Third Misconceptions Seminar Proceedings (1993)

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Author: Farrokh, Kaveh

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Keywords: Theories,,,Learning Theory,Concept Formation,Cognitive Mapping,,,
General School Subject:
Specific School Subject:
Students:

Macintosh File Name: Farrokh - Memory
Release Date: 5-14-1994 G, 11-8-1994 I

Publisher: Misconceptions Trust
Publisher Location: Ithaca, NY
Volume Name: The Proceedings of the Third International Seminar on Misconceptions and Educational Strategies in Science and Mathematics
Publication Year: 1993
Conference Date: August 1-4, 1993
Contact Information (correct as of 12-23-2010):
Web: www.mlrg.org
Email: info@mlrg.org

A Correct Reference Format: Author, Paper Title in The Proceedings of the Third International Seminar on Misconceptions and Educational Strategies in Science and Mathematics, Misconceptions Trust: Ithaca, NY (1993).

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A Connectionist Approach to Information Transfer Between Short-Term and Long-Term Memory: Suggestions For Instruction, Counselling and Research

Kaveh Farrokh
Langara College

Based on experiences with Concept Mapping at Langara College, a theory of information transfer between short-term memory (STM) and long-term memory (LTM) is proposed. A neuron-network/mathematical model based on Rummelhart's connectionist theory (1989) is proposed as to identify the process in which elements of LTM encode new incoming information from STM. Information in LTM is viewed in connectionist analogy in which pieces of information are integrated together. Learning is explained via mathematical models presenting changes in connection between incoming STM units and LTM. Relevance (a mathematical/theoretical construct) is proposed as a necessary facilitator for successful integration and accommodation of STM unit(s) by LTM to occur. Each STM information unit must be compatible with its counterpart(s) in LTM in order for successful integration to occur. An STM unit can simultaneously be connected and integrated to descriptive, semantic and declarative memories or episodic memories. More "connections" between the STM unit and different types of memories in LTM increases speed and efficiency of recall. The final section draws a comparison of the theoretical perspective discussed in the paper with the learning process in concept-mapping. The paper ends with suggestions for research, instruction and counselling.

Introduction: Concept-Mapping and the Origin of the Theory

The use of the concept map is the most notable method of depicting the relationship between concepts today (Novak & Gowin, 1984). It shows the hierarchical relationships of ideas by graphically depicting levels of concepts. It also shows the nature of the relationships between ideas through the use of linking words that connect the concepts. Significantly, concept-mapping offers the student a method by which to unify seemingly disparate pieces of information into a unified whole. Students often complain not only about the amount but of the disparate nature of the information that they must learn.

As a result of successful experiences with faculty and students implementing the concept-mapping procedure at Langara College, a theory has been proposed regarding the connection of newly learned information to long-term memory circuits. As presented later in the paper, the word "circuit" has direct relevance to the hypothesis, since it is based on Rummelhart's connectionist theory (Rummelhart, 1989), which itself derives from a Hebbian theoretical basis (Hebb, 1949, 1966). Concept-mapping is a process in which individual concepts are linked together via semantic networks (Novak, 1990a). This process provides the learner the opportunity to engage in meaningful learning.

Significance of Elaboration for Learning

The effectiveness of concept-mapping lies in its ability to encourage the student to elaborate on the information that he/she endeavors to learn. The process of "elaboration" is forcing the learner to take an active part in the construction of the information; a key factor in the formation of LTM.

Research by Begg, Snider, Foley, & Goddard (1989) as well as Mcdaniel, Ryan & Cunningham (1989) has shown that memory for material requiring active construction (generation) on the part of the learner is recalled better in tests. As noted by Begg, Snider, Foley, & Goddard (1989), generating is another way of encoding information.

Here is a process in which the student is required to make linkages between concepts and to draw upon information that already exists in his/her LTM. Bruning (1983) proposes that the use of "appropriate cognitive processing strategies" can help the transfer of information between STM and LTM.

Students develop scientific literacy as they understand the key concepts and their interrelationships, and make an effort to apply these understandings to new situations. This type of learning is meaningful learning, as it requires the learner to relate new ideas to existing conceptual knowledge (Ausubel, 1968; Novak, 1993). This point will be emphasized in the final section (Implications of Theory...concept-mapping). Siefert and Robertson (1985) have found this type of approach to be effective in the reading process. They found in the course of their research (1985) that the more inferences the reader makes during reading, the better retention he/she achieves for that material across time. Also, the inferences that are made tend to become a part of the LTM process.

The Role of Long-Term Memory (LTM) on counselling and Learning: A Theoretical Proposal

Many models have been used to explain the process, contents and anatomy of memory (Morris, 1988). Many of those models are based on the "dual memory model" (see Diagram 1; see Appendix) which assumes that information first enters the STM stage (Atkinson & Shiffrin, 1971). At this stage, memory can be maintained by rehearsal otherwise it is lost to displacement. The next stage of this model consists of the

LTM stage (Atkinson & Shiffrin, 1971). LTM has an almost infinite capacity, but it is vulnerable to retrieval failures (Atkinson & Shiffrin, 1971). In order for information to be encoded into LTM, it must be transferred to that location via the STM (Atkinson & Shiffrin, 1971). This connection between STM and LTM is critical in the successful retention and recall of information. Davis and Squire even speculate on a possible biochemical connection between STM and LTM (1984). The weakness of the dual memory model, however, lies in its failure to theorize on the process by which specific information items in STM are transferred and encoded into LTM. Concept-mapping involves exactly such a process in that new information items (or STM units) are endeavoring to combine with a data base in LTM, which is the person's initial "map" or knowledge of the information.

For the bulk of the students in the workshops, the main issue of interest is how to improve learning and subsequent recall. Concept mapping techniques allow the student to effectively "elaborate" on information, thus helping it to be placed effectively in LTM, and hopefully leading to efficient recall. The more the learner is conscious of the transition of information between STM and LTM, the more effective he/she becomes in sending information to more readily accessible addresses in LTM. As a consequence, information becomes more accessible to recall.

This author suggests a more thorough examination of what actually happens between STM and LTM. As information items are pushed out of STM by new incoming information, they find themselves entering the vast storage capacity of LTM. The more the student or learner can actively "participate" in that transition process, the better the chances of encoding that information onto LTM.

As the information enters LTM, it can be seen as being linked to various "addresses" located in LTM. These addresses can be viewed as past memories that have already been recorded electrochemically onto various neurons. The new memories are then "linked" to those old memories in LTM. Using the perspective of Canadian psychologist, D.O. Hebb, we thus have a new memory being added onto a "reverberating circuit" composed of a set of interlinked memories (Hebb, 1949; 1966). This new "reverberating circuit" now includes the new memory within its system.

Within the reverberating circuits are stored various memories which manifest themselves as:

(A)episodic memory: the memory for personal episodes (Tulving, 1972). Episodic memory holds the record of our experiences in the context in which they occurred (Wingfield, 1979). This includes examples such as remembering the act of learning a calculus formula or what you had for lunch the day before.

(B)semantic memory: this is memory for facts, concepts and propositions (Martin, in press) with no personal tags to the person (Tulving, 1972). Semantic memory contains the general knowledge of the person (Martin, in press). It holds our organized linguistic and conceptual knowledge (Wingfield, 1979). One example of this ability includes the ability to speak languages such as french or English or knowledge of the historical details of the battle of Hastings in 1066.

(C)procedural memory: this is the knowledge of how to do various tasks such as the performance of various types of mental procedures and psychomotor skills (Martin, in Press).

Items B and C have received considerable attention in educational literature with respect to how students actually learn, however episodic memory has received little academic attention in terms of its relevance to the learning process (Tulving, 1983; Martin, in press). Martin (in press) notes that this bias may have to do with the assumption in educational psychology circles that the role of episodic memory is somehow secondary to the role played by other components of the learning process. Estes (1989) even suggests that episodic memory is simply a subset or "stage...component" of the more complex overall learning process. Episodic memory is as much a part of LTM as are other types of memories. There is no sound academic reason for excluding or minimizing its importance in the learning process. Present research at Langara College is finding in the course of its data collection that episodic memory can play an important part in learning, especially if combined with concept-mapping. In a sense, many researchers have treated episodic memory as a construct void of significant impact in the learning and counselling process. Novak (1993) notes however that:

"seeking understanding...is also an affective experience. It involves the pain and anxiety created by the confusion, and the joy and excitement that we experience when we realize that we have acquired new meaning."

As noted previously, the author proposes that memories are stored in Hebbian-type reverberating circuits (Hebb, 1949, 1966). More specifically, the circuits are proposed to be organized along the lines of Rummelhart's connectionist model for the neurons of the human brain (1989). Within the Rummelhart system seven major components of a connectionist system (1989) are outlined:

1) a set of processing units: These can be likened to neurons in the brain which are responsible for sending and receiving information. Rummelhart also identifies a set of "hidden" units whose only inputs and outputs are within the system.

2)a state of activation defined over the processing units: This represents the energy state of the system at any given time (t). The activation values are given discrete and binary values, where 1 represents the unit as active and 0 is taken to mean that the unit is inactive. The vector a(t) represents the pattern of activation over the set of processing units.

3)an output function for each unit that maps its state of activation into an output: The units interact with other units by sending signals to their neighbors. The degree of activation of the unit will dictate the power of their signals, which in turn affects the degree to which they affect their neighbors. The more powerful the signal emanating from the neuron(s) the likelier that a "circuit" or system will be activated. When a neuron from an episodic memory pattern (see 4) is activated, the chances of it activating the whole system is dictated by the power it emanates to its "neighbors" which may be in the same brain region, or even dispersed and located in totally different zones.

4)a pattern of connectivity among units: Units are connected together in patterns, much like the way Hebb described them (Hebb, 1949, 1966). This pattern of connectivity constitutes the knowledge of the system and determines how it will respond to any arbitrary input. There is research evidence indicating a specific overall pattern of activation for episodic memory. Each type of memory may be represented by specific neuron(s) or clusters of neurons which are connected to each other in the brain centers. Mathematically the pattern of connectivity is represented by the matrix W in which wij identifies the power and sense of the connection from unit uj to unit ui. The overall value of wij is positive if unit uj succeeds in exciting ui; it is negative if uj inhibits ui and 0 if no connection exists between uj and ui. The absolute value of wij shows the strength of the connection.

5)an activation rule: A mathematical model is proposed which states that the inputs impinging on a particular unit combine together, along with the units own activation state to produce a new state of activation. The function F, which takes a(t) and the net inputs, neti=$\sum$ iwijoj(t) produces a new state of activation. More simply we can state that when F is the identity function, a(t+1)=Wo(t)=net(t).

6)a learning rule whereby patterns of connectivity are modified by experience. The paper goes into this aspect in considerable detail shortly.

7)an environment within which the connectionist model-system operates in: At any point in time, there is the probability that any of the possible set of inputs is bearing down on the input units. The function of the probability depends on the history of inputs to the systems well as the output of the system itself. Importantly, the environment is characterized by input patterns which are independent of past inputs and past responses of the system. The set of possible inputs to the system can be listed from 1 to M. The environment is thus characterized by a set of probabilities pi for i=1,...,M. Each input pattern is considered in vector form. As seen later, this has direct impact on the way this proposal examines the relationship between incoming units of information from STM and LTM circuits. On a more practical level, the environment can be seen as the instructional or counselling setting in which the learning is occurring.

According to the above theory, if you have uj and ui as being both active, then the actual "weight" of the connection (wij) is given strength. Given that:

oi(t) = output signal
ai(t) = the activation value of the unit

ti(t) = teaching input into ui
wij = strength of the connection

then the change in connection strength is denoted by:

δ wij = g(ai(t),ti(t)) h(oj(t),wij)

Note that the change in connection between uj and ui is given by the product of the function g() of the activation of ui and its teaching input ti and another function h() of output value uj and the connection strength wij. Later we will simply substitute an incoming unit of information in STM for uj and the LTM as ui.

In the simplest versions of Hebbian theory however, there is no teacher and the functions g() and h() are simply proportional to their first arguments. Therefore we have:

δ wij = e aioj

e simply represents a constant that represents the learning rate. Rummelhart (1989) then expands h() and g() into the Window-Hoff rule or the delta rule which simply states that the amount of learning is proportional to the actual activation achieved and the target activation provided by the teacher.

Before applying these principles to STM and LTM learning, the concept of LTM needs to be defined. Each type of LTM, be it episodic, semantic, etc is viewed as being composed of several discrete and interdependent parts. As a result:

$$\text{ULTM} = \int_1^N (ui1 + ui2 + ui3 + \ldots uiN)dt$$

Note that the term "dt" simply means that LTM formation is contingent on the element of time. LTM is composed of several units (ui) which are interconnected, however each type of LTM is viewed as having its own type or "character" in terms of the way those units are connected to one another. As noted earlier, Rummelhart denotes this as the "pattern of connectivity" between the units and that pattern not only represents the knowledge of the system but the way it will respond to any "outside" input. Outside in this case is simply any unit that is not an integral part of the LTM system. More specifically, it is the incoming information from STM which originates from an instructional or counselling environment. Given that:

ULTM = the LTM system consisting of ui1 to uiN
uSTM = the incoming information from STM

then the change in connection between ULTM and uSTM is given by:

δ wLTM STM = g(aLTM(t), tLTM(t)) h(oSTM(t), wLTM STM)

The item of information in STM does not simply stay connected to LTM on the outside for this reason:

STM is temporary in that items of information inside of it are continuously displaced, therefore the information inside of it must go "somewhere". That somewhere either:

A)fails to integrate to existing LTM networks and the STM trace is permanently "lost"

B)becomes attached to networks inside LTM

Situation B will occur if the connection between STM and LTM has "relevance". For relevance to exist this situation must hold:

δ wLTM STM

Relevance simply means that the connection between STM and LTM must be relevant or compatible. For example, if a physics instructor talks about the concept of inertia, the student will find the information located in his/her STM. In order for that information to be encoded successfully, a link must be found to a compatible LTM circuit. In this case, the student may mobilize his/her episodic memory with respect to childhood memories with respect to his/her father's car. The student recalls being pushed back into the seat as soon as his/her father started the car and drove forward. The motor sensation of being jolted from a resting position and being thrust to the seat is a relevant memory in that it serves as an example to the concept of inertia. The item of information in LTM (episodic) in "relevant" to its counterpart in STM. Successful learning in this scenario is one in which the student has successfully integrated the new information (the theory of inertia) to the relevant information in LTM (episodic memory of daddy's car). The new information coming from STM has become successfully integrated into LTM, therefore:

Given relevance between STM and LTM or ∂ ULTM STM

then U'LTM $= \int (ui1 + ui2 + ui3 + ... uiN + uSTM)dt$

uSTM is the unit of information that originated in STM and has now been integrated into and made a part of the LTM circuit.

Integration means that the memory has become integrated into the previous ULTM circuit. In a sense, ULTM has "accommodated" USTM, thereby incorporating or "integrating" it into itself. The product of this is a new version of ULTM which is U'LTM. The identity of the memory is still the same, however it is different from before since it has made new connections with a new piece of information that it has integrated into itself. The city of Vancouver in British Columbia, Canada can provide an example of this concept. Vancouver's racial and ethnic population in the past thirty years has changed from a white majority to one that is increasingly ethnic as a result of increased immigration from non-European countries. Although the ethnic/racial composition of the city has changed, the name of the city is still Vancouver; same as it was thirty years ago. However, the city is different in that it has accommodated and integrated people of different ethnic/racial backgrounds into itself. In the inertia example for physics, the student has integrated the theoretical concept with his/her own episodic memory which focused on his/her father's car. The episodic memory circuit is still composed of his/her father's car, however it is different from before in that it has integrated a theoretical understanding of the concept of inertia. The "new" episodic memory is composed of the car's motions and classroom experience of the theoretical understanding of inertia.

At this stage, it is important to emphasize Rummelhart's concept of a pattern of connectivity between units. LTM circuits each have their own pattern of connectivity amongst their individual units. These patterns are changed and modified by personal experience. In order for the incoming STM unit to successfully integrate with the LTM circuit, it must become integrated into its pattern of connections. It is proposed that in order for the STM to be strongly connected to the LTM circuit, it must:

1)become linked to as many units in the LTM as possible

2)establish strong links with those units with which connection is established.

As noted earlier in this section, relevance must exist in order for an STM unit to successfully integrate with its compatible LTM circuit. This means that various types of LTM memories exist (i.e episodic, semantic, procedural) that are compatible with various types of incoming STM's. For successful learning to occur, the learner must:

(1) be aware of the nature of his/her memories in LTM, and
(2) be aware of the necessity to mobilize the appropriate LTM circuits during learning when confronting incoming units of information from STM.

Learners can be made aware of point (1) via the concept of metamemory or more simply, the process in which the learner reflects on his/her thinking process (Brown et al., 1983; Flavell, 1981). Andreassen and Waters (1989) discovered that the more students actually thought about their memory (a process called MetaMemory), the better their chances of improving their study skills strategies, which in turn leads to better marks. They also found positive relationships between metamemory and the use of organization during study. Point (2) seems to be more related to the concept of metacognition which is not only the knowledge of one's cognitive processes but also of one's abilities to control those processes (Weinstein, 1987).

Before concluding this section, it is necessary to consider various other ramifications of this theory with respect to these areas: (1)the linkage of LTM systems, (2)conditions of negative transfer of information (3)distinction between facts and concepts.

(1) The Linkage of Long-Term Memory Systems

Having considered the entry of STM information pieces and its subsequent accommodation and integration into LTM, it is vital to define the STM's category of membership in the LTM circuit. "Membership" means where the STM is actually "belongs". For example a person may be born in Athens, Greece yet be a Canadian citizen and be living in Canada. However, the person can be holding dual citizenship; Greek and Canadian. Likewise, by using Hebb's analogy of "cell assemblies" (Hebb,1947, 1966) recently accommodated STM units can be shared between different LTM circuits (see Figure 2a and 2b; see Appendix). As an STM information unit has entered LTM it may not simply get linked to one LTM system, but become linked to various other links as well (see Figure 2a and 2b). As seen in the diagrams, various LTM circuits may be interlinked by way of sharing certain "memories". A certain STM unit may become linked to cell assembly A, however it also has become linked, albeit indirectly, to cell assemblies B and C. This means that an STM unit that is linked to an episodic memory (recall physics example on inertia) may also become indirectly linked to procedural or semantic memories as well. It may also be possible for an STM unit to be linked in locations in which it is "simultaneously" a member of circuits A,B and C (see Diagram 2a and 2b; see Appendix). In an actual learning situation, the more control or "awareness" the learner has, the better he or she is able to "steer" the STM units towards the "appropriate" cell assemblies.

Another point of view may be a neuro-biological one. Each neuron corresponding to a particular memory can be linked by countless other connections to other neurons. Various neurons are linked together in "systems", yet each neuron can be member of a number of systems.

(2)Conditions of Negative Transfer

Another way of defining this is old learning interfering with new learning. So far, we have discussed situations in which old learning can help facilitate new learning. In reality, many learning situations involve negative transfer which results in impaired learning efficiency (Wingfield, 1979).

When learning languages, especially those belonging to the same family group (i.e Germanic, Slavic, Italic, Iranian, Hamito- Semitic, etc) there are strong possibilities of negative transfer occurring in the learning of vocabulary. English for example, is a member of the Germanic languages; however as in all language groups in the Indo-European family a great deal of consonet-pronounciation shifts and vocabulary changes take place with each linguistic rule over time (Renfrew, 1987). Each word or concept in one language can actually interfere with the learning of its counterpart in another language. This is interesting in lieu of the fact that we have a semantic type memory (the English language) interfering with one's ability to absorb and create a new language data base (a new "semantic memory" for French). This raises the interesting question of whether there is an "innate" response in terms of a need to assimilate new incoming STM information into existing LTM circuits. Discussion of this possibility is beyond the scope of this paper, and more research needs to be done over this topic.

(3)distinction between facts and concepts

As Wingfield notes in Human Learning and Memory (1979), concepts are far easier to recognize than to define. Wingfield (1979) further states:

Concepts involve abstractions; the appreciation of relationships between stimuli which give rise to *generalizations free of the specific stimuli from which they were derived...the actual process of abstraction and generalization...comes almost entirely from within the individual...*

Of course, some concepts can be more easily defined than others, such as mathematical concepts (sets, whole numbers, etc). Wingfield further states that facts are teachable whereas, concept learning is entirely "internal" (1979). Concept-mapping is a tool which facilitates that internal learning process. Little research, however, has been done on what actually occurs in the learning process via concept-mapping. The following section endeavors to provide a brief explanation based on the theories and mathematical concepts discussed earlier.

Implications of the Theory on the Efficacy of Concept-Mapping: A Perspective

The power of concept-mapping lies in its ability to synthesize a large amount of key concepts into a unified conceptual gestalt. As noted previously, linkages between concepts are cemented by way of prepositional links. The Rummelhart-Hebbian analogy of the relationship between STM and LTM may provide a theoretical explanation of why concept-mapping actually works.

Concept maps actually "evolve" from simpler formats into more complex ones as more learning takes place (Ault, 1985; Novak, 1990a; Novak, 1990b; Wallace & Mintzes, 1990). This is a direct consequence of the addition of more concepts and prepositional links and their integration into the existing conceptual map. In a sense, it can be said that the existing conceptual map is located in the person's LTM. The new pieces of information, in this case concepts and prepositional links, can be likened to STM units which are coming in to be linked to the conceptual map. The conceptual map can be seen as a LTM, however it's difficult to classify it strictly as episodic, semantic or otherwise. As noted in "The Linkage of LTM systems", many memories are themselves combinations of various types of memories, and the concept map is no exception. A typical concept map is able to integrate a wide variety of information. Mathematically this process can be described as such:

Each concept on the concept map can be described as uic, where uic1 to uicN represents the range of concepts existing in the concept map. If ULTM(CONCEPT MAP) represents the memory representation of the concept map in the person's LTM, then:

$$\text{ULTM(CONCEPT MAP)} = \int_{1}^{N} (uic1 + uic2 + uic3 + \ldots uicN)dt$$

A new concept that is relevant to the existing concept map and is entering via the STM is represented by:

uSTM (NEW CONCEPT) = the incoming information from STM

In order for a connection to exist between ULTM(CONCEPT MAP) and uSTM (NEW CONCEPT), relevance between the two must exist in order for the possibility of a linkage between the two to occur:

δ wLTM(CONCEPT MAP) STM(NEW CONCEPT)

As a result of this, the change in connection between ULTM and uSTM is given by:

δ wLTM (CONCEPT MAP) STM (NEW CONCEPT) = g(aLTM(concept map)(t), tLTM(concept map)(t)) h(oSTM (NEW CONCEPT) (t), wLTM(CONCEPT MAP) STM(NEW CONCEPT))

The integration of the STM unit in this case is as thus:

U'LTM(CONCEPT MAP)= $\int$ (uic1 + uic2 + uic3 + ... uicN + uSTM(NEW CONCEPT))dt

The U'LTM(CONCEPT MAP) is simply the "new" concept map with the new concept that has been integrated into it.

A subtle but important point must be made with respect to U'LTM(CONCEPT MAP). This concerns the issue of relevance (δwLTM(CONCEPT MAP) STM(NEW CONCEPT)) which is in danger of being viewed in simplistic terms in this presentation. It would seem as if the new concept (uSTM (NEW CONCEPT)) is making a singular connection to all of the memory unit, or concept-map, in LTM. In reality, by "integrating" into the existing concept map (ULTM(CONCEPT MAP)), the new concept (uSTM (NEW CONCEPT)) is making specific links to specific parts, or concepts, of the concept map. Integration is correct in the overall sense in which the new concept has become a part of the old concept map (ULTM(CONCEPT MAP)) resulting in essentially the same but improved concept map (U'LTM(CONCEPT MAP)).

Concept-mapping allows the student to view information as a whole body in which concepts are interlinked in a unified network. With concept-mapping the student has the opportunity to integrate information into a gestalt and awareness of such a gestalt allows new, but related concepts (relevance or change with respect to the CONCEPT MAP as a result of the NEW CONCEPT assimilation) to be accommodated and integrated into itself.

Conclusions: Implications for Instruction, Research and Counselling

This paper has endeavored to theorize on the connection between STM and LTM as related to concept-mapping. At Langara College, concept-mapping is viewed as a tool for student success. The mathematical theorizing based on Hebb (1947, 1966) and Rummelhart (1989) along with experiences in Langara college in Vancouver, have led to these recommendations:

1)Emphasize the technical role of memory in study skills workshops

In order to help improve students study habits, it is essential to make them reflect on their own memory and learning processes or metamemory. In a research study, Andreasson and Waters (1989) found that study strategy awareness initially arises after reflecting on one's own strategic behavior. They also found positive relationships between metamemory and the use of organization during study. Metamory can be expanded to include more specific contents such as the role of episodic memory.

2)Provide students with the option of using concept-maps to facilitate their learning

Counsellors and instructors concerned with improving students memory acquisition are in need of innovative techniques to enhance student success. The concept map allows the student to map out and identify the relationship between concepts (Novak & Gowin, 1984), and shows the nature of those relationships through the use of linking words. According to connectionist analogy, LTM circuits seem to operate in an integrated fashion where groups or units of information are linked together to form cohesive units. Each memory can represent a concept, however it can also be a compilation of many smaller individual concepts. For the student to understand the nature of his/her memory with respect to learning, he/she needs to view information as being integrated into a whole and simultaneously being composed of several discrete parts. Those discrete parts can also be linked together. Concept mapping is consistent with this view of memory function because it allows the student to map out the relationships between the concepts, elaborate on the connections between them and to see all of the information as an integrated whole. As a result, concept mapping leads students away from rote-learning strategies and leads them toward the true understanding of concepts and how they relate to each other (Ault, 1985), a key factor to successful learning, retention and recall. As Ault (1985) notes in his paper "Concept Mapping as a Study Strategy in Earth Science", each concept depends upon its relationships to many others for meaning. The efficacy of "conceptual mapping" as a way of reviewing or learning maths, sciences and humanities has already been demonstrated in numerous research studies (Ault, 1985; Novak, 1990; Alvarez, 1987; Weinstein, 1987; Jegede, Alaiyemola and Okebukola, 1990). However, students still seem to be learning in rote-learning methods that don't emphasize the integration of concepts. Concept-mapping provides the student with a tool in which he/she can engage in the meaningful learning of concepts.

3)Researchers need to examine the specific nature of the encoding process between STM and LTM

By the "specific nature" we are emphasizing the role specific STM units with respect to specific LTM circuits. Such an endeavor may mean more collaboration between researchers in education and the fields of brain physiology. In the case of the amygdala and hippocampus, physiological studies of the brain have shown that they play important roles in learning and memory (Restak, 1984). Mishkin and Ungerleiter state that each memory has an indirect pathway to both the amygdala and the hippocampus (Restak, 1984). Put simplistically, the hippocampus seems to play an important role in simple recall whereas the amygdala seems implicated in the re-arrangement of memory images (Restak, 1984). Apart from the amygdala and hippocampus, equal consideration must be given to each brain component in the formation of each memory. In the case of episodic memory, Mishkin (1985) notes that it is represented in the brain via a temporal lobe-hippocampal-mammilary body-frontal lobe circuit (Mishkin, 1985).

Findings such as those stated above may prove useful to education researchers endeavoring to develop tools facilitating student success. The works cited by Restak (1984) for example are interesting in that the system for straight recall is not necessarily the same as that implicated in the re-arrangement of memory images. In fields such as biology in which memory images are important (i.e recall of the cell's structure) exercises which simply emphasize rote recall may be inadequate in that they fail to allow the student to manipulate the more "visual" aspects of the information (i.e the cell structure or the metabolism of insulin). Tools such as concept-mapping or computer assisted instruction allow learners access to more "multi-media-like" tools to learning in which more aspects of their cognition are allowed to be mobilized in order to facilitate learning.

4)More research is needed to examine how the process of concept-mapping actually allows information to be stored in LTM

As noted in the introductory sections, a great deal of research exists in the field of long-term and short-term memory as well as implications of these studies to education. However, despite the great deal of literature available showing the efficacy of concept-mapping (Ault, 1985; Novak, 1990; Alvarez, 1987; Weinstein, 1987; Jegede, Alaiyemola and Okebukola, 1990), research into the mechanics of how concept-mapping affects LTM may illuminate new findings useful to education. Such findings may allow educators to add new innovations to concept-mapping itself. This paper has attempted to provide a conceptual definition of what actually "happens" in concept-mapping. This is a field that is clearly open to empirical inquiry by researchers in education and other related fields.

5)Instructors can use concept-mapping in order to improve the quality of instruction

The organized and integrated presentation of information by instructors can be of immense help to students. Research findings by researchers such as Schmid and Telaro (1990) as well as Kackman, Moellenberg and Brabson (1990) have demonstrated the efficacy of concept-mapping as a tool of instruction. As noted in this paper, the more integrated and linked the information pieces are, the better chances they have of being recalled. As a result, students will have the opportunity to see key concepts in context as opposed to unrelated discrete parts.

6)Counsellors need to be made aware of the importance of episodic memory in counselling as well as its relationship to other types of memories

Earlier in the paper, the role of all types of memory were emphasized (i.e semantic, procedural and episodic). Apart from instruction and learning, counselling also deals heavily with episodic memory, a point which Martin (in Press) has drawn attention to. The theorizing engaged in this paper concludes that episodic memory itself can be linked (directly or indirectly) to other types of memories. This perspective can help illuminate more dimensions in counselling sessions.

7)Emphasize the multifaceted nature of learning and memory to students, instructors and counsellors

One final implication of the theorizing of this paper is the multifaceted nature of learning. Some cognitive strategies used by students are algorithmic in nature, which means that they have one right way of being implemented (Weinstein, 1987). The problem is that they end up using a "standard" method of trying to solve all types of different problems in study situations and exams. We can't teach students the exact way to solve any problem that they encounter, but we can teach them general guidelines that can help to maximize the search for an optimal problem solution (Weinstein, 1987). Problem-solving inevitably engages memory and memory is itself multifaceted. Successful learning and problem-solving must be strategic in that they accommodate the multifaceted nature of the memory system.

Finally, the understanding of the multifaceted nature of memory can be of immense help to counsellors by allowing them to view the complex nature of their clients' issues.

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APPENDIX: DIAGRAMS 1-2b

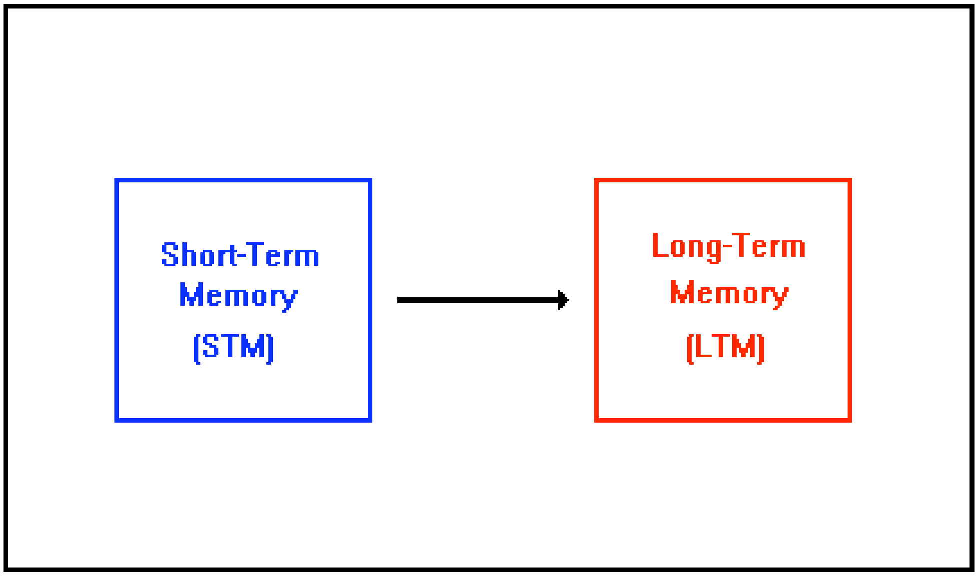

Diagram 1

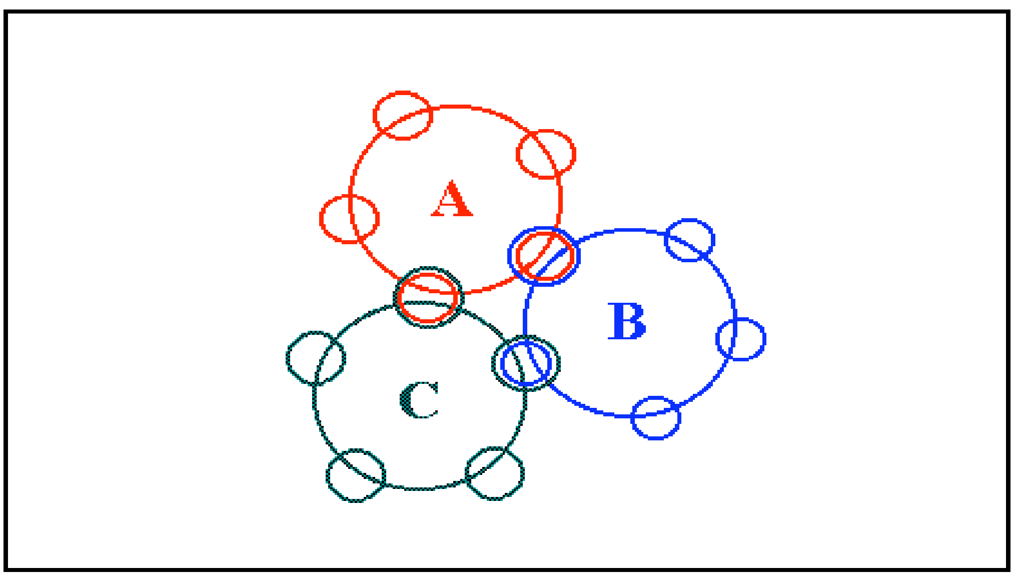

Diagram 2a

APPENDIX (Continued...)

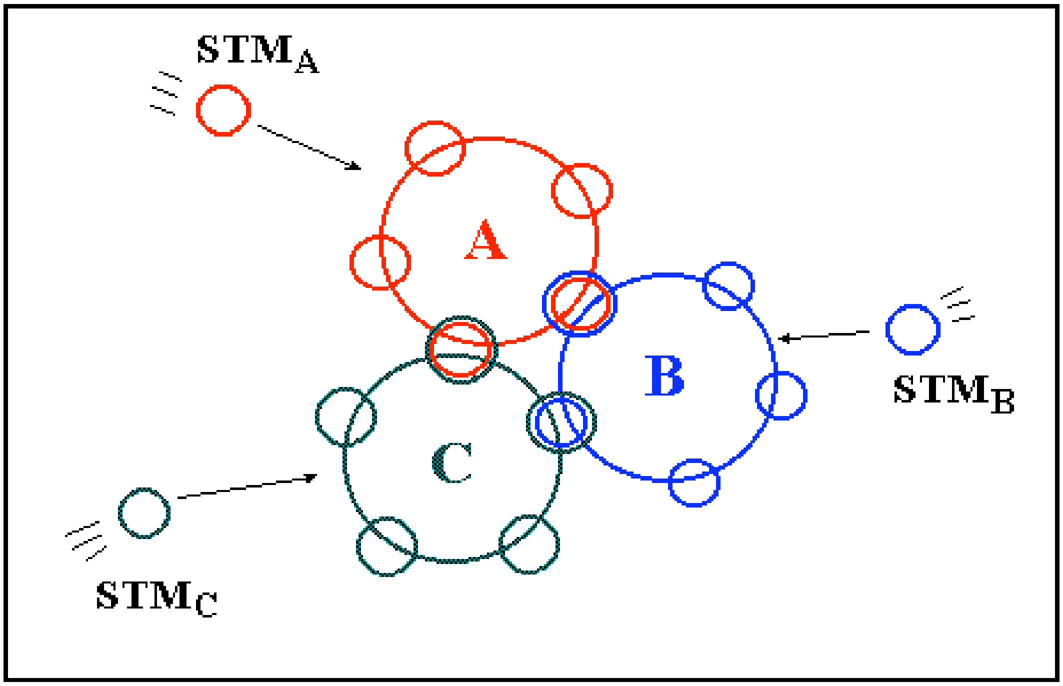

Diagram 2b