MODERN APPROACHES TO MEMORY

LICU MONICA*

licu.monica@gmail.com

Abstract: *This work refers to short-term memory, as researched by Baddeley, as well as to long-term memory. For each of them, there are references to their educational utility, as well as useful analogies and comparisons in decoding and expanding various mnesic systems, and suggestions for ways in which teachers can increase their students' abilities.*

Keywords: *verbal repetition paradigm (phonological loop) or spatial repetition paradigm (visuo-spatial sketchpad), duration of storage of certain information, deficient information management (inefficient combination strategies).*

"It seems, then, that we owe to memory almost all that we either have or are; that our ideas and conceptions are its work, and that our every perception, thought, and movement is derived from this source. Memory collects the countless phenomena of our existence into a single whole; and as our bodies would be scattered into the dust of their component atoms if they were not held together by the attraction of matter, so our consciousness would be broken up into as many fragments as if we had lived seconds but for the binding and unifying force of memory." (Hering, 1920)

Distinctions regarding memory are still considered to be necessary. One of them refers to the three stages of memory: encoding, storage and retrieval of information. Other distinctions refer to the different types of memory. These can be used to store information in the short term or long term, as well as to store different types of information (for instance, one memory type for facts and another for skills).

Short-term memory

If we wish to remember a visual image, we try to revisualise it repeatedly; if we wish to remember what someone is telling us, we repeat this in our minds several times. In both situations we use the so-called

* **Lecturer Ph.D, - „*Dimitrie Cantemir*" Christian University, Bucharest.**

repetition paradigm, whether it is verbal (phonological loop) or spatial (visuo-spatial sketchpad), as Baddeley termed them. A phonological loop is thought to have a capacity of 5-9 units (Miller's so-called "magic number" 7+/-2). Thus, if we are asked to remember a 6 digit telephone number we will be able to reproduce it, whereas with a 9 digit number we will remember around 5-7 digits.

Contrary to Miller's results, recent research has shown that there is no fixed number of items that we are able to remember. There is a strong link between the length of the words memorised and our ability to remember them. The fact that we have difficulties remembering long words is due to the fact that repeating them in our mind is more time consuming, because each separate word is longer. Thus, the longer a word is, the more time we require to repeat the syllables that make it up. As a consequence, the level of activation of the previous words will be reduced, since the amount of time that separates them from the last word is even longer.

In order to explain repetition, Baddeley uses the metaphor of the juggler spinning several plates simultaneously. Every time we repeat a piece of information we *spin the plates* corresponding to the information we wish to retrieve. If we have to process several pieces of information simultaneously or if they require more time to *spin* (4-5 syllable words), the plates stop spinning before their information reaches us. A situation in which a plate stops spinning is the subjective equivalent of forgetting that piece of information.

In order for the information to be transferred from the STM to the LTM, it needs to pass through three stages: encoding, storage and retrieval.

Encoding represents the process of forming linguistic, visual or semantic representations corresponding to an experience (Anderson, 1995; Siegler, 1991). At the level of STM, a stimulus can be doubly encoded: verbally, as well as semantically. Verbal encoding or verbalising in one's internal language extends the duration of the storage of the stimulus in STM, from a few hundredths of a second (the duration of sensory storage) to a few seconds. Far from being an exact copy of reality, encoding is selective. This means that representations in memory mostly include essential, relevant, aspects of experience. As a consequence, much of the information to which we are exposed will not be stored in STM and will not be retrievable at a later time.

A significant limit to the processing of information in STM is given by the number of items that can be processed at a given time. Miller (1956) believes this number to vary by 2 around the figure of 7 unrelated items or elements. Current research, however, suggests that for most items stored in STM the number is actually around 5. However, if we establish certain connections between the items memorised and the information stored in the LTM, performance in retrieval tasks can radically change; this is how we create memory chunks – the minimum grouping of items to be memorised into units with meaning. Creating chunks is an important technique in encoding and storing information in STM. This context raises the problem of the source of this information, on the basis of which we can segment it into chunks. We are naturally referring to LTM, where our information is stored. We are more likely to group items into some units with meaning rather than into others. One of the main factors facilitating the integration into units with meaning is predictability. There are, of course, other factors that influence STM performance. Among these are:

- Position in the series – stimuli from the beginning and end of the series are better retrieved;
- Rhythm of presentation of the stimuli – a slower presentation ensures better mnesis performance;
- Degree of familiarity (familiar items are easier to retrieve than new ones);
- Level of abstraction (concrete materials are memorised more efficiently compared to abstract ones, especially by children).

We can conclude that we can extend STM capacity by regrouping the items inside this mnesic system.

Educational implications for STM (Mih, 2010)

Taking new information and integrating it into different structures with meaning represents an important principle of learning. On the other hand, teaching a large volume of new information at a rapid pace can become counterproductive because the students do not have enough time to repeat in their mind (to encode) every piece of the new information acquired. When teachers pause in the middle of a class in order to clarify potential misunderstandings, they give students the opportunity to rethink for a few moments the information presented and also to clarify and reorganize the material in their STM. Both situations present a more efficient encoding of the information in the STM and implicitly facilitate its subsequent transfer into the LTM. This process is essential especially when the learning material has a high level of difficulty.

Working memory

It is defined by Baddeley as the human cognitive system's ability to store for a short period of time information relevant to the task and at the same time to operate with this information. Consequently, WM has two components: short-term storage and processing (Baddeley & Hitch, 1974).

Defining WM as a space for storing and processing information received from the internal and external environment allows for a clear distinction between it and STM, which is defined in specialist literature as simply a temporary storage space for information (Baddeley, 1996).

WM can be considered a reconceptualisation and at the same time an extension of the classic concept of STM (Engle, 1994; Smith, 1999). STM has two significant limitations: limited capacity (5-9 items) and limited storage duration (2-20 seconds). LTM capacity can be extended through various information management strategies (strategies for creating chunks, generating inferences and reasoning). The storage duration of certain information can also be extended, which is why Walter Kintsch has suggested the concept of long-term working memory. This concept has radically changed Atkinson and Schiffrin's classic model of STM. To describe the two theoretical types of memory, Sternberg and Williams (2004) use the following metaphors:

1. As far as the standard model of information processing is concerned, memory is similar to storage facilities (or libraries) where information is stored passively. In this model, STM is a temporary storage space and the information it contains is meant to be transferred to different locations in the LTM. Depending on the task they are set at a certain time, the subject accesses (retrieves) the information from its respective location.
2. The WM model, on the other hand, is similar to a multimedia production class, constantly generating and manipulating images and sounds and coordinating their integration into meaningful messages. Once stored, these messages (images, sounds and other information) can be reformatted and integrated into new structures at any time, depending on the information available at that moment, the subject's tasks, strategies and experience.

Table 1. STM (from the perspective of the classic model of information processing) vs. WM (adapted from Sternberg and Williams, 2004) - Mih, 2010.

Characteristics	STM (from the perspective of the classic model of memory)	Working memory
Conceptualisation	STM is distinct from LTM	WM includes both STM and part of LTM (LTM's activated part)
Relationship between the memory storage registers	Information can be transferred from STM into LTM (i.e. from one mnesic register into another)	WM is not distinct from LTM, but rather the activated part of LTM
Key aspect of the model	Distinction between different types of storage	The role of activating information in WM and errors in reactivating information

The concept of WM describes the active and flexible part of LTM, made up of the information that we activate and operated with at a certain time in order to solve different mental tasks (Baddeley, 2000, qtd. in Mih, 2010).

Contrary to the traditional concept of STM, WM is characterised by the following aspects:

1. Due to the fact that it integrates several different subsystems (auditory, visual, etc.), WM does not function as a unitary, modular system. However, the activity of each of these subsystems is monitored by the so-called central executive system. Some of the subordinate systems have the function of short-term storage and will thus make part of the system's resources available for the execution of more elaborate operations. In this way, cognitive and time resources will be allotted to solve new and complex problems.
2. It plays an essential role in complex cognitive tasks such as learning, understanding language, problem solving, reasoning and, at the same time, it explains the mechanisms involved in these processes (Goldman-Rakic, 1996, qtd. in Mih, 2010).

3. It makes use of active manipulation and integration of acoustic and visual information (i.e. operation mechanisms), not simply memorising and storing them separately.

One of the important educational implications of the concept of WM strengthens the idea that requiring students to keep information activated while at the same time operating with it facilitates its integration into the dynamic structures of LTM.

Baddley (1998) asserts that WM plays an essential role in understanding written and spoken language. Thus, a series of studies have revealed a strong direct connection between WM capacity and the level of understanding abilities (Just and Carpenter, 1992; Montgomery, 2000). Thus, children with a low level of WM show poor abilities to understand verbal messages. Mih argues that such deficiencies are not due to any specific memory or language problems but to deficient information management (inefficient combination strategies) by the executive central system. Combination strategies can take on various forms, the most important of which being elaboration and organisation. These means of operation facilitate the expansion of WM capacity.

A. Elaboration consists of activating information that does not appear in the memorised content but can easily be inferred on the basis of this content.

The expansion of WM is strongly linked to a person's level of expertise. Ericson and Kintsch (1995) support the idea that the size of a person's WM is an indicator of their expertise in a certain field. This means that WM depends both on a person's declarative knowledge in a certain field as well as on their set of procedural abilities. These generalisable abilities are usually independent from the area of declarative knowledge, being operating systems which can be modified and applied to different areas. Thus, WM training should target the two types of knowledge, both the declarative kind in order to increase the level of expertise and the procedural kind and automatic processes, respectively.

B. Another means of increasing WM's efficiency is to organise the material into units with meaning. Specialist literature describes several types of organisation, which facilitate the processing and storing of information.

- Hierarchical organisation,
- Sequential-chronological organisation;
- Transactional organisation.

To conclude, WM represents a cognitive system characterised by a variety of processing resources (imaging, verbal) and consists of simultaneously activating and processing momentary tasks. Working memory plays an important part in all complex forms of cognitive processes such as problem solving, decision making, reasoning, learning, etc. (Baddley, 1986).

Educational implications of WM in learning

A. One of the important aspects a teacher must take into consideration when planning and teaching a lesson is the limited capacity of working memory (Sweller, van Merrienboer and Pass, 1998). This means that exposing students to an exceedingly large volume of information which is either insufficiently organised or difficult to connect to their pre-existing knowledge is counterproductive because it exceeds their processing resources (Slavin, 2006). In the same way, the use of excessively long sentences during an oral exposition or cluttering it with too many details can also make processing at the level of WM more difficult. We can conclude that a more simple and to the point lesson leads to higher mnesic performance.

B. A second important educational implication has to do with the manner in which content is organised in WM.

C. The duration for which knowledge is activated – the more time a teacher allots in order to facilitate the operation with information at the level of WM, the more likely it is for it to be remembered over time.

D. The fourth aspect highlights inter-individual differences in WM capacity when accomplishing a specific task (knowledge base, abilities to organise information).

Long-term memory (LTM)

As teachers, we cannot recognise performance in a student without having reliable indications that the new knowledge has been encoded and stored in LTM. LTM is an essential component of the cognitive system which guides attention, perceptive and decisional processes through WM. It is LTM that guides the trajectory, i.e. the sequential steps in solving tasks. LTM is the mnesic system's component where knowledge is stored for longer periods of time and where it undergoes a process of subactivation.

A series of researchers support the idea that we do not forget the information stored in LTM, but rather lose the ability to access it (Slavin, 2006).

In STM encoding is mostly acoustic and serial, whereas in LTM it is parallel and based on the meaning of the items (semantic encoding) and less on their verbal form (verbal or acoustic encoding).

Within LTM we can distinguish between two relatively distinct subsystems: semantic memory (contains general knowledge about reality which usually is emotionally neutral) and episodic memory (Tulving, 1984). These differ depending on their content and the ways in which knowledge is represented and organised.

Table 2. Semantic memory vs. episodic memory

	Semantic memory	Episodic memory
Reference system	reality	The subject itself
Question being answered	Is this knowledge true?	Has this happened to me? Did this really happen to me then, in that place?
Information retrieval model	Independent of context	Dependent on context
Reliability	High	Low, subject to interference
Organisation of knowledge	In affectively neutral schemes and semantic networks	Chronological, associated to certain emotional reactions

Education targets the development of the quality of semantic memory rather than episodic memory.

Educational applications of LTM

The duration of storage in LTM varies according to the type of information that is processed. Thus, concepts are generally stored for a longer period of time compared to proper names (Conway, Cohen and Stanhope, 1991). Secondly, the rhythm of forgetting rapidly increases during the first weeks after learning, the curve of forgetting becoming flat at a later time (Bahrich and Hall, 1991). Content remembered by students for around 12-24 hours from the time when it was memorised stands a great chance of being permanently stored.

Research in the mnesic field has highlighted a series of factors that contribute to better storage of information in LTM.

1. A primary factor is the initial level of processing, i.e. the degree of information encoding (Bahrich and Hall, 1991). In general, students with a higher level of memorising abilities perform better in school. Very often, however, the curve of forgetting for the information learned by these students follows the same evolution as the curve of diminishing mnesic performance in students with lower memorising abilities. Consequently, the long-term effects of memorising abilities have not yet been sufficiently explained (Semb and Elis, 1994).

2. Learning strategies which actively involve students in processing by generating inferences increase storage duration in LTD. Active learning refers to how minutely the material which needs to be learned is processed.

3. Research on memory has shown that inserting in a series of information to be memorised information from other categories increases mnesic performance. Furthermore, the more the interval between two instances of the same information increases, the more likely it is that the information memorised will be reproduced correctly and in its entirety (Miclea, 1999). Thus, repetitions at longer intervals have better results than immediate repetitions (Hintzman, 1974). This phenomenon is termed the spacing effect.

Teachers are advised to practice repeating knowledge or skills in as varied contexts as possible and not immediately after they are learned for the first time. These spaced reactivations, correlated with a variety of contexts, will be able to increase the likelihood of the materials being stored in LTM.

The concept of LTM has several important implications for teachers. Mih (2010) has formulated a few suggestions for ways in which teachers can increase their students' mnesic abilities:

- Prior organisation of the information;
- Restructuring and recalibrating at certain intervals the initial format in which the material was presented;
- Accompanying verbal presentations with image ones;
- Exercising the transfer of contents and operating structures from one task or context to another;

- Giving greater weight to learning conditional knowledge – this includes rules or guidelines for processing new information;
- Encouraging learning new procedural knowledge "by doing";
- Creating memorable learning experiences;
- Exercising automatisation.

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