UNIT 2 INFORMATION PROCESSING IN LEARNING AND MEMORY

"The mechanisms of learning and memory are at the essence of how the brain works."

— Brown

Structure

2.0 INTRODUCTION

One of the most fascinating and mysterious properties of the brain is its capacity to learn, or its ability to change in response to experience and to retain that knowledge throughout an organism's lifetime. The ability to learn and to establish new memories is fundamental to our very existence; we rely on memory to engage in effective actions, to understand the words we read, to recognise the objects we see, to decode the auditory signals representing speech, and even to provide us with a personal identity and sense of self. Memory plays such an important and ubiquitous role that it is often taken for granted—the only time most people pay attention to their memory is when it fails, as too often happens through brain injury or disease.

2.1 OBJECTIVES

After reading this unit, you will be able to:

- Define the concept of learning and memory;
- Explain types of memory;
- Explain cognitive information processing; and
- Explain the theories of information processing.

2.2 LEARNING AND MEMORY

Learning is acquiring new knowledge, behaviours, skills, values, preferences or understanding, and may involve synthesising and processing different types of information. Benjamin Bloom (1965) has suggested three domains of learning

1) *Cognitive* – to recall, calculate, discuss, analyse, problem solve, etc.; *psychomotor* – to dance, swim, ski, dive, drive a car, ride a bike, etc.; and *affective* – to like something or someone, love, appreciate, fear, hate, worship, etc. These domains are not mutually exclusive. For example, in learning to play chess, the person will have to learn the rules of the game (cognitive domain); but he also has to learn how to set up the chess pieces on the chessboard and also how to properly hold and move a chess piece (psychomotor). Furthermore, later in the game the person may even learn to love the game itself, value its applications in life, and appreciate its history (affective domain).

2) *Memory* is usually divided into three storage systems: sensory, short-term, and long-term.

   i) *Sensory Memory* - Sensory memory is affiliated with the transduction of energy (change from one form of energy to another). The environment makes available a variety of sources of information (light, sound, smell, heat, cold, etc.), but the brain only understands electrical stimulation. The body has special sensory receptor cells that transduce this external energy to something the brain can understand. In the process of transduction, a memory is created. This memory is very short (less than 1/2 second for vision; about 3 seconds for hearing).

      The sensory memory retains an exact copy of what is seen or heard (visual and auditory). It is absolutely critical that the learner attend to the information at this initial stage in order to transfer it to the next one. There are two major concepts for getting information into STM: *first*, individuals are more likely to pay attention to a stimulus if it has an interesting feature. *Second*, individuals are more likely to pay attention if the stimulus activates a known pattern.

   ii) *Short-Term Memory (STM)* - After entering sensory memory, a limited amount of information is transferred into short-term memory. Selective attention determines what information moves from *sensory memory* to *short-term memory*. STM is most often stored as sounds, especially in recalling words, but may be stored as images. It works basically the same as a computer's RAM (Random Access Memory) in that it provides a working space for short computations and then transfers it to other parts of the memory system or discards it. STM is vulnerable to interruption or interference. STM is characterised by:

      A limited capacity of up to seven pieces of independent information (Miller,1956).

      The brief duration of these items last from 3 to 20 seconds.

      Decay appears to be the primary mechanism of memory loss.

Miller's Magic Number - George Miller's classic 1956 study found that the amount of information which can be remembered on one exposure is between five and nine items, depending on the information. Applying a range of +2 or -2, the number 7 became known as *Miller's Magic Number*, the number of items which can be held in Short-Term Memory at any one time. Miller himself stated that his magic number was for items with one aspect. His work is based on subjects listening to a number of auditory tones that varied only in pitch. Each tone was presented separately, and the subject was asked to identify each tone relative to the others s/he had already heard, by assigning it a number. After about five or six tones, subjects began to get confused, and their capacity for making further tone judgments broke down. He found this to be true of a number of other tasks. But if more aspects are included, then we can remember more, depending upon our familiarity and the complexity of the subject (in Miller's research, there was only one aspect — the tone). For example, we can remember way more human faces as there are a number of aspects, such as hair color, hair style, shape of face, facial hair, etc. We remember phone numbers by their aspects of 2 or more groupings, i.e. chunking. We don't really remember "seven" numbers. We remember the first group of three and then the other grouping of four numbers. If it is long distance, then we add an area code. So we actually remember 10 numbers by breaking it into groups of three.

Within STM, there are three basic operations:

Iconic memory - The ability to hold visual images.

Acoustic memory - The ability to hold sounds. Acoustic memory can be held longer than iconic memory.

Working memory - Short-term memory is also called working memory and relates to what we are thinking about at any given moment in time. In Freudian terms, this is conscious memory. It is created by our paying attention to an external stimulus, an internal thought, or both. An active process to keep it until it is put to use (think of a phone number you'll repeat to yourself until you can dial it on the phone). Note that the goal is not really to move the information from STM to LTM, but merely put the information to immediate use.

iii) *Long-Term Memory (LTM)* - This is relatively permanent storage. Information is stored on the basis of meaning and importance. The process of transferring information from STM to LTM involves the encoding or consolidation of information. This is not a function of time, that is, the longer a memory stayed in STM, the more likely it was to be placed into LTM; but on organising complex information in STM before it can be encoded into LTM. In this process of organisation, the meaningfulness or emotional content of an item may play a greater role in its retention into LTM. We must find ways to make learning relevant and meaningful enough for the learner to make the important transfer of information to long-term memory.

Also, on a more concrete level, the use of chunking has been proven to be a significant aid for enhancing the STM transfer to LTM. Remember, STM's capacity is limited to about seven items, regardless of the complexity of those items. Chunking allows the brain to automatically group certain items together, hence the ability to remember and learn better.

The knowledge we store in LTM affects our perceptions of the world, and influences what information in the environment we attend to. LTM provides the framework to which we attach new knowledge. It contrasts with short-term and perceptual memory in that information can be stored for extended periods of time and the limits of its capacity are not known.

Schemas are mental models of the world. Information in LTM is stored in interrelated networks of these schemas. These, in turn, form intricate knowledge structures. Related schemas are linked together, and information that activates one schema also activates others that are closely linked. This is how we recall relevant knowledge when similar information is presented. These schemas guide us by diverting our attention to relevant information and allow us to disregard what is not important.

Since LTM storage is organised into schemas, instructional designers should activating existing schemas before presenting new information can be helpful in processing of the new information. This can be done in a variety of ways, including graphic organisers, curiosity-arousing questions, movies, etc.

LTM also has a strong influence on perception through *top-down processing* - our prior knowledge affects how we perceive sensory information. Our expectations regarding a particular sensory experience influence how we interpret it. This is how we develop bias. Also, most optical illusions take advantage of this fact. An important factor for retention of learned information in LTM is rehearsal that provides transfer of learning.

2.3 COGNITIVE INFORMATION PROCESSING

Information processing is the change (processing) of information in any manner detectable by an observer. Within the field of cognitive psychology, information processing is an approach to the goal of understanding human thinking. It began in the 1940s and 1950s. Educators are very interested in the study of how humans learn. This is because how one learns, acquires new information, and retains previous information guides selection of long-term learning objectives and methods of effective instruction. To this end, cognition as a psychological area of study goes far beyond simply the taking in and retrieving information. It is a broad field dedicated to the study of the mind holistically. Neisser (1967), one of the most influential researchers in cognition, defined it as the study of how people encode, structure, store, retrieve, use or otherwise learn knowledge. Cognitive psychologists hypothesise an intervening variable or set of variables between environment and behaviour—which contrasts it with behavioural theories.

2.3.1 Principles of the Information Processing

Even though there are widely varying views within cognitive psychology, there is general agreement among most cognitive psychologists on some basic principles of the information processing system (Huitt, 2000).

The *first* is the assumption of a limited capacity of the mental system. This means that the amount of information that can be processed by the system is constrained in some very important ways. Bottlenecks, or restrictions in the flow and processing of information, occur at very specific points (e.g., Broadbent, 1975; Case, 1978).

A *second* principle is that a control mechanism is required to oversee the encoding, transformation, processing, storage, retrieval and utilisation of information (e.g., Atkinson & Shiffrin, 1971). That is, not all of the processing capacity of the system is available; an executive function that oversees this process will use up some of this capability. When one is learning a new task or is confronted with a new environment, the executive function requires more processing power than when one is doing a routine task or is in a familiar environment.

A *third* principle is that there is a two-way flow of information as we try to make sense of the world around us. We constantly use information that we gather through the senses (often referred to as *bottom-up processing*) and information we have stored in memory (often called *top-down processing*) in a dynamic process as we construct meaning about our environment and our relations to it. This is somewhat analogous to the difference between inductive reasoning (going from specific instances to a general conclusion) and deductive reasoning (going from a general principle to specific examples.) A similar distinction can be made between using information we derive from the senses and that generated by our imaginations.

A *fourth* principle generally accepted by cognitive psychologists is that the human organism has been genetically prepared to process and organise information in specific ways. For example, a human infant is more likely to look at a human face than any other stimulus. Other research has discovered additional biological predispositions to process information. For example, language development is similar in all human infants regardless of language spoken by adults or the area in which they live (e.g., rural versus urban, Asia versus Europe.) All human infants with normal hearing babble and coo, generate first words, begin the use of telegraphic speech (example, ball gone), and overgeneralise (e.g., using "goed to the store" when they learn the verbs) at approximately the same ages(Discussed in detail in Block 3).

2.4 INFORMATION PROCESSING IN LEARNING AND MEMORY

One of the primary areas of cognition studied by researches is memory. There are many hypotheses and suggestions as to how this integration occurs, and many new theories have built upon established beliefs in this area. Currently, there is widespread consensus on several aspects of information processing; however, there are many dissentions in reference to specifics on how the brain actually codes or manipulates information as it is stored in memory.

Schacter and Tulving (as cited in Driscoll, 2001) state that "a memory system is defined in terms of its brain mechanisms, the kind of information it processes, and the principles of its operation". This suggests that memory is the combined total of all mental experiences. In this light, memory is a built store that must be accessed in some way in order for effective recall or retrieval to occur. It is premised on the belief that memory is a multi-faceted, if not multi-staged, system of connections and representations that encompass a lifetime's accumulation of perceptions.

Eliasmith (2001) defines memory as the "general ability, or faculty that enables us to interpret the perceptual world to help organise responses to changes that take place in the world". It is implied by this definition that there must be a tangible structure in which to incorporate new stimuli into memory. The form of this structure has been the source of much debate, and there seems to be no absolute agreement on what shape a memory structure actually takes, but there are many theories on what constitutes both the memory structure and the knowledge unit.

Winn and Snyder (2001) attribute the idea that memory is organised into structures to the work of Sir Frederick Charles Bartlett. Bartlett's work established two consistent patterns regarding recall. First, memory is inaccurate. His second finding, though, brought about somewhat of a revolution in traditional thinking about memory. Bartlett suggested that the inaccuracy of memory is systematic. A systematic difference makes allowable the scientific study of inaccuracy, and this suggestion led to an entirely new mode of thought on memory. What accounted for systematic inaccuracies in memory were the intervening influences of previous information and the experiences of the person. This demonstrates that knowledge units are not simply stored and then left alone, but that they are retained, manipulated, and changed as new knowledge is acquired.

2.4.1 Cognitive Information Processing Model (CIP) of Learning

Information theorists approach learning primarily through a study of memory. The following Cognitive Information Processing model (CIP) of learning presents a well-established paradigm of cognitive-behavioural psychology. The model articulates the limited capacity of "working memory." Working memory is tasked with the burden of processing incoming information, transferring information to long-term memory and retrieval of information from long-term memory. The concept of "cognitive load" — the amount of work imposed on working memory by a learning task — is based on observations of the functions of working memory.

Information processing in memory can be viewed from a computer model perspective. Like the computer, the human mind takes in information, performs operations on it to change its form and content, stores the information, retrieves it when needed, and generates responses to it. Processing involves *encoding* (gathering and representing information); *storage* (holding information); and *retrieval* (getting the information when needed). The entire system is guided by a *control process* that determines how and when information will flow through the system. Some theorists suggest that the operation of the brain resembles a large number of computers all operating at the same time (in parallel).

2.4.2 Development of Memory and Information Processing

As previously stated, cognition is the encoding, structuring, storing, retrieving, using, or otherwise learning knowledge (Neisser, 1967). There are important developmental aspects for each of these activities. According to Flavell et al. (2002), from an information processing perspective some of the most important are:

- Brain changes brought about by biological maturation or experience;
- Increased processing capacity, speed, and efficiency as a result of both maturation and knowledge development;
- Modifications of connections in a neural network;
- New emergent concepts arising from repeated self-organisation as a result of adapting to the demands of a changing environment; and
- Increased capacity for problem-solving and metacognition.

Encoding - Encoding occurs during the initial processing of a stimulus or event. Maturation and experience influence this process. In terms of maturation, Dempster (1981) suggests that the adult capacity for short-term memory of 5 + 2 digits might be as much as 2 digits lower for children aged 5 and 1 digit lower for children aged 9. As for experience, in a series of well-known studies of expertise, novices remember new information less well than experts (e.g., Chi, 1978; Schneider, Korkel, & Winert, 1989). One of the most important differences between novices and experts is the structure and organisation of domain-specific knowledge.

Structuring and Organising - Structuring and organising information occur as the learner processes and stores information. The learner's ability changes over time as a result of both maturation and experience. When presented with information they are asked to remember, younger children do not rehearse information in order to remember it. As they get into school, they begin to develop or are taught various strategies. At first these strategies are only used when prompted by someone else, but as the child becomes more competent in their use and uses them more frequently, the child will increasingly use the strategies spontaneously (Flavell et al., 2002).

One of the most important information processing capacities a child develops is the ability to organise information; this is, in turn, influenced by the child's ability to categorise. As is the case with other information-processing capacities, this ability changes with both maturation and experience.

One of the basic types of categorisation is the grouping of specific events, ideas, people, things, etc. into concepts. Rosch and his colleagues (e.g., Mervis & Rosch, 1981; Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976) demonstrated two fundamental features to the development of concepts: the ease of identifying similarities of members of the concept and distinguishing differences between members that are not. For example, the development of the concept of animal would be more difficult than developing the concept of dog or cat because it would be easier to identify similarities among dogs or cats and differences between cats and dogs than it would be to identify similarities among all animals or to differentiate all animals from all plants.

This has important implications as we design learning activities for children and youth that can help them develop their organisational and storage capacities.

Storage and Retrieval - How much information can be stored and retrieved relative to a stimulus or event also changes over time. For example, prior to about age 7 months an infant will not seek an object that has been shown and then removed from view. The infant has encoded the object (such as a rattle) and will reach for it, but seems to lose interest as soon as it is no longer in view. At about 7 months attains what is called “object permanence” and will begin to seek the object if it is removed from view.

A series of studies by Bauer, Mandler and associates (as cited in Flavell et al., 2002) demonstrates a child’s increasing ability to perform simple multiple-act sequences. By age 13 months infants can reproduce three-act sequences; by age 24 months this has increased to five-act sequences; and by age 30 months to eight separate actions. As children gain language skills, their ability to store and recall more complex events increases. This is shown first in autobiographical accounts of daily activities and then to events they may have witnessed or heard about.

Flavell et al. (2002) made four observations about strategy development:

Strategy development is not linear. When developing any particular strategy, development will often stall or even regress before it becomes systematically and correctly used.

A strategy will continue to develop after it is first demonstrated in its mature form. This continued development may take months or even years.

Children show considerable variability in their use of strategies. Children often go back and forth in their use of strategies, changing strategies even after they have been found to work well.

Children differ in their abilities to integrate different strategies into a coherent pattern for successful learning. Children must be given ample opportunity to create successful learning programs that work for them.

2.5 THEORIES OF INFORMATION PROCESSING

There are important theories which explain information processing. Some of the major theories are presented in the following section.

2.5.1 Designing Instruction that Incorporates Best Practices for Information Processing

The understanding of how the mind processes and stores information is invaluable to educators as they plan for instruction. If there is little to no understanding of the information processing skills of the students with whom one is working, it would be almost impossible to design instruction that contributes to high levels of learning and achievement. However, attempting to understand the myriad theories of information processing and cognitive development can be overwhelming and contradictory. There are means of structuring instruction, though that can incorporate the best of all of these ideas, and in order to help students reach higher-level thinking and learning skills, educators must draw from all of these theories.

If learning is to occur, educators must ensure that new information is processed in such a way that it can be retained in long-term memory. In order to achieve this, elaboration and connection must occur between previously learned memory and new information. It has been established that the more deeply information is processed and the more connections that can be made between new information and existing memory structures, the more information will be retained in long-term memory. Therefore, in order to make new material meaningful, instruction must be presented in such a way that students can easily access and connect previous learning and experiences with the new material. One of the most often cited references to levels of elaboration for instructional purposes is the Taxonomy of the Cognitive Domain developed by Bloom and his colleagues (Bloom, Englehart, Furst, Hill, & Krathwohl, 1956) and recently revised by Anderson and Krathwohl (2000).

2.5.2 Bloom's Taxonomy of Cognitive Domain

Bloom et al. (1965) proposed that information processing can be classified in six levels, each more complex than the previous. The first level is labeled *knowing* and simply requires a learner to repeat back what was heard or seen. This involves very little elaboration. The second level is labeled *comprehension* and requires some rudimentary levels of understanding that might involve having the student summarize or paraphrase some information. Again, this requires only modest levels of elaboration. The next two levels, *application* and *analysis*, involve more elaboration and show a significant impact on long-term learning when they are used during the learning process. Application involves using the concepts or principles to solve a problem, while analysis involves understanding the relationship among the parts and how they are organised into a whole. The last two levels, *synthesis* and *evaluation*, are the most complex and require the highest levels of elaboration. Synthesis involves putting the parts or components together in an original manner, while evaluation is the process of making judgments based on comparison to a standard.

Research has confirmed that the first four levels are indeed a hierarchy, while there seems to be a problem with the ordering of the two highest levels (Hummel & Huitt, 1994). Anderson and Krathwohl (2000) propose that the ordering is reversed, with evaluation being less difficult than synthesis, while Huitt (2000) proposes that they are both at the same level of difficulty though they incorporate different types of processing. There seems to be consensus that both synthesis and evaluation are based on analysis or the ability to compare and contrast parts of a whole and understand the relationship among parts.

2.5.3 Sternberg's Information Processing Approach

Another theorist firmly grounded in the information processing approach is Sternberg (1988). Sternberg's theory suggests that development is skills-based and continuous rather than staged and discontinuous as stage theorists believe, and his focus is on intelligence. This focus on intelligence separates his ideas from stage theorists because it rejects the idea of incremental stages, but rather suggests that development occurs in the same way throughout life differentiated only by the expertise of the learner to process new information. First, and very importantly, Sternberg's model does not differentiate between child and adult learning. Also, he deals solely with information processing aspects of development and does not incorporate any facets of biological development into his theory. Cognitive development is viewed as a novice to expert progression; as one becomes better at interaction and learning, one is able to learn more and at higher levels. Development changes as a result of feedback, self-monitoring, and automatisation. In this theory, intelligence is comprised of three kinds of information processing components: metacomponents, performance components, and knowledge-acquisition components.

In Sternberg's (1988) model, each of these three components works together to facilitate learning and cognitive development. Metacomponents are executive in nature. They guide the planning and decision making in reference to problem solving situations; they serve to identify the problem and connect it with experiences from the past. There is, however, no action directly related to metacomponents, they simply direct what actions will follow. Performance components are the actions taken in the completion of a problem-solving task. Performance components go beyond metacomponents in that they perform the function also of weighing the merit and or consequences of actions in comparison to other options rather than simply identifying options. Sternberg's third proposed type of intelligence is the knowledge-acquisition component. This type is characterised by the ability to learn new information in order to solve a potential problem. This type is much more abstract and may or may not be directly related to a current problem-solving task (Driscoll, 2001). This three-leveled view of intelligence comprises the componential aspect of Sternberg's theory, but this is only one of three parts to his larger triarchic theory of intelligence (Kearsley, 2001).

Sternberg's (1988) theory adds the components of feedback to theories of cognitive development; this suggests that an individual's social interaction has some impact on cognitive development. In fact, one of the three parts of his theory is based on the context in which learning takes place; this subpart of the theory "specifies that intelligent behaviour is defined by the sociocultural context in which it takes place and involves adaptation to the environment, selection of better environments, and shaping of the present environment" (Kearsley, 2001). The addition of social context as a factor in cognitive development links Sternberg to the interactional theories of development of Bruner (1977, 1986) and Vygotsky (1978). These theories, and others of this type, are premised on the assumption that learning does not occur in a vacuum. Therefore, one must discuss the social and cultural contexts of learning. Driscoll (2001) says, "Of central importance is viewing education as more than curriculum and instructional strategies. Rather, one must consider the broader context in how culture shapes the mind and provides the toolkit by which individuals construct worlds and their conceptions of themselves and their powers".

These theories all work under the assumption that new information can most effectively be learned if the material can be matched to memory structures already in place (Winn and Snyder, 2001). Most theories hold that the mind contains some type of framework into which new information is placed. This structure is multi-leveled and has varying degrees of specificity. New information can be matched with, compared to, contrasted to, joined with, or modified to fit with existing structures. This in-place structural system allows for differing levels of complexity of information processing. The formation of and continual building of these structures, then, is critical in order for learners to process information in various ways and at higher levels.

2.6 LET US SUM UP

One of the most fascinating and mysterious properties of the brain is its capacity to learn, or its ability to change in response to experience and to retain that knowledge throughout an organism's lifetime. The ability to learn and to establish new memories is fundamental to our very existence; we rely on memory to engage in effective actions, to understand the words we read, to recognise the objects we see, to decode the auditory signals representing speech, and even to provide us with a personal identity and sense of self.

Learning is acquiring new knowledge, behaviours, skills, values, preferences or understanding, and may involve synthesising and processing different types of information.

Memory is usually divided into three storage systems: sensory, short-term, and long-term.

We then discussed Miller's Magic number. We pointed out how within STM, there are 3 basic operations, viz., iconic memory, acoustic memory and working memory. Long Term Memory has been then presented which includes schemas etc. Then the principles of information processing was taken up and and highlighted the limited capacity of the mental system and secondlhy the control mechanism is required to oversee the encoding, transformation, processing storage etc.

Then we dealt with information processing in learning and memory. It was pointed out that from an information processing perspective some of the most important aspects include

- Brain changes brought about by biological maturation or experience;
- Increased processing capacity, speed, and efficiency as a result of both maturation and knowledge development;
- Modifications of connections in a neural network;
- New emergent concepts arising from repeated self-organisation as a result of adapting to the demands of a changing environment; and
- Increased capacity for problem-solving and metacognition.

Then we discussed about encoding which involves structuring, organising, storage, retrieval etc. This was followed by theories of informationprocessing which highlighted Bloom's Taxonomy and Sternberg's information processing theory. It was pointed out that that new information can most effectively be learned if the material can be matched to memory structures already in place. Most theories hold that the mind contains some type of framework into which new information is placed. This structure is multi-leveled and has varying degrees of specificity. New information can be matched with, compared to, contrasted to, joined with, or modified to fit with existing structures.

2.7 UNIT END QUESTIONS

1) Describe two characteristics each of sensory memory, short term memory, and long term memory.
2) Discuss the information processing approaches of learning and memory.
3) How would you design a study program to process the information so that it can be retained in long term memory?
4) Describe the development of memory with reference to information processing.

4) How would your life be different if you could greatly enhance your memory skills?

5) What are the basic principles of information processing?

6) What are the three things you have learned about memory that can help you learn new information so that you can effectively recall the information over the long-term?

2.8 SUGGESTED READINGS AND REFERENCES

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