: Schematic representation of a semantic network

is a method of representing knowledge as a system of connections between concepts in memory. This section explains the basic assumptions of semantic networks and describes several different types of knowledge.

Semantic Networks

According to semantic network models, knowledge is organized based on meaning, such that semantically related concepts are interconnected. Knowledge networks are typically represented as diagrams of nodes (i.e., concepts) and links (i.e., relations). The nodes and links are given numerical weights to represent their strengths in memory. In Figure 1, the node representing DOCTOR is strongly related to SCALPEL, whereas NURSE is weakly related to SCALPEL. These link strengths are represented here in terms of line width. Similarly, some nodes in Figure 1 are bolded to represent their strength in memory. Concepts such as DOCTOR and BREAD are more memorable because they are more frequently encountered than concepts such as SCALPEL and CRUST.

Mental excitation, or activation, spreads automatically from one concept to another related concept. For example, thinking of BREAD spreads activation to related concepts, such as BUTTER and CRUST. These concepts are primed, and thus more easily recognized or retrieved from memory. For example, in a typical semantic priming study (Meyer &

Schvaneveldt, 1976), a series of words (e.g., BUTTER) and nonwords (e.g., BOTTOR) are presented, and participants determine whether each item is a word. A word is more quickly recognized if it follows a semantically related word. For example, BUTTER is more quickly recognized as a word if BREAD precedes it rather than NURSE. This result supports the assumption that semantically related concepts are more strongly connected than unrelated concepts.

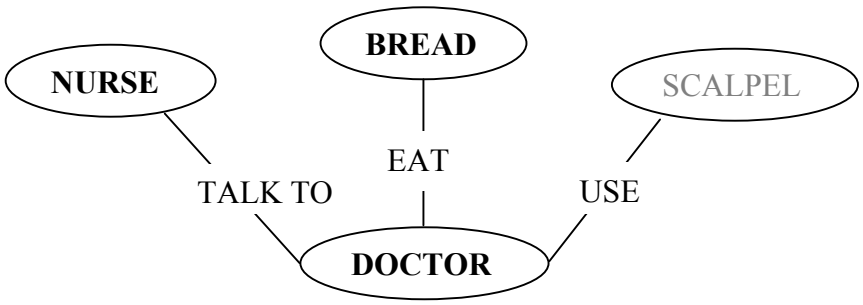

Figure 2: Schematic representation of ideas (propositions) in a semantic network.

Network models represent more than simple associations. They must represent the ideas and complex relationships that comprise knowledge and comprehension. For example, the idea "The doctor uses a scalpel" can be represented as the proposition USE(DOCTOR,SCALPEL) consisting of the nodes DOCTOR and SCALPEL and the link USE (see Figure 2). Educators have successfully used similar diagrams, called concept maps, to communicate important relations and attributes amongst the key concepts of a lesson (Guastello, Beasley, & Sinatra 2000).

Types of Knowledge

There are numerous types of knowledge, but the most important distinction is between declarative and procedural knowledge. Declarative knowledge refers to our memory for concepts, facts, or episodes, whereas procedural knowledge refers to the ability to perform various tasks. Knowledge of how to drive a car, solve a multiplication problem, or throw a football are all forms of procedural knowledge, called procedures or productions. Procedural knowledge may begin as declarative knowledge, but is proceduralized with practice (Anderson, 1982). For example, when first learning to drive a car, you may be told to put the key in the ignition to start the car, which is a declarative statement. However, after starting the car numerous times, this act becomes automatic and is completed with little thought. Indeed, procedural knowledge tends to be accessed automatically and require little attention. It also tends to be more durable (less susceptible to forgetting) than declarative knowledge (Jensen & Healy, 1998).

Knowledge Acquisition

This section describes five guidelines for knowledge acquisition that emerge from how knowledge is represented and organized.

Process the material semantically. Knowledge is organized semantically; therefore, knowledge acquisition is optimized when the learner focuses on the meaning of the new material. Craik and his colleagues were among the first to provide evidence for the importance of semantic processing (Craik & Tulving, 1975). In their studies, participants answered questions concerning target words that varied according to the depth of processing involved. For example, semantic questions (e.g., Would the word fit appropriately in the sentence?: "He met a

____ on the street"? FRIEND vs. TREE) involves a greater depth of processing than phonemic questions (e.g., Does the word rhyme with LATE?: CRATE vs. TREE), which in turn have a greater depth than questions concerning the structure of a word (e.g., Is the word in capital letters?: TREE vs. tree). They found that words processed semantically were better learned than words processed phonemically or structurally. Further studies have confirmed that learning benefits from greater semantic processing of the material.

Process and retrieve information frequently. A second learning principle is to test and retrieve the information numerous times. Retrieving, or self-producing information can be contrasted with simply reading or copying it. Decades of research on a phenomenon called the generation effect has shown that passively studying items by copying or reading them does little for memory in comparison to self-producing, or generating, an item (Slamecka & Graf, 1978). Moreover, learning improves as a function of the number of times information is retrieved. Within an academic situation, this principle points to the need for frequent practice tests, worksheets, or quizzes. In terms of studying, it is also important to break up, or distribute retrieval attempts (Melton, 1967; Glenberg, 1979). Distributed retrieval can include studying or testing items in a random order, with breaks, or on different days. In contrast, repeating information numerous times sequentially involves only a single, retrieval from long-term memory, which does little to improve memory for the information.

Learning and retrieval conditions should be similar. How knowledge is represented is determined by the conditions and context (internal and external) in which it is learned, and this in turn determines how it is retrieved: Information is best retrieved when the conditions of learning and retrieval are the same. This principle has been referred to as encoding specificity (Tulving & Thompson, 1973). For example, in one experiment, participants were shown sentences with an

adjective and a noun printed in capital letters (e.g. The CHIP DIP tasted delicious.) and told that their memory for the nouns would be tested afterward. In the recognition test, participants were shown the noun either with the original adjective (CHIP DIP), a different adjective (SKINNY DIP), or without an adjective (DIP). Noun recognition was better when the original adjective (CHIP) was presented than when no adjective was presented. Moreover, presenting a different adjective (SKINNY) yielded the lowest recognition (Light & Carter-Sobell, 1970). This finding underscores the importance of matching learning and testing conditions.

Encoding specificity is also important in terms of the questions used to test memory or comprehension. Different types of questions tap into different levels of understanding. For example, recalling information involves a different level of understanding, and different mental processes than does recognizing information. Likewise, essay and open-ended questions assess a different level of understanding than do multiple-choice questions (McNamara & Kintsch, 1996). Essay and open-ended questions generally tap into a conceptual or situational understanding of the material, which results from an integration of text-based information and the reader's prior knowledge. In contrast, multiple-choice questions involve recognition processes and typically assess a shallow or text-based understanding. A text-based representation can be impoverished and incomplete because it consists only of concepts and relations within the text. This level of understanding, likely developed by a student preparing for a multiple-choice exam, would be inappropriate preparation for an exam with open-ended or essay questions. Thus, students should benefit by adjusting their study practices according to the expected type of questions. Alternatively, students may benefit from reviewing the material in many different ways, such as recognizing the information, recalling the information, and interpreting the information. These latter processes improve understanding and maximize the probability that the various ways the

material is studied will match the way it is tested. From a teacher's point of view, including different types of questions on worksheets or exams ensures that each student will have an opportunity to convey their understanding of the material.

Connect new information to prior knowledge. Knowledge is interconnected; therefore, new material that is linked to prior knowledge will be better retained. A driving factor in text and discourse comprehension is prior knowledge (Bransford & Johnson, 1972). Skilled readers actively use their prior knowledge during comprehension. Prior knowledge helps the reader to fill in contextual gaps within the text and to develop a better global understanding or situation model of the text. Given that texts rarely (if ever) spell out everything needed for successful comprehension, using prior knowledge to understand text and discourse is critical. Moreover, thinking about what you already know about a topic provides connections in memory to the new information – the more connections that are formed, the more likely the information will be retrievable from memory.

Create cognitive procedures. Procedural knowledge is better retained and more easily accessed. Therefore, one should develop and use cognitive procedures when learning information. Procedures can include short cuts for completing a task (e.g., using "fast 10s" to solve multiplication problems) as well as memory strategies that increase the distinctive meaning of information. Cognitive research has repeatedly demonstrated the benefits of memory strategies, or mnemonics, for enhancing the recall of information. There are numerous types of mnemonics, but one well-known mnemonic is the method of loci. This technique was invented originally for the purpose of memorizing long speeches in the times before luxuries such as paper and pencil were readily available (Yates, 1966). The first task is to imagine and memorize a series of distinct locations along a familiar route, such as a pathway from one campus building

to another. Each topic of a speech (or word in a word list; Crovitz, 1971) can then be pictured in a location along the route. When it comes time to recall the speech or word list, the items are simply "found" by mentally traveling the pathway.

Mnemonics are generally effective because they increase semantic processing of the words (or phrases) and render them more meaningful by linking them to familiar concepts in memory. Mnemonics also provide “ready-made” effective cues for retrieving the information. Another important aspect of mnemonics is that mental imaging is often involved. Images not only render the information more meaningful, but they provide an additional route for "finding" information in memory (e.g., Paivio, 1990). As mentioned earlier, increasing the number of meaningful links to information in memory increases the likelihood it can be retrieved.

Strategies are also an important component of metacognition (Hacker, Dunlosky, & Graesser, 1998). Metacognition is the ability to think about, understand and manage one’s learning. First one must develop an awareness of one's own thought processes. Simply being aware of thought processes increases the likelihood of more effective knowledge construction. Second, the learner must be aware of whether or not comprehension has been successful. Realizing when comprehension has failed is crucial to learning. The final, and most important stage of metacognitive processing is fixing the comprehension problem. The individual must be aware of and use strategies to remedy comprehension and learning difficulties. For successful knowledge acquisition to occur, all three of these processes must occur. Without thinking or worrying about learning, the student cannot realize whether the concepts have been successfully grasped. Without realizing that information has not been understood, the student cannot engage in strategies to remedy the situation. If nothing is done about a comprehension failure, awareness is futile.

Conclusion

Knowledge acquisition is integrally tied to how the mind organizes and represents information. Learning can be enhanced by considering the fundamental properties of human knowledge as well as the ultimate function of the desired information. The most important property is that knowledge is organized semantically; therefore, learning methods should enhance meaningful study of the new information. Learners should also create as many links to the information as possible. In addition, learning methods should be matched to the desired outcome. Just as using a bus timetable to find a bus stop location is ineffective, learning to recognize information will do little good on an essay exam.

2,161 words

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