Med Educ Online [serial online] 1999;1,1. Available . from URL http://www.Med-Ed-Online.org

The Multidimensional Learning Model: A Novel Cognitive Psychology-Based Model for Computer Assisted Instruction in Order to Improve Learning in Medical Students.

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Abstract **-** In the recent years there has been a huge increase in the amount of information needed to be understood and memorized by medical students. Many authors have advocated the need for utilizing cognitive psychology strategies to allow students learn the expanding medical information in a more effective and efficient manner. The present paper describes a novel and interactive method for teaching and learning (the Multidimensional Learning Model) that allows the students to 'think' to generate the information. The model integrates different memory strategies to facilitate the learning process and is heavily dependent on illustrations and graphics. Furthermore, the model is potentially suitable for designing Computer Assisted Instruction. A pilot study was performed on the model and the preliminary results are promising.

One of the commonly observed problems in medical education is the explosion of medical information. As an attempt to solve this problem most of the publishers and medical authors decrease the size of the print or increase the number of pages of the texts. At the same time respected medical educationalists point out that cognitive psychology studies are running parallel to medical education, and they have advocated merging of the two disciplines.[1] Such a merge can allow utilization of memory strategies in medical education so that the students understand the information and retain it in a more efficient manner.

Another observed problem in medical education is the lack of good instructional design for Computer Assisted Instruction (CAI). Friedman[2] mentioned that "putting hundreds of X-rays, pathology slides, or electrocardiograms on the WWW is not the same as developing high-quality, interactive teaching material". The same author points out that most of WWW-based teaching programs simply transfer factual material, like other textbooks or lectures do, and he advocated the need for interactive programs to utilize the enormous potentials of the WWW in teaching medicine.

The aim of this article is to describe a novel model for teaching and learning that allows utilization of different memory strategies in medical education and provides a suitable design for CAI. The model was originally developed by the present author as Tarek's Integrated System for Learning and Memory (TISLM) and is now called the Multidimensional Learning Model (MDLM)[3].

Memory Background

Studies in the process of learning and memory showed that the following mechanisms could enhance understanding and recall of the data:

- the generation effect
- the spreading activation model
- the use of pictures

The generation effect **-** Generation refers to the fact that when an individual generates an item, it is better recalled than when it is merely read. The empirical finding of the generation effect is not in question.[4]

The spreading activation model **-** This model assumes that stored knowledge is best thought of as a network of multiple interconnected and related data wherein processing of an item leads to activation of other related items (Figure 1). Activation process tends to spread in all directions to activate the related information. An activated item is recalled, retrieved, recognized, judged, and evaluated better than an inactivated one.[5]

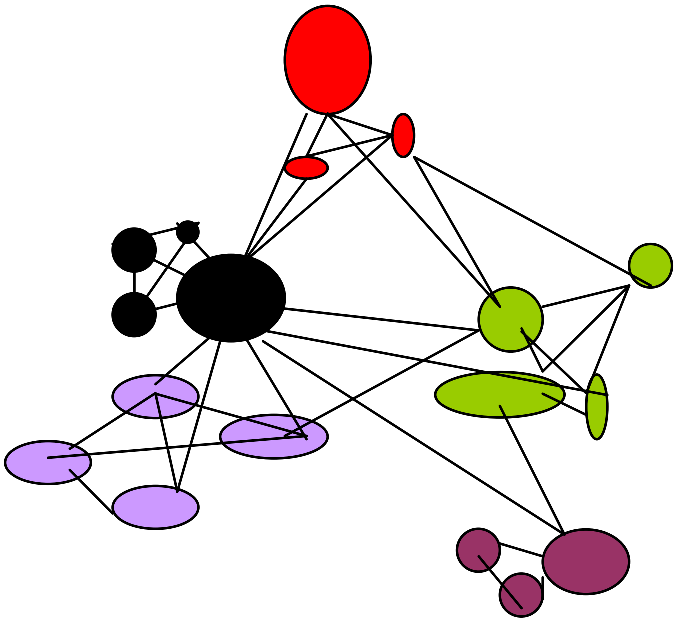

Figure 1 According to the spreading activation model the information (represented by circles) are memorized as a network of interrelated data. Once an item is processed, activation process spreads in all directions to activate other related items.

The use of pictures - Research in the field of memory and learning has also indicated that the use of pictorial images can aid the learning process better than verbal description can. Memorization of the images can be further enhanced by presenting the data in a single visual image and by using high imagery-value items (easy to imagine)

Other factors that play a role in our memory include:

The separate store model - According to this model, sensory stimuli e.g. visual or auditory will be lost from our memory immediately unless *attention* was given to that stimulus. Attention seems to be necessary to shift the information from the sensory register to our short-term memory stores (STM). Information tends to be lost from these STM unless rehearsed within the next 30 seconds (Figure 2). This rehearsal process seems to be necessary to shift the data from the STM to the long-term memory (LTM) or in other words to our permanent memory. Re-

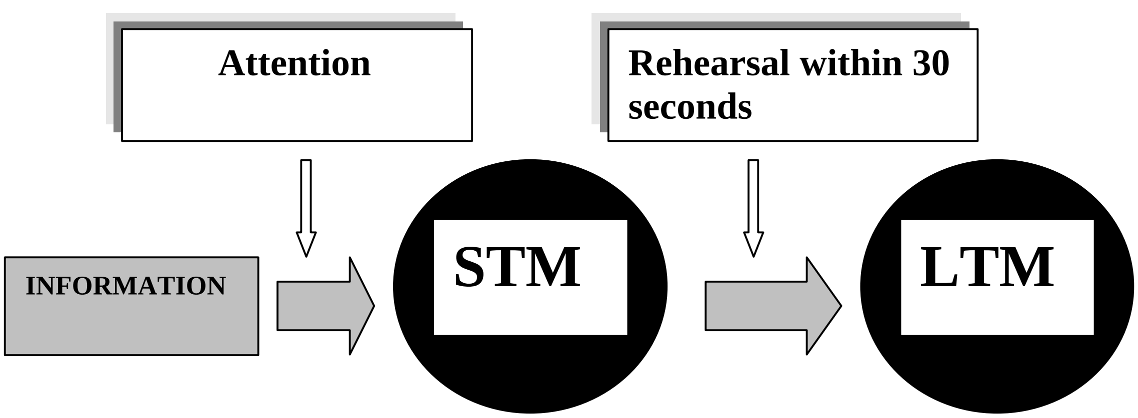

Figure 2 The separate store model for memory. Attention is needed to shift the information to Short Term Memory (STM) and rehearsal of the information within 30 seconds is important to shift it to the Long Term Memory (LTM).

hearsal could be intentional or unintentional, overt or covert, voluntary or involuntary.

Level of processing approach **-** Another memory model, 'the levels-of-processing approach', challenges the entire notion of the separate stores and argues that the durability of a memory trace is essentially determined by the "depth" to which it is processed. Accordingly, attending to the "physical" properties of an item (what it looks like) leads to shallow form of processing, attending to the "acoustic" properties of an item (what it sounds like) will lead to relatively deeper form of processing, while attending to the meaning of an item will lead to the deepest and he most durable form of processing the "semantic level of processing" (Figure 3).

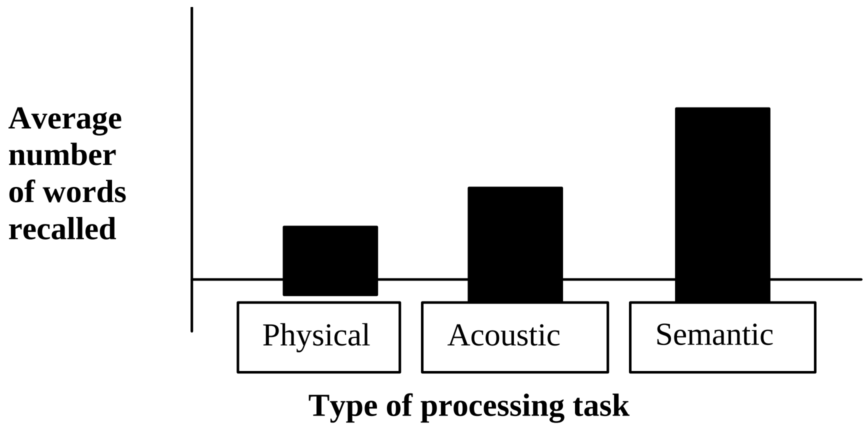

Figure 3 According to the level of processing approach the semantic (meaningful) coding of information provides the deepest form of processing.

Story-like presentation **-** Studies in cognitive psychology have also indicated that presenting the to be remembered information as a story is far superior in terms of learning and memory than presenting the same information in a random manner.[4] In the story like-presentation, each sentence refers to something in a previous sentence and adds something new.

Acoustic coding and memory **-** Early studies in memory had indicated that "acoustic coding" is involved essentially in STM while semantic coding is involved in LTM. However, more recent evidence indicates that acoustic coding is involved in LTM as well. Furthermore, acoustic coding was also shown to be more involved in encoding the data that are presented 'sequentially' or distributed in time, while visual memory is more involved in data that are distributed in space.[4]

A Brief Description of the Model

The MDLM presents the information visually as a logical sequence of events, one following the other, until the whole subject is created as a network of interrelated data in a single visual image. Highly memorable illustrations and graphics are used to enhance the recalling process. In order to follow this, a simplified example of some aspects of the model is presented in Figure 4 (please follow the steps from 1-11)*.

In real teaching the visual presentation of the steps appears if the students generate the data. Generation of the data is usually directed by guiding questions until the whole picture is created. To make it clearer, in the previous example, instead of telling the students that serum calcium is high in hyperparathyroidism, the students are usually asked: *what do you expect serum calcium will be if serum PTH is high?* If the answer was high, the correct answer, the image of the answer immediately appears on the page. If the answer was incorrect, more information is given to the students to help them generate it. Finally, if the students fail to generate the answer, the tutor explains it and records it visually on the page.

Furthermore, some concepts from the network are linked and applied to other related con-

* Figure 4 is an executable program. It can either be run via a hyperlink if you are reading this document in your browser or you can download the file.

cepts in other networks. For example, the bone abnormality in the given illustration is correlated with and compared to other bone abnormalities such as osteoporosis and osteomalacia so that all of these networks become linked together.

The students are also asked to color the items once they are recorded on the summative page (a copy of the whole summative page is usually given to them before teaching). It is important to note that Figure 4 does not show the questions that lead to neither generation of the answers nor the application of the concepts in other diseases (outward spread of the spreading activation model).

A Pilot Study

In 1996, a pilot study was performed at the University of Auckland, School of Medicine and Health Science to study the potential effectiveness of the model.[3] Volunteer medical students were divided into two groups. The model was used to teach them endocrinology and nephrology. The first group (11 students) studied endocrinology in the first semester and nephrology in the second one (E1N2 group), while the other group (7 students) studied the same subjects but in the opposite order (N1E2 group).

The model was used in tutorials presented to the students in both the lunchtime and the evening after the end of the normal teaching in the medical school. Approximately one third of the subjects were omitted from the teaching but were tested to detect external acquisition of knowledge from other sources e.g. clinical rounds, personal reading, and others.

A pretest and posttest after the first and second semesters were used to evaluate the model. Forty true and false type questions (each consisting of 5 items to answer) were used in all the tests. An additional forty multiple matching type questions were used only in the posttests. The questions were evaluated by 3 different consultants in the taught areas and were considered to be appropriate for the purpose of the study.

The student's provided feedback on the instruction via a questionnaire including free field comments. A psychometrician at the medical school analyzed the data.

The results of this pilot study showed that the students' academic performance was significantly increased in the areas covered by the MDLM while there was no significant improvement in the areas not covered by the model. Furthermore, the students strongly preferred this model to their medical school teaching (traditional teaching).

The results of the true and false type questions are shown in table 1 (the results of the multiple matching questions also showed the same pattern of improvement).[3]

Table 1

	Question area	Pretest score(%) (April)	Posttest 1 score(%) (July)	Posttest 2 score(%) (October)
E1N2 (n=11)	Endocrinology **covered** by MDLM	34.2 (14.7)	80.0 (9.1)	74.7 (14.1)
	Endocrinology **not** covered by MDLM	41.7 (10.2)	41.0 (16.7)	39.3 (14.1)
	Nephrology **covered** by MDLM	49.9 (13.2)	37.1 (18.3)	73.7 (9.4)
	Nephrology **not** covered by MDLM	32.9 (17.2)	24.6 (20.1)	29.2 (14.9)
N1E2 (n=7)	Nephrology **covered** by MDLM	40.5 (14.4)	77.9 (8.1)	68.1 (10.4)
	Nephrology **not** covered by MDLM	26.7 (11.7)	20.8 (17.2)	25.0 (15.5)
	Endocrinology **covered** by MDLM	32.4 (12.6)	30.8 (9.6)	74.1 (11.7)
	Endocrinology **not** covered by MDLM	39.6 (14.7)	38.1 (9.3)	33.8 (8.7)

Table 1: Mean percentage scores for students after using the MDLM to teach endocrinology and nephrology. Approximately one third of the material was not covered by the model to test for external acquisition of knowledge. The standard deviations are shown in the brackets.

Discussion

Analysis of different components of the model can show us that it allows the students to recall the information in 4 different dimensions at the same time as seen in Figure 5 below.

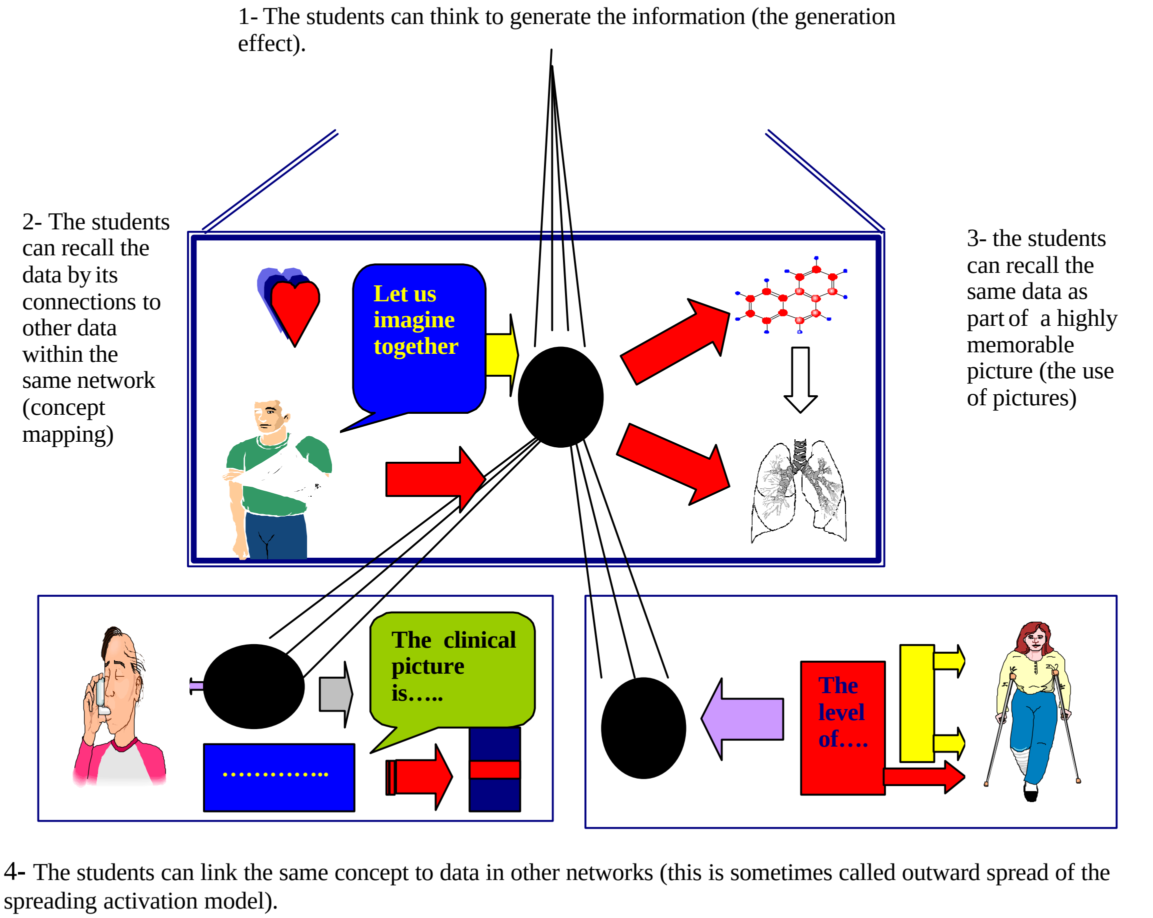

Figure 5: The students can recall the information (represented by the black circle) in 4 different dimensions at the same time (1,2 , 3 and 4). Activation of an item in the network can activate other related data in the same and other networks.

1. The students can think to generate the information (*the generation effect*).

2. The students can interrelate the data in a network so that if the student remember one data he/she can recall the other interrelated information in the network (*the spreading activation model*)

3. The students can recall the information as a single visual image (*the use of pictures to enhance memory*).

4. The students can link the concept to other network concepts.

5. The students can link the same concept to data in other networks (*this is sometimes called outward spread of the spreading activation model*).

For example, in Figure 4, the student can recall that bone damage is one of the features of hyperparathyroidism because of the following reasons:

1. The student can logically generate the fact due to the excessive shift of calcium by the elevated PTH (the generation effect)

2. He/she can remember it via its interconnections to other related data in the network or

(the concept map) e.g. the connection of the bone abnormality to the high calcium level in blood and to the x ray picture, etc (the spreading activation model)

3. The visual presentation of the bone and the whole picture of the taught subject can facilitate the recall process (the use of pictures)

Furthermore, the students can recall the same information (bone damage) if it was applied to other related subject networks, for example, if the bone abnormality in hyperparathyroidism was discussed in view of other bone abnormalities. This 4th dimension is usually used in the MDLM. The latter may be called ‘outward’ simply because the process of spreading activation can go beyond the same network to activate other networks.

Other memory strategies used in the MDLM

In addition to the previously mentioned memory strategies, the MDLM integrates the following mechanisms to facilitate the learning process:

1. The use of questions to generate the answers (the generation effect) is used to direct the student's attention to the described information. As mentioned earlier this attention is needed to shift the information from the sensory register to STM. Following this, rehearsal of this information within 30 seconds occurs via the following 3 mechanisms:

    a. Once an item is generated the student waits until it appears on the page (or the screen). During this time the student will expect what is going to be recorded then he/she can visualize it. This can provide immediate rehearsal for the item in the following few seconds.

    b. The students are usually asked to color the item once it is recorded. This can provide another way of rehearsal for the same item.

    c. When the next step is recorded visually, the student unintentionally rehearse the previous one since they are presented adjacent to each other on the page . For example, when step 3 (bone damage) appears in Figure 4, step2 (the high calcium) is immediately rehearsed visually at the same time. This can provide another rehearsal mechanism for the item.

As described earlier, rehearsal of the data within 30 seconds is important to shift the information from the STM to the LTM. According to the separate store model, the MDLM may provide a very effective way for learning.

2. An item in the MDLM is presented visually, acoustically and meaningfully so that it can be processed at three different levels at the same time. The first is how it looks like? (Shallow processing), the second is how it sounds like? (Intermediate processing), and the third is its meaning (semantic level of processing). This means that, according to *the level of processing approach* the MDLM provides many different ways to process the information including the deepest level of processing (the semantic level).

3. The information in the MDLM is typically presented one following the other and are connected in such a way that each sentence refers to something in a previous sentence and adds something new (a story like-presentation). As mentioned earlier, this story-like presentation of the data is far superior in terms of memory and learning than their random presentation.

4. The data in the MDLM is distributed in both time (as it is a sequence of events) and space (steps appearing on the same page). Since acoustic coding was shown to be more involved in encoding the data that are presented 'sequentially' or distributed in *time*, while visual memory is more involved in data that are distributed in *space*, it seems that the use of *both* acoustic and visual coding provides the best mode to encode this information.

    In the MDLM the teacher describes the items verbally (acoustic coding) and draws them on the page (visual coding). In other words, the model is using the best ways for encoding such information. Furthermore, acoustic coding may also facilitate storing of the information in the LTM.

    Finally, other mechanisms to enhance memory may also be used in the MDLM. For example, the use of colors to enhance associations, the use of bizarre interactions and the use of some organizational processes (e.g. categorizing the causes of a disease).

Possible Advantages of the Model

In addition to using different memory mechanisms to facilitate the learning process, the model provides the following advantages:

1. It provides an interactive form of teaching (as the students generate the information in response to the guiding questions). This can also give the students the motivation of self-discovery, one of the objectives of problem-based learning, (PBL).[6]

2. The students usually share in generating the whole picture with each student usually asked to generate at least one step in the process. This can encourage co-operative learning, another objective of PBL.[6]

3. The model provides 'deep' rather than rote learning. The information is generated by the students and linked logically and visually together as in the case of concept maps.

4. Its design is potentially suitable for computer assisted instruction (CAI). Once the students write or click the correct answer for a given question, the fact immediately appears visually on the screen until the whole subject is created as a single visual image.

5. By integrating different memory mechanisms to facilitate the learning process, the model may provide a very large and deeply understood theoretical base for medicine. This may aid the process of problem solving exercises in PBL, as prior knowledge facilitates the process of problem solving.[4]

Limitations

The initial results of the MDLM were not conclusive as the study was done on a small number of students and there was no counter teaching to compare the model to other methods for teaching. At this stage, we can only conclude that the model is at least promising and more in-depth studies are needed to prove its effectiveness. Furthermore, a comparison between the model and other educational methods used in medicine is mandatory.

The future studies should separate the personality of the model originator from the model itself to prove its generalizability. This could be achieved by using the model in a CAI form. The latter can also add more potentials to the MDLM e.g. by incorporating real XRAY, pathology slides, pictures, animation, and other multimedia potentials. Finally, the model may prove to be useful supplement for PBL and case base learning and further studies are needed to show the real potentials of this new model.

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Acknowledgments

The author wants to acknowledge the following people for their help and their positive role in his life:

My wife Maha, the person for whom this model was created initially to help her in studying medicine.

My thesis supervisors for their continuous help and support: Stephen Wealthall M.D., Professor David Richmond M.D., associate professor Keri Wilton and associate professor Michael Townsend.

My friend and former colleague Marcus Henning for assisting in statistical analysis of the results of the study.

Professor John P. Collins for providing me with very useful references.

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