Introduction

Memory is the process by which knowledge of the world is encoded, stored and later retrieved. Learning is the process by which we acquire knowledge about the world. So, memory is closely related to learning and both are usually considered together (Kandel et al., 2000). It is an essential function for the survival of individual and the species because the majority of cognitive abilities depend on the successful storage of information (Squire et al., 1993).

Brain areas involved in the neuroanatomy of memory such as the hippocampus, the amygdale, the striatum, or the mammillary bodies are thought to be involved in specific types of memory (LaBar and Cabeza, 2006).

Research in the neurobiology of memory and learning indicates that encoding, storage, and retrieval processes involved in learning and memory entail the action of at least two neural systems: (a) the neuron that involves specific molecular changes in networks of synaptic junctures, and (b) larger brain structures such as the amygdala and hippocampus at the limbic-hypothalamic system level (Mishkin et al., 1984).

Learning and memory are attributed to changes in neuronal synapses, thought to be mediated by long-term
potentiation and long-term depression (LaBar and Cabeza, 2006).

There are three distinct types of memory depending on how long information is stored (duration of memory retention): sensory register, short term or working memory, and long term memory.

**Sensory memory** processes incoming sensory information for very brief periods of time, usually on the order of 1/2 to 3 seconds. The amount of information held at any given moment in sensory memory is limited to five to seven discrete elements such as letters of the alphabet or pictures of human faces. It is also characterized by being outside of conscious control (i.e. it happens automatically and unbidden). The purpose of sensory memory is to help people make initial subconscious assessment and judgment of sensory stimuli (Kuhn, 1999).

**Short term memory** refers to the capacity for holding a small amount of information in mind in an active, readily available state for a short period of time, (sometimes referred to as "primary memory" or "active memory"). The duration of short-term memory (when rehearsal is prevented) is about 20 seconds. Estimates of the capacity of short-term memory vary from about 3 or 4 elements (i.e., words, digits, or letters) to about 9 elements. A commonly-cited capacity is 7±2 elements.
In contrast, long-term memory indefinitely stores a seemingly unlimited amount of information (*Miller, 1956*).

**Working memory** refers to a brain system that provides temporary storage and manipulation of the information necessary for such complex cognitive tasks as language comprehension, learning, and reasoning. (*Oberauer et al., 2003*).

**Working memory** consists of three basic stores: the central executive, the phonological loop and the visuo-spatial sketchpad. In 2000 this model was expanded with the multimodal episodic buffer (*Baddeley and Hitch, 1974*).

**Long-term memory** is type of memory in which Information is stored permanently. Long-term memory includes two components: declarative (DM) or explicit memory ("knows that") and nondeclarative (NDM) or implicit memory ("knows how") (*Craik, 2000*).

Declarative memory (sometimes referred to as explicit memory) is one of two types of long term human memory. It refers to memories which can be consciously recalled such as facts and knowledge its counterpart is known as non-declarative or procedural memory, which refers to unconscious memories such as skills (e.g., learning to ride a bicycle). Declarative memory can be divided into two categories: **episodic memory**
which stores specific personal experiences and semantic memory which stores factual information (*Ullman, 2004*).

Learning occurs over a period of time, and moves through different stages, rather than occurring as a result of a single moment of experience (*Block, 1973*). *Mastropieri and Scruggs (2002)* reported that a learner progresses when acquiring new knowledge, skills and strategies through stages that include: 1- Attention to task, 2- Acquisition, 3- Application, 4- Fluency, 5- Maintenance (Automaticity), 6- Generalization and 7- Adaptation.

In addition *Cowan and Alloway (2008)* added that working memory is linked to key learning outcomes in literacy and numeracy.

The information needs to enter working memory before it can be stored into long-term memory e.g. in vision, the speed with which information is stored into long-term memory is determined by the amount of information that can be fit, at each step, into working memory. In other words, the larger the capacity of working memory for certain stimuli, the faster these materials can be learned (*Nikolić and Singer, 2007*).

Variety of memory problems are evidenced in the learning-disabled. These include problems in receptive memory, sequential memory, rote memory, short term memory, and long term memory. *Receptive memory* (sensory memory)
refers to the ability to note the physical features of a given stimulus to be able to recognize it at a later time. The child who has receptive memory difficulties invariably fails to recognize visual or auditory stimuli such as the shapes or sounds associated with the letters of the alphabet, the number system, etc. **Sequential memory** refers to the ability to recall stimuli in their order of presentation. Many dyslexics have poor visual sequential memory and this will affect their ability to read and spell correctly. Some also have poor auditory sequential memory and therefore may be unable to repeat longer words orally without getting the syllables in the wrong order. **Rote memory** refers to the ability to learn certain information as a habit pattern, such as the alphabet, the number system, multiplication tables, spelling rules, grammatical rules, etc *(Bender, 2008)*.

The memory demands for school and college-age students are tremendous. Students are constantly bombarded with new information that they are expected to learn relatively quickly. Thus, the assessment of memory is a critical component of a student’s learning profile and should be included in a neurodevelopment or psychoeducational evaluation *(Postle, 2006)*.
General techniques for improving attention and memory *(Mastropieri and Scruggs, 1993):*

1) Increase Attention: Students will not remember something that they did not pay attention to in the first place. Strategies for enhancing attention include intensifying instruction, teaching enthusiastically, using more visual aids and activities, and reinforcing attending.

2) Enhance Meaningfulness: Find ways to relate the content being discussed to the student's prior knowledge.

3) Minimize Interference: Avoid digressions and emphasize only the critical features of a new topic.

4) Promote Active Manipulation: Students remember content better when they experience it for themselves.

5) Promote Active Reasoning: Students remember better if they actively think through new information, rather than simply repeating it.

6) Increase the Amount of Practice: Students should be taught the necessity of "over learning" new information. Often they practice only until they are able to perform one error-free repetition of the material.
7) Review material right before going to sleep at night. Any task that is performed after reviewing and prior to sleeping interferes with consolidation of information in memory.

8) Note taking is an activity that may help students register information in memory as well as to consolidate it.

9) All students would benefit from self-testing.

10) Draw diagrams or flow charts of the steps/events.

11) Information is remembered better when it is rehearsed using multiple sensory modalities.

12) Use the test questions that require recognition memory rather than recall (e.g., multiple choices and/or matching) [Mastropieri and Scruggs, 1993].
Aim of the Work

The aim of this review is to clarify the concept of memory and learning, as well as the relation between memory and learning processes in order to explain the breakdown mechanism in learning disorders with memory deficits background.
Neuroanatomy of Memory and Learning

Memory has been defined as the process of encoding, storage, consolidating and retrieving information. It is an emergent process in our brain results from complex interactions between the biochemistry of neurons and their electrical activity in specific anatomical structure (Van Stien et al., 2009).

The first step toward understanding the brain organization of learning and memory is to identify the particular brain circuit that contains the site or sites forming and retaining the memory traces induced by a specific learning experience (Thompson, 2005). It is known that the Papez circuit of the brain is one of the major brain circuits or pathways of the limbic system and is chiefly involved in the cortical control of emotion. The Papez circuit plays a role in storing memory (Bear et al., 2006).

The American neurologist James Papez (1937) (Cited from Bear et al., 2006) proposed that there is an ‘emotion system,’ lying on the medial wall of the brain that links the cortex with the hypothalamus. Papez believed that the experience of emotion was determined by activity in the cingulate cortex and, less directly, other cortical areas. Emotional expression was thought to be governed by the hypothalamus. The cingulate cortex projects to the
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The hippocampus, and the hippocampus projects to the hypothalamus by way of the bundle of axons called the fornix. Hypothalamic effects reach the cortex via a relay in the anterior thalamic nuclei (*Bear et al.*, 2006). (*Figure 1*)

The Papez circuit involves various structures of the brain. It begins and ends with the hippocampus (or the hippocampal formation). Fiber dissection indicates that the average size of the circuit is 350 millimeters (*Shah et al.*, 2012).

*Figure 1*: The Papez circuit. Key components include the hippocampal formation, the fornix, the mammillary bodies (M), the anterior nucleus of the thalamus (AN), the cingulate gyrus and the presubiculum (*Budson*, 2001).
Neuroanatomy of Memory and Learning

Brain parts involved in neuroanatomy of memory and learning include: (Squire et al., 1993 and van Strien et al., 2009). (Figure 2).

A- Cortical structures include frontal, parietal, temporal and occipital lobes.

B- Subcortical structures include hippocampus, amygdale, basal ganglia and cerebellum.

Figure 2: Anatomical correlates of memory (Squire et al., 1993 and van Strien et al., 2009).
A theory of multiple parallel memory systems in the brain is described. Each system consists of a series of interconnected neural structures. The “central structures” of the three systems described are the hippocampus, the matrix compartment of the dorsal striatum (caudate-putamen), and the amygdala. Information, coded as neural signals, flows independently through each system (Norman and Robert, 2002).

**Hippocampus:**

The hippocampus is a structure in the brain that has been associated with various memory functions. It is part of the limbic system, and lies next to the medial temporal lobe. It is made up of two structures, the Ammon’s horn, and the Dentate gyrus (Kolb nd Whishaw, 2008).

Although many psychologists believe that the entire brain is involved with memory, the hippocampus and surrounding structures appear to be most important in declarative memory (Eichenbaum, 2001).

**Amygdalae:**

The amygdalae are almond-shaped groups of nuclei located deep within the medial temporal lobes of the brain in complex vertebrates. Amygdalae are divided into multiple nuclei which include the basolateral complex, the cortical
nucleus, the medial nucleus, and the central nucleus. The basolateral complex can be further subdivided into the lateral, the basal, and the accessory basal nuclei (Solano-Castiella et al., 2010). (Figure 3).

Amygdala performs a primary role in the processing of memory and emotional reactions, the amygdala are considered part of the limbic system (Amunts et al., 2005).

Figure 3: Parts of amygdala (Solano-Castiella et al., 2010).

Basal ganglia:

The basal ganglia are a group of nuclei which are located in the medial temporal lobe, above the thalamus and connected to the cerebral cortex. Specifically, the basal ganglia includes the subthalamic nucleus, substantia nigra, the globus pallidus,
the ventral striatum and the dorsal striatum, which consists of the putamen and the caudate nucleus. The basic functions of these nuclei deal with cognition, learning, and motor control and activities. The basal ganglia are also associated with learning, memory, and unconscious memory (Packard and Knowlton, 2002). (Figure 4).

**Basal Ganglia and Related Structures of the Brain**

![Basal Ganglia Diagram](image)

**Figure 4**: Basal ganglion and related structures of the brain (Packard and Knowlton, 2002).

**Cerebellum:**

The cerebellum ("little brain") is a structure located at the rear of the brain, near the spinal cord. It looks like a miniature version of the cerebral cortex, in that it has a wavy or convoluted surface. Unlike the hippocampus which is involved
in the encoding of complex memories, the cerebellum plays a role in the learning of procedural memory, and motor learning, such as skills requiring co-ordination and fine motor control (Mahut et al., 1982). (Figure 5)

Frontal lobes:

When considering the frontal lobes in regards to memory, we see that it is very important in the coordination of information. Therefore, the frontal lobes are important in working memory (Frankland and Bontempi, 2005). (Figure 5)

The frontal lobes are also involved in the ability to remember what we need to do in the future; this is called prospective memory (Winograd, 1988).

Temporal lobes:

The temporal lobes are a region of the cerebral cortex that is located beneath the Sylvian fissure on both the left and right hemispheres of the brain (Squire and Zola-Morgan, 1991). Lobes in this cortex are more closely associated with memory and in particular autobiographical memory (Conway and Pleydell Pearce, 2000). Autobiographical memory, the type of memory that forms people's life stories (Parker et al., 2006). (Figure 5).
Parietal lobes:

The parietal lobe is located directly behind the central sulcus, superior to the occipital lobe and posterior to the frontal lobe. The parietal lobe helps us to mediate attention when necessary and provides spatial awareness and navigational skills. Parietal lobe also assists with verbal short term memory (Kandel et al., 1991). (Figure 5)

Figure 5: Brain Anatomy & Limbic System (© 2000 - 2013 BrightFocus Foundation).
Physiology of Memory and Learning

Functions of Memory Include:

1- **Encoding:** It is the initial registration or acquisition of information. It involves the capture of information by sensory systems and its conversion by neuronal coding for use beyond simple perception. The nature of encoding differ considerably depending on different memory demand (*Roediger, 2007*).

2- **Storage:** It is the creation of relatively stable memory trace or a record of knowledge in the brain (*Basar, 2004*). Such trace require neuronal network that can engage in neuronal coding which is the substrate of information storage, and is evoked when we remember specific information (*Jenson, 2006*).

3- **Consolidation:** Refers to slow physical process, which continue after perception that enable temporary changes in activity and synaptic strength to become long lasting, and the later reactivation of neural activity to allow for the induction of long term synaptic changes. This occur both in the region where the representation was initially formed (e.g. the hippocampus) and in additional regions where the representation was initially weaker (e.g. neocortical structure) but which receive spreading neural activity from the hippocampus (*Hasselmo, 2007*).
4-Retrieval: refers to accessing stored information. It requires the reactivation of knowledge and is closely related to encoding. Any successful act of retrieval requires initial encoding and the persistence of information in the nervous system (Tuiving, 2002).

Sites of Memory Storage:

The biological approach to memory and learning hypothesizes that memories begin their journey by entering the brain through the senses (i.e., all information must come through the physical senses) and wind their way through brain circuits to either the hippocampus located in the interior limbic-hypothalamic-pituitary brain structure for the temporary processing of semantic and episodic memories before migrating for final storage elsewhere, or to the cerebellum located in the brain stem for the formation and storage of procedural skill and respondent/operantly conditioned association memories. All forms of respondent and operant conditioning of associations, and all episodic, semantic, and procedural memories are somehow encoded and stored in the complex pattern of changes in the strengths of synaptic interconnections among neurons in neural networks located throughout the brain (e.g., medial temporal lobe, neocortex, and elsewhere). Synaptic changes occur as a consequence of the repeated neuronal stimulation that occurs as the result of experience. Learned information forms a memory by creating a physical representation of itself.
the “memory trace” in the brain’s neural network at those junctions where neurons communicate with each other via neurotransmitters (e.g., serotonin, acetylcholine). Increased stimulation and activity of particular neurons forms and strengthens new interconnections with other adjacent neurons, makes the neuron more sensitive to future stimulation, and causes it to release more neurotransmitters a phenomenon known as “long-term potentiation (LTP). LTP is believed to be the biological basis for learning and remembering associations formed during respondent and operant conditioning (Lynch and Staubli, 1991).

Mechanisms of Information Storage:

Long-term memory encodes information semantically for storage, (Baddeley, 1966). The information needs to enter working memory before it can be stored into long-term memory. This is evidenced by the fact that the speed with which information is stored into long-term memory is determined by the amount of information that can be fit, at each step, into visual working memory. In other words, the larger the capacity of working memory for certain stimuli, the faster will these materials be learned (Nikolić and Singer, 2007).

Information storage is by the modification of interneuronal connections and the experience-dependent synaptic strengthening. Although there is no clear
understanding of how experience gets into the brain, how the brain organizes itself to get/remember/forget the knowledge, contemporary theoretical formulations of learning and memory are based on two plausible principles: one is concerned with the activity (neuronal firing) and the other with the plasticity of the neurons (sprouting of new axons and dendrites, and new synapses (Arendt, 2001 and Shriver et al., 2002).

**Neuronal plasticity:**

Neuronal plasticity is a fundamental process by which the brain acquires sensory, cognitive, emotional, social, as well as endocrine inputs, or combinations of this information, and makes the appropriate adaptive responses in future related settings (Duman, 2002).

Considering the synaptic plasticity, in some areas of the neuronal system, once neuronal connections are established during the brain development period, these networks tend to be relatively stable (rigid synaptic connections). Whereas in other areas, particularly the areas involved in the higher brain functions (e.g., hippocampus, neocortical association areas and the cholinergic basal forebrain neurons), the structural synaptic remodeling of the brain continues throughout life as a mechanism of self-adaptation (flexible synaptic connections). Having the combination of these flexible and rigid connections, the brain ensures the stability of the principal characteristic
functions on one hand, while it has the opportunity to continuously reoptimize and self-adjust throughout the life (Arendt, 2001).

According to the classical hypothesis, the information in the brain is stored in a neural network. Strengthening of certain synapses allows for the establishment of a neural network specific to that information (Roman et al., 1999). It is also likely that some of the mechanisms used in information processing are also involved in the reactivation of the neural network during the retrieval of information (Alescio-Lautier et al., 2000). Both in the developing and mature brain, by the “selective stabilization of synapses” (the strengthening of existing synapses, the formation of new synapses and the destabilization of previously established synaptic contacts). The specification in the neuronal networks allows for the achievement of new epigenetic information (Arendt, 2001). So structural synaptic remodeling is not limited to the developmental stage; besides the “developmental” one, “adaptive” and “restorative” plasticity are also seen. The experimental studies based on sensory deprivation, early neonatal handling and “enriched environmental conditions” indicate that the structural changes are seen not only in the developmental stage, but are also evident in adulthood (Lyons and Schatzberg, 2003).
Learning and memory are attributed to changes in neuronal synapses, thought to be mediated by long-term potentiation (LTP) which is a long-lasting enhancement in signal transmission between two neurons that results from stimulating them synchronously. It is one of several phenomena underlying synaptic plasticity, the ability of chemical synapses to change their strength. As memories are thought to be encoded by modification of synaptic strength, LTP is widely considered one of the major cellular mechanisms that underlie learning and memory (Cooke and Bliss, 2006).

The phenomenon of long-term potentiation (LTP) has been recently shown to be associated with the formation of new synapses and long-term depression are currently regarded as one of the best and universally accepted models of learning and memory formation (Hölscher, 1999). The discovery of long lasting potentiated synapses provided a possible cellular mechanism for learning and memory. In addition to its duration (lasting for several hours in vitro, several weeks in vivo), LTP is rapidly induced, strengthened by repetition, demonstrates specificity and associativity (Kim and Yoon, 1998). However, LTP alone cannot provide enough explanation for the synaptic model of learning and memory. During this process, along with these increases in synaptic efficacy in the form of LTP, decreases in synaptic efficacy, termed as long-term depression (LTD), are also needed. Both LTP and LTD occur prominently
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in the hippocampus (a structure implicated in memory storage and retrieval processes) and appear to be mediated by mechanisms that are triggered by Ca2+ influx via activation of N-methyl-d-aspartate (NMDA) receptors. In these mechanisms, while low levels of intracellular Ca 2+ lead to the activation of phosphatases that depress the synapse, high levels lead to the activation of kinases, which potentiate the synapse (Kim and Yoon, 1998).

Models and theory of long term potentiation:

A synapse is repeatedly stimulated.

More dendritic receptors.
More neurotransmitters.

A stronger link between neurons.

**Figure 6:** Models and theory of long term potentiation (*Paradis et al.*, 2007).

When LTP occurs, "a cell is electrically stimulated over and over so that it excites a nearby cell. If a weaker stimulus is then applied to the neighboring cell a short time later, the cell's ability to get excited is enhanced." Our brain changes with learning in functional ways. When we learn something that stays with us for any length of time, it goes from the short-term into our medium- or long-term memory. When that occurs, certain genes in the brain turn on. When they turn on, new
proteins are made and the connections between the axons and dendrites increase in complexity. In other words, new memories create new interconnecting pathways between neurons. As we learn something new, each chemical message is laid down as a chain of neurons called a neural network. Those connections become stronger the more often our brains access the network. Synapses, or spaces between the neurons, also become stronger (Weiss, 2000).

Most of the molecular mechanisms contributing to long-term memory have been found to consolidate information within a brief time window after learning, but not to maintain information during memory storage. However, with the discovery that synaptic long-term potentiation is maintained by the persistently active protein kinase, protein kinase M (PKM), a possible mechanism of memory storage has been identified. Recent research shows how PKM might perpetuate information both at synapses and during long-term memory (Sacktor, 2011).

**Cellular Mechanism Underlying Memory Storage:**

Long-term memory, unlike short-term memory, is dependent upon the construction of new proteins (Costa-Mattioli and Sonenberg, 2008). This occurs within the cellular body and concerns in particular transmitters, receptors, and new synapse pathways that reinforce the communicative strength
between neurons. The production of new proteins devoted to synapse reinforcement is triggered after the release of certain signaling substances (such as calcium within hippocampal neurons) in the cell. In the case of hippocampal cells, this release is dependent upon the expulsion of magnesium (a binding molecule) that is expelled after significant and repetitive synaptic signaling. The temporary expulsion of magnesium frees NMDA receptors to release calcium in the cell, a signal that leads to gene transcription and the construction of reinforcing proteins (Neihoff, 2005).

One of the newly synthesized proteins in LTP is also critical for maintaining long-term memory. This protein is an autonomously active form of the enzyme protein kinase C (PKC), known as PKM. PKM maintains the activity-dependent enhancement of synaptic strength and inhibiting PKM erases established long-term memories, without affecting short-term memory or, once the inhibitor is eliminated, the ability to encode and store new long-term memories is restored. Also, Brain Derived Neurotrophic Factor (BDNF) is important for the persistence of long-term memories (Bekinschtein et al., 2008).

**Molecular bases of long-term memories:**

Molecular models of learning and short-term memory (STM) consider multiple types of mechanisms. Some of these might also apply to LTM.
• **Modulation of transmitter release:**

The classical model of sensitization and classical conditioning of defensive reflexes in *Aplysia* focused on short-term plasticity in transmitter release, and considered the same mechanism to contribute to long-term plasticity. Studies of LTP have rerouted much of the attention to the postsynaptic terminal. Controversy, however, exists regarding the site(s) of plasticity in LTP. Recent papers provide additional evidence for the candidate role of enhanced transmitter release in LTP (*Zakharenko et al. 2002*). used a fluorescent dye, taken up by synaptic vesicles by activity-induced endocytosis and later unloaded by subsequent presynaptic activity via exocytosis. Enhanced unloading was found up to an hour after induction of hippocampal LTP, suggesting increased neurotransmitter release. Whether this persists longer is yet unclear.

• **Recycling receptors:**

The hypothesis that synaptic facilitation is achieved by increased availability of postsynaptic receptors was somewhat neglected for almost two decades, but is now central to models of LTP. Excitatory synapses in the mammalian brain release glutamate onto either ionotrophic or metabotropic receptors. The principal subtypes of glutamatergic ionotropic receptors include the α-amino-3-hydroxy-5-methyl-4-isoxazole propionic acid receptor (AMPAR), which mediates ongoing excitatory
transmission, and the \( N \)-methyl-D-aspartate receptor (NMDAR), which triggers synaptic plasticity. The number of AMPAR molecules in the postsynaptic membrane is a function of the synaptic history (i.e. how much the synapse has previously been active). This can range from negligible (silent synapse), to small (depressed synapse), to large (potentiated synapse). Insertion of AMPARs into the synaptic membrane involves trafficking from the Golgi apparatus and exocytic mechanisms shared with transmitter release. Removal of AMPARs involves dynamin-dependent endocytosis of clathrin-coated vesicles (Lüscher et al., 1999). (Figure 7).

Activity-dependent membrane trafficking of AMPARs uses intracellular sorting mechanisms different from those used in constitutive recycling (Ehlers, 2000).

LTP, brief applications of NMDA or the NMDAR coagonist glycine under conditions that induce LTP, as well as increased activity of calcium/calmo protein kinase type II (CaMKII) (Hayashi et al., 2000) were all found to be associated with AMPAR insertion. In contrast, long-term depression (LTD), certain protocols of NMDAR activation (Beattie et al., 2000) and AMPAR activation are accompanied by AMPAR removal. Again, the central issue here is: how long can the change persist? Association with other receptors, enzymes, scaffolding and cytoskeletal proteins, controls the anchoring and localization of receptors in the synaptic
membrane. Recycling of AMPARs in the membrane is thus expected to involve the activity of a complex proteinaceous web (Lisman and Zhabotinsky, 2001).

- **Kinase–phosphatase systems:**

  Protein kinases are considered in models of plasticity in two contexts. First, as an information storage device: the persistent activation of CaMKII provides such an example. A recent analysis, however, was unable to demonstrate a role of persistent CaMKII activity in LTP maintenance (Chen et al., 2001).

  Second, as a switch that triggers other plasticity mechanisms. A number of kinases were considered as switches in both LTP and behavioral conditioning. Only a few recent examples are mentioned here (Muller, 2000), measured protein kinase A (PKA) activity induced in the antennal lobe of the honeybee by associative olfactory conditioning of proboscis extension. Only multiple-trial conditioning, which induces LTM, was associated with persistent PKA activation. Inhibition of PKA during conditioning blocked LTM but not acquisition. However, inducing PKA activation in the antennal lobe by light-induced local release of aged cyclic adenosine monophosphate (cAMP) compound in combination with a single trial conditioning that normally does not result in LTM, was sufficient to induce LTM. Even in prolonged activation, the
decay time of PKA activation was in the minute range only, implying that the activated PKA is an induction switch rather than an autonomous LTM device. Previous reports in *Aplysia* have shown that persistently active PKA is necessary, during the first 12 hours after training, for the maturation of long-term synaptic facilitation, a cellular analogue of long-term sensitization (*Chain et al., 1999*). *(Figure 7).*

A particularly exciting development in LTM research is the resurgence of interest in the possibility that some items in LTM reconsolidate each time they are retrieved. It has long been known in cognitive psychology that episodic memories are reconstructed with use. The notion was less popular in neurobiology, as most investigators tended to assume that, for any memorized item, consolidation starts and ends just once. Over the years, however, a number of studies suggested that reconsolidation could occur (*Sara, 2000*).

Although there are many unanswered questions about the role of LTP as a cellular mechanism of memory storage (*Martin et al., 2000*). It is clear that the study of LTP has provided a way to identify and characterize molecular mechanisms that potentially underlie memory storage. On a molecular level, studies of LTP in hippocampal area CA1 have focused on the NMDA receptor and intracellular signaling events downstream of Ca2+ influx through the NMDA receptor (*Abel et al., 1997*). *(Figure 7).*
Figure 7: Molecular events that underlie the early and late phases of long-term potentiation (Abel et al., 1997). Stimulation of NMDA-type glutamate receptors, as a result of postsynaptic depolarization through AMPA receptors and the binding of glutamate, allows Ca2+ to enter the postsynaptic neuron. Among the immediate effects of Ca2+ are the activation of CaMKII, PKC and calcineurin. Long-lasting LTP occurs when adenylyl cyclase is activated by Ca2+ or by modulatory inputs, which stimulate adenylyl cyclase through G-protein-coupled receptors. This leads to increases in cAMP levels, which activate PKA, which then translocates into the nucleus where it phosphorylates CREB. Other protein kinases, such as CaMKII, CaMKIV and MAP kinase, also regulate gene expression (Weng et al., 1999).
Cellular and molecular studies of both implicit and explicit memory suggest that experience dependent modulation of synaptic strength and structure is a fundamental mechanism by which implicit and explicit memories are encoded and stored within the brain. The eleven critical cellular and molecular mechanisms of memory storage identified are:

1. Neurotransmitter release and short term strengthening of synaptic connections.
2. Equilibrium between kinase and phosphatase activities at the synapse.
3. Retrograde transport from the synapse to the nucleus.
4. Activation of nuclear transcription factors.
5. Activity dependent induction of gene expression.
6. Chromatin alteration and epigenetic changes in gene expression.
7. Synaptic capture of newly synthesized gene products.
8. Local protein synthesis at active synapses.
10. Activation of pre existing silent synapses and
11. Self perpetuating mechanisms and the molecular basis of memory persistence.

The location of the above events moves from the synapse (1-2) to the nucleus (3-6) and then back to the synapse (7-11) (Emmanuel, 2007).

This process of long lasting enhancement in signal transmission following stimulation of the synapse is termed long term potentiation (LTP). LTP has proven to be the most viable candidate so far for a cellular mechanism of memory storage. LTP is thus the important linkage between our philosophical understanding and the biophysical aspect for memory and learning. Since the discovery of LTP, huge advances have been made in understanding exactly how it works. The major transmitter in the brain is glutamate, which when released binds to AMPA receptors across the synapse, causing positively charged ions to rush into the cell. If enough receptors are stimulated by glutamate, a threshold charge will build up inside the cell, and the neuron will pass the signal on down the network. LTP works by increasing the amount of receptors available to detect glutamate release; so that the next time the same stimulus comes around it will pass the signal on even more easily. For example, if you have a bad reaction to shellfish one day, your neurons will undergo LTP so that you will never go near shellfish again (Shors and Matzel, 2000).
A remarkable feature of the human brain is its ability to store and recall a seemingly endless series of experiences many of which occur only once. Clinical studies suggest that this capacity, referred to as episodic memory, is critically dependent on the hippocampus and related medial temporal lobe structures (Milner et al., 1998). Molecular studies of hippocampal synapses have revealed that memory-related modifications in synaptic transmission occur in stages. The first stage, known as early phase long-term potentiation (E-LTP), involves rapid increases of intracellular calcium concentrations and subsequent activation of protein kinases (Bliss and Collingridge, 1993). A second stage, referred to as late phase LTP (L-LTP), recruits the cAMP and CREB (cAMP-responsive element binding protein). Signaling pathway to direct protein synthesis-dependent in structure and function of hippocampal synapses (Kandel, 2001). One protein in particular, brain derived neurotrophic factor (BDNF) appears to play an important role in both (Poo, 2001).

Evidence that BDNF is involved in hippocampal LTP, learning, and memory in nonhuman species is substantial (Poo, 2001). BDNF gene expression is markedly enhanced by tetanic stimulation that induces LTP (Patterson et al., 1992) and during spatial memory tasks (Hall et al., 2000). BDNF application facilitates LTP while reduction of BDNF levels attenuates LTP (Figurov et al., 1996). Studies using a variety of
approaches demonstrate that BDNF enhances high frequency synaptic transmission by facilitating synaptic vesicle docking. BDNF also elicits rapid postsynaptic effects on ion channels and NMDA receptors. In addition to acute modulation of synaptic transmission and E-LTP, recent studies have demonstrated a role of BDNF in long-term changes in hippocampal synapses and L-LTP (Tartaglia et al., 2001). Inhibition of BDNF signaling in by gene knockout or infusion of antisense BDNF impairs spatial learning and memory (Mizuno et al., 2000). Despite substantial progress in animal studies, BDNF’s relevance in human memory and hippocampal function has not been examined directly.

Unlike other growth factors, which are secreted mainly via a constitutive pathway, at least in hippocampal neurons, BDNF appears to be sorted into a regulated pathway that secretes BDNF in response to neuronal activity (Mowla et al., 2001). Transfection experiments using BDNF-GFP (green fluorescence protein) fusion structs demonstrate that BDNF is packaged into secretory vesicles, which are transported to somatodendritic compartments (Kojima et al., 2001). Activity-dependent BDNF secretion from postsynaptic dendrites may serve as a retrograde or paracrine messenger that regulates hippocampal LTP (Poo, 2001). Indeed, electric stimulation of hippocampal neurons elicits BDNF-GFP secretion from dendrites (Hartmann et al., 2001). Taken together, these results
strongly argue for a critical role of activity-dependent secretion of BDNF in hippocampus based synaptic plasticity and learning and memory. Based on these experimental data, one might predict that genetic interference of BDNF secretion would lead to deficits in hippocampal function, learning, and memory. The BDNF gene, like other peptide growth factors, encodes a precursor peptide (proBDNF), which is proteolytically cleaved to form the mature protein (Seidah et al., 1996).

**Neuronal firing:**

There is great interest in how the brain can maintain the persistent neural activity encoding recent stimuli that is thought to be the basis of working memory (Fuster, 1988). Several theoretical mechanisms for the maintenance of persistent activity have been described (Durstewitz et al., 2000), including local recurrent feedback and intrinsic persistent activity on a single-cell basis. Recurrent excitation at the local circuit level has received the most attention (Durstewitz et al., 2000). There is now renewed interest in the concept that individual neurons might have some inherent ability to sustain persistent activity without recurrence. The remarkable finding that individual entorhinal cortical neurons can sustain graded persistent activity (Egorov et al., 2002)

The biological basis for such bistability remains little explored. Ca2+ has been shown experimentally (Egorov et al., 2002) and theoretically (Fransen et al., 2002) to contribute to
persistent firing of neurons, via upregulation of a nonspecific cation current. Neuromodulators linked to Ca2+ release or Ca2+ sensitive signaling cascades have been shown to increase synaptic NMDA currents (Seamans et al., 2001) and the persistent sodium current (Yang and Seamans, 1996) both of which might increase the efficacy of synaptic input. There is a fair amount of controversy over the effects of neuromodulators (Seamans and Yang, 2004).

Our brain changes with learning in functional ways. When we learn something that stays with us for any length of time, it goes from the short-term into our medium- or long term memory. When that occurs, certain genes in the brain turn on. When they turn on, new proteins are made and the connections between the axons and dendrites increase in complexity. In other words, new memories create new interconnecting pathways between neurons. As we learn something new, each chemical message is laid down as a chain of neurons called a neural network. Those connections become stronger the more often our brains access the network. Synapses, or spaces between the neurons, also become stronger (Ruth Palombo, 2000).

The hippocampus, a region deep within the brain, is the memory-staging area that connects stimuli and responses. It's vital for consolidation of memories. If we look at the cells in the hippocampus, we find a massive number of axons that move
from deep within the brain as a two-way street. Hippocampal cells are connected widely to many other regions in the brain, stopping at many way stations. Massive parallel processing takes place when we lay down or recall a memory, thus ensuring more flexibility in our ability to think in the sense that we can synthesize information from different sensory modalities (Ruth Palombo, 2000).

Learning and experience can modify the number of neurons. The human brain has approximately 100 billion neurons, each with as many as 5,000 synaptic connections to other neurons. It's those synaptic connections that are forged and reinforced by experience. Therefore, as a broad generalization, one can say that the more experience we have, the more connections are forged. (Ruth Palombo, 2000).

Factors Affecting Memory and Learning:

1-Memory and stress:

Stress has a significant effect on memory formation and learning. In response to stressful situations, the brain releases hormones and neurotransmitters (ex. glucocorticoids and catecholamines) which affect memory encoding processes in the hippocampus. Behavioral research shows that chronic stress produces adrenal hormones which impact the hippocampal structure in the brains (Conrad, 2010). Researchers suggest that stress experienced during learning distracts people by diverting
their attention during the memory encoding process, learning under stress also decreases memory recall in humans. However, memory performance can be enhanced when material is linked to the learning context, even when learning occurs under stress. This research on the effects of stress on memory may have practical implications for education, for eyewitness testimony and for psychotherapy: students may perform better when tested in their regular classroom rather than an exam room (Schwabe and Wolf, 2010).

Predator Stress has been shown to impair short term memory (STM) (Park et al., 2008). It has been determined that this effect on STM is not due to the fact that a predator is a novel and arousing stimulus, but rather because of the fear that is provoked in the test subjects by the predator (Woodson et al., 2003). Predator stress has been shown to increase Long term memory (LTM) (Sundada et al., 2010).

**Autobiographic Memory:**

Autobiographical memory is personal memory of self-related information and specific events. Stress tends to impair the accuracy of autobiographical memories, but does not impair the frequency or confidence in them. After exposure to an emotional and stressful negative event, flashback memories can be evident. However, the more flashback memories present, the less accurate the autobiographical memory (Moradi et al., 2007).
When stress is induced the memory will be susceptible to other influences, such as suggestions from other people, or emotions unrelated to the event but present during recall. Therefore, stress at the encoding of an event positively influences memory, but stress at the time of recollection impairs memory (*Schwabe and Wolf, 2010*).

2-Memory and emotion:

Emotion can have a powerful impact on memory. Numerous studies have shown that the most vivid autobiographical memories tend to be of emotional events, which are likely to be recalled more often and with more clarity and detail than neutral events. The part of the brain that is critical in creating the feeling of emotion is the amygdala, which allows for stress hormones to strengthen neuron communication. The chemicals cortisone and adrenaline are released in the brain when the amygdala is activated by positive or negative excitement. The most effective way to activate the amygdala is fear, because fear is an instinctive, protective mechanism which comes on strong making it memorable. Recall is linked with emotion. If pain, joy, excitement, or any other strong emotion is present during an event, the neurons activated during this event produce strong connections with each other. When this event is remembered or recalled in the future, the neurons will more easily and speedily make the same connections. The strength and longevity of memories is directly
related to the amount of emotion felt during the event of their creation (Heuer and Reisberg, 1990).

Emotion can enhance or impair memory processes. The modulatory effect of emotion on memory may reflect direct effects of the amygdala (i.e., an emotion region) on the medial temporal lobe (MTL) memory system (i.e., a memory region) or indirect effects mediated by attentional, working memory, and semantic processes mediated by prefrontal cortex (PFC) and parietal regions (LaBar and Cabeza, 2006).

3- Effect of aging on learning and memory:

Several studies provided the evidences that aging has a negative effect on long term potentiation (LTP) formation, which may be secondary to the structural and functional changes in the aged neurons. In contrast, the other form of synaptic plasticity, Long term depression (LTD), is increased during aging (Foy, 2001).

According to “free radical hypothesis of aging”, the generation and accumulation of reactive oxygen species (such as superoxide and hydroxyl radicals) cause oxidative damage in the brain, which results in diminished cognitive performance. With aging, due to significant reductions in antioxidants, the brain becomes more vulnerable to the deleterious effects of oxidative damage. Especially, the hippocampus is sensitive to antioxidant glutathione (GSH) depletion GSH deficiency, when
observed in any tissue, including the brain, results in less protection against oxidative stress (Cruz-Aguado et al., 2001).

4-Attention:

Attention is the process by which a concentration is focused on a point of interest, such as an event or physical stimulus. It is theorized that attention toward a stimulus will increase ability to recall information, therefore enhancing memory (Derryberry and Reed, 1994).

5-Interference from previous knowledge:

Interference can hamper memorization and retrieval. There is retroactive interference, when learning new information makes it harder to recall old information and proactive interference, where prior learning disrupts recall of new information (Underwood, 1957). Although interference can lead to forgetting, it is important to keep in mind that there are situations when old information can facilitate learning of new information. Knowing Latin, for instance, can help an individual learn a related language such as French. This phenomenon is known as positive transfer (Perkins and Salomon, 1992).

6- Memorization is a method of learning that allows an individual to recall information verbatim. Rote learning is the method most often used. The spacing effect shows that an
individual is more likely to remember a list of items when rehearsal is spaced over an extended period of time. In contrast to this is cramming which is intensive memorization in a short period of time (Olsson et al., 2005).

7-Spacing effect:

Information that is spaced over time is better remembered than the same amount of information massed together. This phenomenon, known as the spacing effect, is explored with respect to its effect on learning and neurogenesis in the adult dentate gyrus of the hippocampal formation. This can be explained by the cells are generated over time and because learning enhances their survival, so training with spaced trials would rescue more new neurons from death than the same number of massed trials (Sisti et al., 2007).

8-Mnemonic or Mnemonist:

Mnemonist is derived from the term mnemonic, it refers to the individuals with the unusual ability to recall long lists of information including names, numbers, etc. It has been suggested that individuals with such ability may possess eidetic memory. A mnemonic device is said to be a memory aid that used to help an individual remember and recall information. Mnemonic devices are usually verbal, such as a special phrase or word or a short poem that individuals are familiar with (Parker et al., 2006).
N.B: Eidetic memory commonly referred to as photographic memory, is a psychological or medical term, popularly defined as the ability to recall images, sounds, or objects in memory with extreme precision. The word eidetic, referring to extraordinarily detailed and vivid recall not limited to, but especially of, visual images (American Heritage Dictionary, 4th ed. 2000).

Mnemonic learning might serve as a useful way of getting information into long-term memory. When mnemonics are used during encoding of information, they may provide visual imagery or verbal elaborations that act as cues for recalling information that is low in imagery or in meaningfulness (Belleza, 1996).

9- Sleep:

One of the primary functions of sleep is thought to be improving consolidation of information, as several studies have demonstrated that memory depends on getting sufficient sleep between training and test. (Ellenbogen et al., 2006).

10-Iron deficiency

Iron deficiency (ID) is the most common nutrient deficiency. Early life ID affects at least 3 major neurobehavioral domains, including speed of processing, affect, and learning and memory, the latter being particularly
prominent. The learning and memory deficits occur while the infants are iron deficient and persist despite iron repletion. The neural mechanisms underlying the short and long-term deficits are being elucidated. Early ID alters the transcriptome, metabolome, structure, intracellular signaling pathways, and electrophysiology of the developing hippocampus, the brain region responsible for recognition learning and memory. Until recently, it was unclear whether these effects are directly due to a lack of iron interacting with important transcriptional, translational, or posttranslational processes or to indirect effects such as hypoxia due to anemia or stress. The learning deficits in adulthood likely result from interactions between direct and indirect effects that contribute to abnormal hippocampal structure and plasticity (Stephanie et al., 2011).
11- Factors inhibit learning illustrated in figure 8.

Figure 8: What inhibits learning? (Hanaford, 2005).
Types of Memory

Memory processes:

From information processing perspective there are three main stages in the formation and retrieval of memory (Costa-Mattioli, 2007):

- **Encoding** or registration (processing and combining of received information)
- **Storage** (creation of a permanent record of the encoded information)
- **Retrieval** or recall (calling back the stored information in response to some cue for use in a process or activity).

Classification of Memory:

I - Classification of memory by information type:

**Topographic memory** involves the ability to orient oneself in space, to recognize and follow an itinerary, or to recognize familiar places. Getting lost when traveling alone is an example of the failure of topographic memory. This is often reported among elderly patients who are evaluated for dementia (Sperling, 1963).
Flashbulb memories are clear episodic memories of unique and highly emotional events. Remembering where you were or what you were doing when you first heard the news of President Kennedy’s assassination or about 9/11 are examples of flashbulb memories (Brink, 2008).

II- Classification of memory by temporal direction:

A further major way to distinguish different memory functions is whether the content to be remembered is in the past, retrospective memory, or whether the content is to be remembered in the future, prospective memory. Thus, retrospective memory as a category includes semantic, episodic and autobiographical memory. In contrast, prospective memory is memory for future intentions, or remembering to remember. Prospective memory can be further broken down into event- and time-based prospective remembering. Time-based prospective memories are triggered by a time-cue, such as going to the doctor (action) at 4pm (cue). Event-based prospective memories are intentions triggered by cues, such as remembering to post a letter (action) after seeing a mailbox (cue). Cues do not need to be related to the action (as the mailbox/letter example), and lists, sticky-notes, knotted handkerchiefs, or string around the finger all exemplify cues that people use as strategies to enhance prospective memory (Winograd, 1988).
Types of Memory

_N.B:_ Spatial memory is a cognitive process that enables a person to remember different locations as well as spatial relations between objects. This allows one to remember where an object is in relation to another object. For instance, allowing someone to navigate through a familiar city. Spatial memories are said to form after a person has already gathered and processed sensory information about their environment _**(Morris and Mayes, 2004)**._

**III- Functional classification of memory systems:**
(Figure 11).

A basic and generally accepted classification of memory is based on the duration of memory retention, and identifies three distinct types of memory depending on how long information is stored: sensory register, short term or working memory, and long term memory.
A- SENSORY (RECEPTIVE) MEMORY

Sensory memory processes incoming sensory information for very brief periods of time, usually on the order of 1/2 to 3 seconds. The amount of information held at any given moment in sensory memory is limited to five to seven discrete elements such as letters of the alphabet or pictures of human faces. It is also characterised by being outside of conscious control (i.e. it happens automatically and unbidden). The purpose of sensory memory is to help people make initial subconscious assessment and judgment of sensory stimuli (Kuhn, 1999).

Sensory memory holds sensory information for a few seconds or less after an item is perceived. The ability to look at an item, and remember what it looked like with just a second of observation, or memorisation, is an example of sensory memory. It is out of cognitive control and is an automatic response. Sperling, (1963) stated that the capacity of sensory memory was approximately 12 items, but that it degraded very quickly (within a few hundred milliseconds). This form of memory degrades so quickly, participants would see the display, but be unable to report all of the items before they decayed. This type of memory cannot be prolonged via rehearsal (Sperling, 1963).
Four common features have been identified for all forms of Sensory memory (SM):

1. The formation of a SM trace is independent of attention to the stimulus.

2. The information stored in SM is modality specific. This means for example, that echoic memory is for the exclusive storage of auditory information, and haptic memory is for the exclusive storage of tactile information.

3. Each SM store represents an immense amount of detail resulting in very high resolution of information.

4. Each SM store is very brief and lasts a very short period of time. Once the SM trace has decayed or is replaced by a new memory, the information stored is no longer accessible and is ultimately lost. All SM stores have slightly different durations. (Winkler et al., 2005).

It is widely accepted that all forms of SM are very brief in duration; however, the approximated duration of each memory store is not static. Iconic memory for example has an average duration of 500 ms which tends to decrease with age (Walsh et al., 1978). The SM is made up of spatial or categorical stores of different kinds of information, each subject to different rates of information processing and decay (Elizabeth, 2011). Genetics also play a role in SM capacity;
mutations to the brain-derived neurotrophic factor (BDNF), a nerve growth factor, and N-methyl-D-aspartate (NMDA) receptors, responsible for synaptic plasticity, decrease iconic and echoic memory capacities respectively (Beste et al., 2011).

**Relationship of sensory memory with other memory systems:**

SM is **not** involved in higher cognitive functions such as consolidation of memory traces or comparison of information (Dick, 1974).

Likewise, the capacity and duration of SM cannot be influenced by top-down control; a person cannot consciously think or choose what information is stored in SM, or how long it will be stored for (Winkler et al., 2005).

The role of SM is to provide a detailed representation of our entire sensory experience for which relevant pieces of information can be extracted by short-term memory (STM) and processed by working memory (WM). STM is capable of storing information for 10–15 seconds without rehearsal while working memory actively processes, manipulates, and controls the information. Information from STM can then be consolidated into long-term memory where memories can last a lifetime. The transfer of SM to STM is the first step in the Atkinson–Shiffrin memory model which proposes a structure of memory (Coltheart and Max, 1980).
Types of Sensory Memories:

Sensory memories include:

1- Iconic memory.

2- Echoic memory.

3- Haptic memory.

1- Iconic memory

Definition:

Iconic memory is a fast decaying store of visual information, a type of sensory memory that briefly stores an image which has been perceived for a small duration. Iconic represents SM for the visual sense of visual perception/sight. Visual information is detected by photoreceptor cells in the eyes which is then sent to the occipital lobe in the brain. (*PNAS Proceedings of the National Academy of Sciences, 2005*).

Iconic memory is the visual sensory memory (SM) register pertaining to the visual domain and a fast-decaying store of visual information. It is a component of the visual memory system which also includes visual short term memory (VSTM) and long term memory (LTM). Iconic memory is described as a very brief (<1000 ms), pre-categorical, high capacity memory store. It contributes to VSTM by providing a
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coherent representation of our entire visual perception for a very brief period of time (Sperling, 1960 and Dick, 1974).

Development of Iconic memory:

The development of iconic memory begins at birth and continues as development of the primary and secondary visual system occurs. By 6 months of age, infants' iconic memory capacity approaches adults'. By 5 years of age, children have developed the same unlimited capacity of iconic memory that adults possess. The duration of informational persistence however increases from approximately 200 ms at age 5, to an asymptotic level of 1000 ms as an adult (>11 years). A small decrease in visual persistence occurs with age (Blaser and Zsuzsa, 2010).

Components of Iconic Memory:

The two main components of iconic memory are visible persistence and informational persistence. The first is a relatively brief (150 ms) pre-categorical visual representation of the physical image created by the sensory system. This would be the "snapshot" of what the individual is looking at and perceiving. The second component is a longer lasting memory store which represents a coded version of the visual image into post-categorical information. This would be the "raw data" that is taken in and processed by the brain. A third component may also be considered which neural persistence is: the physical
activity and recordings of the visual system. "Neural persistence is generally represented by neuroscientific techniques such as EEG and fMRI (Loftus et al., 1992).

**Visible Persistence:**

Visible persistence is the phenomenal impression that a visual image remains present after its physical offset. This can be considered a by-product of neural persistence. Visible persistence is more sensitive to the physical parameters of the stimulus than informational persistence which is reflected in its two key properties. (Coltheart, 1980):

1. The duration of visible persistence is inversely related to stimulus duration. This means that the longer the physical stimulus is presented for, the faster the visual image decays in memory.

2. The duration of visible persistence is inversely related to stimulus luminance. When the luminance, or brightness of a stimulus is increased, the duration of visible persistence decreases (Dick, 1974). Due to the involvement of the neural system, visible persistence is highly dependent on the physiology of the photoreceptors and activation of different cell types in the visual cortex. This visible representation is subject to masking effects whereby the presentation of interfering stimulus during,
or immediately after stimulus offset interferes with one’s ability to remember the stimulus. *(Long, 1980).*

Different techniques have been used to attempt to identify the duration of visible persistence. The **Duration of Stimulus Technique** is one in which a probe stimulus (auditory "click") is presented simultaneously with the onset, and on a separate trial, with the offset of a visual display. The difference represents the duration of the visible store which was found to be approximately 100-200 ms. *(Loftus et al., 1992).*

**Neural Basis of Visible Persistence**

Underlying visible persistence is neural persistence of the visual sensory pathway. A prolonged visual representation begins with activation of photoreceptors in the retina. Although activation in both rods and cones has been found to persist beyond the physical offset of a stimulus, the rod system persists longer than cones *(Irwin and Thomas, 2008).* Other cells involved in a sustained visible image include M and P retinal ganglion cells. M cells (transient cells), are active only during stimulus onset and stimulus offset. P cells (sustained cells), show continuous activity during stimulus onset, duration, and offset. *(Levick and Zacks, 1970).* Cortical persistence of the visual image has been found in the primary visual cortex (V1) in the occipital lobe which is responsible for processing visual information *(Nikolić et al., 2009).*
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**Informational Persistence:**

Information persistence represents the information about a stimulus that persists after its physical offset. It is visual in nature, but not visible. Sperling's experiments were a test of informational persistence (*Coltheart, 1980*). Stimulus duration is the key contributing factor to the duration of informational persistence. As stimulus duration increases, so does the duration of the visual code. (*Greene, 2007*). The non-visual components represented by informational persistence include the abstract characteristics of the image, as well as its spatial location. Due to the nature of informational persistence, unlike visible persistence, it is immune to masking effects. The characteristics of this component of iconic memory suggest that it plays the key role in representing a post-categorical memory store for which VSTM (visual short term memory) can access information for consolidation (*Irwin and James, 1986*).

**Neural Basis of Information Persistence:**

Unlike visible persistence, informational persistence is thought to rely on higher-level visual areas beyond the visual cortex. The anterior superior temporal sulcus (STS) and middle occipital gyrus (MOG) were found to be active in during iconic memory tasks. STS is associated with object recognition and object identity. MOG activation was found to persist for approximately 2000ms suggesting a possibility that iconic
memory has a longer duration than what was currently thought. Iconic memory is also influenced by genetics and proteins produced in the brain. Brain-derived neurotrophic factor (BDNF) is a part of the neurotrophin family of nerve growth factors. Individuals with mutations to the BDNF gene which codes for BDNF have been shown to have shortened, less stable informational persistence (Beste et al., 2011).

Role of Iconic Memory:

Iconic memory provides a smooth stream of visual information to the brain which can be extracted over an extended period of time by VSTM for consolidation into more stable forms. One of iconic memory's key roles is involved with change detection of our visual environment which assists in the perception of motion (Urakawa et al., 2010).

1- Temporal Integration:

Iconic memory enables integrating visual information along a continuous stream of images, for example when watching a movie. In the primary visual cortex new stimuli do not erase information about previous stimuli. Instead the responses to the most recent stimulus contain about equal amounts of information about both this and the preceding stimulus. This one-back memory may be the main substrate for both the integration processes in iconic memory and masking effects. The particular outcome depends on whether the two
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subsequent component images (i.e., the “icons”) are meaningful only when isolated (masking) or only when superimposed (integration) (Nikolić et al., 2009).

2- Change Blindness:

The brief representation in iconic memory is thought to play a key role in the ability to detect change in a visual scene. The phenomenon of change blindness has provided insight into the nature of the iconic memory store and its role in vision. Change blindness refers to an inability to detect differences in two successive scenes separated by a very brief blank interval, or interstimulus interval (ISS). As such change blindness can be defined as being a slight lapse in iconic memory. When scenes are presented without an ISS, the change is easily detectable. It is thought that the detailed memory store of the scene in iconic memory is erased by each ISS, which renders the memory inaccessible. This reduces the ability to make comparisons between successive scenes (Urakawa et al., 2010).

3- Saccadic Eye Movement:

It has been suggested that iconic memory plays a role in providing continuity of experience during saccadic eye movements (Jonides et al., 1982). These rapid eye movements occur in approximately 30 ms and each fixation lasts for approximately 300 ms. Research suggests however, that memory for information between saccades is largely dependent
on VSTM and not iconic memory. Instead of contributing to trans-saccadic memory, information stored in iconic memory is thought to actually be erased during saccades. A similar phenomenon occurs during eye-blinks whereby both automatic and intentional blinking disrupts the information stored in iconic memory (Thomas and David, 2006).

### 2-Echoic memory

**Definition:**

Echoic memory is a fast decaying store of auditory information, another type of sensory memory that briefly stores sounds which has been perceived for a small duration. Echoic represents SM for the auditory sense of hearing. Auditory information travels as sound waves which are sensed by hair cells in the ears. Information is sent to and processed in the temporal lobe (Darwin, 1972). Today, characteristics of echoic memory have been found mainly using a Mismatch Negativity (MMN) paradigm which utilizes EEG and MEG recordings. MMN has been used to identify some of the key roles of echoic memory such as change detection and language acquisition. Change detection, or the ability to detect an unusual or possibly dangerous change in the environment independent of attention, is key to the survival of an organism (Sabri et al., 2003). With regards to language, a characteristic of children who begin speaking late in development is reduced duration of echoic
memory \cite{Grossheinrich2010}. In short, "Echoic Memory is a fast - decaying store of auditory information \cite{Schacter2011}. In the case of damage to or lesions developing on the frontal lobe, parietal lobe, or hippocampus, echoic memory will likely be shortened and/or have a slower reaction time \cite{Claude2012}.

**Echoic memory** is one of the sensory memory registers; a component of sensory memory (SM) that is specific to retaining auditory information. The sensory memory for sounds that people have just perceived is the form of echoic memory \cite{Carlson2010}. Unlike visual memory, in which our eyes can scan the stimuli over and over, the auditory stimuli cannot be scanned over and over. Overall, echoic memories are stored for slightly longer periods of time than iconic memories (visual memories). Auditory stimuli are received by the one ear at a time before it can be processed and understood. For instance, hearing the radio is very different from reading a magazine. A person can only hear the radio once at a given time, while the magazine can be read over and over again. It can be said that the echoic memory is like a "holding tank" concept, because a sound is unprocessed (or held back) until the following sound is heard, then only can it be made meaningful \cite{Clark1987}. This particular sensory store is capable of storing large amounts of auditory information that is only retained for a short period of time (3–4 seconds). This echoic sound resonates in the mind
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and is replayed for this brief amount of time shortly after the presentation of auditory stimuli (Radvansky, 2005). Echoic memory encrypts only moderately primitive aspects of the stimuli, for example pitch, which specifies localization to the non association brain regions (Strous et al., 1995).

3-Haptic memory

Haptic memory is a type of sensory memory that represents a database for touch stimuli. Itching and pain are a form of haptic memory. Sensory receptors all over the body detect sensations such as pressure, itching, and pain. Information from receptors travel through afferent neurons in the spinal cord to the postcentral gyrus of the parietal lobe in the brain. This pathway comprises the somatosensory system. Evidence for haptic memory has only recently been identified resulting in a small body of research regarding its role, capacity, and duration (Dubrowski, 2009). Already however, fMRI studies have revealed that specific neurons in the prefrontal cortex are involved in both SM, and motor preparation which provides a crucial link to haptic memory and its role in motor responses (D'Esposito et al., 2002).

Forgetting of sensory memory (decay theory):

It is thought that sensory memories consist of physiological changes in the brain. Changes that appear and disappear very rapidly. Thus, sensory memories are forgotten
very rapidly. This explanation of the forgetting of sensory memories is referred to as decay theory because the neural traces of the memories are thought to ‘decay’ or disappear. The physiological or physical change underlying a memory is called an engram (also known as a biological memory trace (Lashley, 1950).

**Decay theory** states that the forgetting of a memory is caused by the disappearance over time of its engram. Once the engram has disappeared, the memory no longer exists anywhere in the memory system: it has decayed. As stated, the engrams that make up sensory memories are thought to decay very rapidly. Thus, unless a sensory memory is attended to, which transfers it to short-term memory, the sensory memory will decay almost immediately. Because we can attend to only a small number of sensory memories, virtually all sensory memories at any one moment disappear within a few seconds. Thus, we forget almost every perception that we experience (preconsciously or unconsciously) during our lives (Thompson, 1976). (Figure 9).
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**Sensory Memory**
- **Iconic Memory**
  - **Duration:** < 1 second
  - **Capacity:** >20 items
  - **Levels of Awareness:**
    - Preconscious
    - Unconscious
- **Echoic Memory**
  - **Duration:** ≤ 3 seconds
  - **Capacity:** 1-6 items
  - **Levels of Awareness:**
    - Preconscious
    - Unconscious
- **Other Senses**
  - **Not Well Studied**

**Short-Term Memory**

Forgetting

*Decay Theory: The disappearance of a biological memory trace (engram)*

**Figure 9:** A summary of the major characteristics of sensory memory *(Thompson, 1976).*
**B- SHORT TERM MEMORY**

Refers to the capacity for holding a small amount of information in mind in an active, readily available state for a short period of time, (sometimes referred to as "primary memory" or "active memory"). The duration of short-term memory (when rehearsal is prevented) is about 20 seconds. Estimates of the capacity of short-term memory vary from about 3 or 4 elements (i.e., words, digits, or letters) to about 9 elements. A commonly-cited capacity is 7±2 elements (*Miller, 1956*).

**Relationship between short-term memory and working memory:**

The relationship between short-term memory and working memory is described differently by various theories, but it is generally acknowledged that the two concepts are distinct. Working memory is a theoretical framework that refers to structures and processes used for temporarily storing and manipulating information. As such, working memory might also be referred to as working attention. Working memory and attention together play a major role in the processes of thinking. Short-term memory in general refers, in a theory-neutral manner, to the short-term storage of information, and it does not entail the manipulation or organization of material held in memory. Most theorists use the concept of working memory to
replace or include the older concept of short-term memory, thereby marking a stronger emphasis on the notion of manipulation of information instead of passive maintenance (*Parmentier et al., 2005*).

**Duration of short-term memory:**

The most important characteristic of a short-term store is, clearly, that it retains information for less than a minute; no more than about 30 seconds (*Jonides et al., 2008*).

The limited duration of short-term memory quickly suggests that its contents spontaneously decay over time. In order to overcome the limitation of short-term memory, and retain information for longer, information must be periodically repeated or rehearsed either by articulating it out loud or by mentally simulating such articulation. In this way, the information will re-enter the short-term store and be retained for a further period (*Jonides et al., 2008* and *Lewandowsky et al., 2004*).

Authors doubting that decay causes forgetting from short-term memory often offer as an alternative some form of interference: When several elements (such as digits, words, or pictures) are held in short-term memory simultaneously, their representations compete with each other for recall, or degrade each other. Thereby, new content gradually pushes out older content, unless the older content is actively protected against
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interference by rehearsal or by directing attention to it (Oberauer and Kliegl, 2006).

Capacity of short-term memory:

The capacity of short-term memory is often called "memory span", in reference to a common procedure of measuring it: The experimenter presents lists of items (e.g., digits or words) of increasing length; the tested person's span is determined as the longest list length that she or he can recall correctly in the given order on at least half of all trials (Jonides et al., 2008).

In a typical test of memory span, the experimenter presents lists of items (e.g., digits or words) of increasing length at about the rate of one per second. Recognizable patterns (for example: 2, 4, 6, 8) should be avoided. The tested person's span is determined as the longest list length that she or he can recall correctly in the given order on at least half of all trials (Parmentier et al., 2005). Rudolph et al. (2003) stated that the ability to recall digits normally increases from recall of two digits by 2 ½ years of age to seven or eight digits by age 14 years.

Memory span refers to the longest list of items (e.g., digits, letters, words) that a person can repeat back immediately after presentation in correct order on 50% of trials. Miller
observed that memory span of young adults is approximately seven items (Miller, 1956).

Later research on short-term memory and working memory revealed that memory span is not a constant even when measured in a number of chunks. A chunk is the largest meaningful unit in the presented material that the person recognizes thus, it depends on the knowledge of the person what counts as a chunk. The number of chunks a human can recall immediately after presentation depends on the category of chunks used (e.g., span is around seven for digits, around six for letters, and around five for words), and even on features of the chunks within a category. Chunking is used by the brain’s short-term memory as a method for keeping groups of information accessible for easy recall (Shiffrin and Robert, 1994). The storage capacity is dependent on the information being stored. For instance, span is lower for long words than it is for short words. In general, memory span for verbal contents (digits, letters, words, etc.) strongly depends on the time it takes to speak the contents aloud. Some researchers have therefore proposed that the limited capacity of short-term memory for verbal material is not a "magic number" but rather a "magic spell" (Schweickert and Boruff, 1986). Baddeley used this finding to postulate that one component of his model of working memory, the phonological loop, is capable of holding around 2 seconds of sound (Baddeley, 1992).
The ability to recall words in order depends on a number of characteristics of these words: fewer words can be recalled when the words have longer spoken duration; this is known as the word-length effect (Baddeley et al., 1975) or when their speech sounds are similar to each other; this is called the phonological similarity effect (Conrad and Hull, 1964). More words can be recalled when the words are highly familiar and/or occur frequently in the language; recall performance is also better when all of the words in a list are taken from a single semantic category (such as sports) than when the words are taken from different categories (Poirier and Saint-Aubin, 1996).

Short-term memory allows recall for a period of several seconds to a minute without rehearsal. Its capacity is also very limited: Miller (1956) conducted experiments showing that the store of short-term memory was 7±2 items (the title of his famous paper, "The magical number 7±2"). Modern estimates of the capacity of short-term memory are lower, typically of the order of 4–5 items in young adults (and less in children and older adults) (Cowan, 2001).

Though the average person may only retain about 7±2 different units in his or her short term memory, chunking can greatly increase a person's recall ability. For example, in recalling a phone number, the person usually chunks the digits into three groups: first, the area code (such as 814), then a
three-digit chunk (123) and lastly a four-digit chunk (4567). This method of remembering phone numbers is far more effective than attempting to remember a string of 10 digits (Ericsson et al., 1980). This is because we are able to chunk the information into meaningful groups of numbers. This may be reflected in some countries in the tendency to display telephone numbers as several chunks of three numbers, with the final four-number group generally broken down into two groups of two (Miller, 1956).

Short-term memory is believed to rely mostly on an acoustic code for storing information, and to a lesser extent a visual code. Conrad (1964) found that test subjects had more difficulty recalling collections of letters that were acoustically similar (e.g. E, P, D). Confusion with recalling acoustically similar letters rather than visually similar letters implies that the letters were encoded acoustically (Conrad, 1964).
WORKING MEMORY

Definition:

The term working memory refers to a brain system that provides temporary storage and manipulation of the information necessary for such complex cognitive tasks as language comprehension, learning, and reasoning. This definition has evolved from the concept of a unitary short-term memory system. Working memory has been found to require the simultaneous storage and processing of information (Oberauer et al., 2003).

Working Memory is a memory system used for keeping information in mind while carrying out a number of other cognitive tasks. These tasks include the insertion of information into long term memory, and the retrieval of information from long term memory (Klingberg et al., 2002).

Working memory has been referred to as our "cognitive counter space" and involves holding all of the parts of a task in mind while completing the task. For example, when we are following a series of three directions that someone has given us, we must remember the second and third direction while carrying out the first. Working memory also functions as the computational file manager of the mind, selecting and retrieving from long-term memory information and plans.
needed moment-by-moment for current tasks. Working memory is a critical element of those executive functions which constitute the management system of the mind (Pennington et al., 1996).

Theories:

There have been numerous models proposed regarding how working memory functions, both anatomically and cognitively. These models include:

I- Baddeley and Hitch's working memory model.

II - Cowns model.

I- Baddeley and Hitch's working memory model:

The working memory model:

In 1974 Baddeley and Hitch proposed a working memory model which replaced the general concept of short term memory with an active maintenance of information in the short term storage.

In this model, working memory consists of three basic stores: the central executive, the phonological loop and the visuo-spatial sketchpad. In 2000 this model was expanded with the multimodal episodic buffer (Baddeley, 2000).
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Working memory model

Figure 10: Working memory model (Baddeley and Hitch, 1974).

1- **The central Executive**: essentially acts as attention. It channels information to the three component processes: the phonological loop, the visuo-spatial sketchpad, and the episodic buffer. Central Executive co-ordinates the activity of both the Phonological Loop and the Visuospatial Sketch Pad. Imagine the following situation: You are driving a car and your friend in the passenger seat has the map and gives you directions. The directions are given verbally, i.e. they are handled by the Phonological Loop, while the perception of the traffic, street lights, etc. is obviously visual, i.e. dealt with in the Visuospatial Sketch Pad. It also links the Working Memory to Long Term Memory, controls the storage in Long Term Memory and the retrieval from it. The process of storage is influenced by the duration of holding
information in Working Memory and the amount of manipulation of the information. The latter is stored for a longer time if it is semantically interpreted and viewed with relation to other information already stored in Long Term Memory. This is called Deep Processing. Pure syntactical processing (reading a text for typos) is called Shallow Processing.

Norman and Shallice (1986) suggested that actions of central executive as attentional control system are controlled in two ways. Behavior that is routine and habitual is controlled automatically by a range of schemas, well-learned processes that allow us to respond appropriately to the environment. An experienced driver on a routine trip would be a good example of this, sometimes arriving at the destination with no memory of the journey. When such procedures are no longer adequate, for example finding the normal route blocked by an accident, a second system, the Supervisory Attentional System (SAS) comes into operation. This is capable of using long-term knowledge in order to set up possible solutions, and reflect on them before choosing the best. In the case of our interrupted journey, this might involve the central executive of working memory, probably in connection with LTM, the visuo-spatial sketchpad, and possibly the phonological loop. In its original version, the central executive was regarded as a general system capable of both processing and storage.
Executive functioning has been extensively investigated particularly in connection with its disruption following damage to the frontal lobes of the brain, a deficit referred to as the dysexecutive syndrome. This may result in major problems of attentional control, including sometimes repeatedly perseverating on a single action, while at others failing to maintain a goal against distraction. In the case of memory, this may result in confabulation where, in attempting to retrieve a memory, recall is captured by inappropriate associations, sometimes resulting in totally false memories (*Baddeley and Wilson, 1986*).

2- The phonological loop (Phonological memory): stores auditory information by silently rehearsing sounds or words in a continuous loop: the articulatory process (for example the repetition of a telephone number over and over again). A short list of data is easier to remember. Phonological loop which stores and rehearses speech-based information and is necessary for the acquisition of both native and second-language vocabulary. The phonological loop has two components: short term storage for phonological information for a time period of seconds called the phonological store, and a second component to refresh this store called the articulatory process.

*The Phonological Loop* is responsible for auditory and verbal information, such as phone numbers, people’s names or
general understanding of what other people are talking about. We could roughly say that it is a system specialized for language. This system can again be subdivided into an active and a passive part. The storage of information belongs to the passive part and fades after two seconds if the information is not rehearsed explicitly. Rehearsal, on the other hand, is regarded as the active part of the Phonological Loop. The repetition of information deepens the memory. There are three well-known phenomena that support the idea that the Phonological Loop is specialized for language: The **phonological similarity effect**, the **word-length effect** and **articulatory suppression**. Phonological similarity effect refers to that memory for a list of consonants that had similar sounds, such as B, C, T, G, V, was poorer compared to memory for a list of consonants that had different sounds, such as H, K, L, M, W. Similarity of meaning (HUGE LARGE BIG WIDE TALL) has little effect on immediate recall. On the other hand if several trials are given to learn a longer list of say 10 words, meaning becomes all-important and sound loses it power, consistent with different systems for short-term and long-term storage (**Baddeley, 1966**).

The word-length effect refers to the fact that it is more difficult to memorize a list of long words and better results can be achieved if a list of short words is memorized (**Baddeley, 1974**).
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Memory trace of items in the short-term store would rapidly fade, but could be maintained by saying them to oneself. Long words take longer to say, allowing more fading and hence more forgetting to occur. Consistent with this interpretation, preventing subjects from saying words to themselves by requiring the continuous utterance of an item such as the word 'the', removes the word length effect (Baddeley et al., 1975). Other interpretations have been proposed, differing principally in the implications of the effect for whether items in the short-term store are forgotten as a result of spontaneous decay of the memory trace, or by disruption from later material (Baddeley, 2010).

The articulatory control process can recode visually presented information into a phonological code via subvocalisation. Thus, the presentation of a picture or written word can be stored in the phonological loop by subvocally repeating the name of the object or the word. The phonological loop processes verbal or acoustic information and temporarily stores this information through subvocal rehearsal. Visual information, such as a picture of an object, also can be processed in the phonological loop by vocally or subvocally rehearsing the name of the object. Interfering with the rehearsal of information can reduce dramatically the amount of information recalled (Baddeley, 1992).
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3- **The visuospatial sketchpad**: which manipulates, stores visual images and spatial information. It can be used, for example, for constructing and manipulating visual images, and for the representation of mental maps. The sketchpad can be further broken down into a *visual subsystem* (dealing with, for instance, shape, colour, and texture), and a *spatial subsystem* (dealing with location). It is engaged when performing spatial tasks (such as judging distances) or visual ones (such as counting the windows on a house or imagining images).

4- **The episodic buffer**: is dedicated to linking information across domains to form integrated units of visual, spatial, and verbal information and chronological ordering (e.g., the memory of a story or a movie scene). The episodic buffer is also assumed to have links to long-term memory and semantical meaning *(Baddeley, 2000)*.

Episodic buffer holds information not covered by the other components (e.g., semantic information, musical information). The component is episodic because it is assumed to bind information into a unitary episodic representation. The episodic buffer resembles the concept of episodic memory, but it differs in that the episodic buffer is a temporary store *(Baddeley, 2000)*.
II- Cowan's Model:

An alternative view of working memory is provided by Cowan who postulates an attentional system with a capacity of about four chunks as the central feature of working memory (Cowan, 2001). Outside this central focus, short-term storage is assumed to depend on activated long-term memory. Cowan's model could be seen as one way of specifying the interaction between the central executive and the episodic buffer. Cowan's emphasis on working memory as activated long-term memory might seem to provide a clear contrast with the multicomponent model. The difference is however more apparent than real. Both assume that interaction with LTM plays an important role, with the multicomponent model assuming that such links operate at a number of different levels.

Cowan (2005) regards working memory not as a separate system, but as a part of short-term memory. He extends it to include long-term memory as well. Representations in working memory are a subset of the representations in long-term memory. Working memory is organized into two embedded levels. The first level consists of long-term memory representations that are activated. There can be many of these; there is no limit to activation of representations in long-term memory. The second level is called the focus of attention. The
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focus is regarded as having a limited capacity and holds up to four of the activated representations

Capacity of working memory:

Working memory is generally considered to have limited capacity. The earliest quantification of the capacity limit associated with short-term memory was the "magical number seven" suggested by Miller in 1956 (Miller, 1994). He noticed that the memory span of young adults was around seven elements, called chunks, regardless whether the elements were digits, letters, words, or other units. Later research revealed that span depends on the category of chunks used (e.g., span is around seven for digits, around six for letters, and around five for words), and even on features of the chunks within a category. For instance, span is lower for long words than for short words. In general, memory span for verbal contents (digits, letters, words, etc.) strongly depends on the time it takes to speak the contents aloud, and on the lexical status of the contents (i.e., whether the contents are words known to the person or not) (Hulme et al., 1995). Several other factors also affect a person's measured span, and therefore it is difficult to pin down the capacity of short-term or working memory to a number of chunks. Nonetheless, Cowan proposed that working memory has a capacity of about four chunks in young adults (and fewer in children and old adults) (Cowan, 2001).
Whereas most adults can repeat about seven digits in correct order, some individuals have shown impressive enlargements of their digit span – up to 80 digits. This feat is possible by extensive training on an encoding strategy by which the digits in a list are grouped (usually in groups of three to five) and these groups are encoded as a single unit (a chunk). To do so one must be able to recognize the groups as some known string of digits. Several such chunks can then be combined into a higher-order chunk, thereby forming a hierarchy of chunks. In this way, only a small number of chunks at the highest level of the hierarchy must be retained in working memory. At retrieval, the chunks are unpacked again. That is, the chunks in working memory act as retrieval cues that point to the digits that they contain. It is important to note that practicing memory skills such as these does not expand working memory capacity proper: It is the capacity to transfer (and retrieve) information from long-term memory that is improved (Gobet, 2000).

**Individual differences of working memory (Tamara van Gog et al., 2005).**

- Current research demonstrates that individual differences in working memory capacity may account for differences in performance of information processing tasks, like reading and note-taking.
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- In studies with children, those who have a poor ability to store material over brief periods of time (difficulties with working memory) fail to progress normally in tasks related to literacy.

- An individual’s developmental age and level of expertise probably account for differences in working memory. For example, facilitating learning with certain strategies can be helpful for novices but detrimental to experts.

The capacity of working memory is better characterized as the ability to mentally form relations between elements, or to grasp relations in given information. For example to compare written statements about the relations between several variables to graphs illustrating the same or a different relation, as in the following sentence: "If the cake is from France, then it has more sugar if it is made with chocolate than if it is made with cream, but if the cake is from Italy, then it has more sugar if it is made with cream than if it is made of chocolate". This statement describes a relation between three variables (country, ingredient, and amount of sugar), which is the maximum most individuals can understand. The capacity limit apparent here is obviously not a memory limit (all relevant information can be seen continuously) but a limit on how many relationships are discerned simultaneously (*Halford et al., 2005*).
Development of working memory:

The capacity of working memory increases gradually over childhood and declines gradually in old age (*Salthouse, 1994*).

Although the capacity working memory increases with age (*Case et al., 1982*), there are nevertheless marked developmental changes in the way working memory is utilised. For example the developmental progression whereby the child masters increasingly complex intellectual operations has been linked to the growth of central executive capacity (*Hitch, 2006*). There are also significant developmental changes in the subsystems of working memory, the best known being the expansion in the range of operation of the phonological loop, ranging from the development of the capacity for inner speech and rehearsal strategies in children to the involvement of a wider range of aspects of executive control in adults (*Saeki and Saito, 2004*).

In *childhood* measures of performance on tests of working memory increase continuously between early childhood and adolescence, while the structure of correlations between different tests remains largely constant (*Gathercole et al., 2004*). Thus, the development of working memory can be described as quantitative growth rather than a qualitative
change. Starting with work in the Neo-Piagetian tradition (Pascual-Leone, 1970). Theorists have argued that the growth of working-memory capacity is a major driving force of cognitive development. This hypothesis has received substantial empirical support from studies showing that the capacity of working memory is a strong predictor of cognitive abilities in childhood (Jarrold and Bayliss, 2007). Particularly strong evidence for a role of working memory for development comes from a longitudinal study showing that working-memory capacity at one age predicts reasoning ability at a later age (Kail, 2007).

In old age working memory is among the cognitive functions most sensitive to decline (Hertzog et al., 2003). Several explanations have been offered for this decline in psychology.

One is the processing speed theory of cognitive aging (Salthouse, 1996). Based on the finding of general slowing of cognitive processes as people grow older, Slower processing leaves more time for working-memory contents to decay, thus reducing effective capacity. However, the decline of working-memory capacity cannot be entirely attributed to slowing because capacity declines more in old age than speed (Park et al., 2002).
Hasher and Zacks (1988) proposed the inhibition hypothesis which assumes that a general deficit in old age in the ability to inhibit irrelevant, or no-longer relevant, information. Therefore, working memory tends to be cluttered with irrelevant contents that reduce the effective capacity for relevant content. The assumption of an inhibition deficit in old age has received much empirical support (Hasher et al., 1999). But so far it is not clear whether the decline in inhibitory ability fully explains the decline of working-memory capacity.

Based on the neural level of the decline of working memory and other cognitive functions in old age. West (1996) argued that working memory depends to a large degree on the pre-frontal cortex, which deteriorates more than other brain regions as we grow old.

**Working memory in the brain:**

**Genetics:**

Little is known of the genetics of working memory. It is heritable, and, at a component level, one candidate gene has been proposed, namely ROBO1 for the phonological loop function of working memory (Sherry and Schacter, 1987).
Neural substrates of working memory:

A good deal of research has been carried out on this topic, initially through the study of patients with localized lesions and subsequently using neuroimaging methods. Broadly speaking, the results fit the three-component model, with the phonological loop being represented in the left hemisphere where storage is associated with a region in the temporoparietal junction (Brodmann area 40), and rehearsal with the more anterior Brodmann area (44) that is known to be associated with speech production \((\text{Paulesu et al., 1993})\). The visuo-spatial sketchpad appears to involve a number of predominantly right hemisphere areas, one visual, presumably reflecting the processing and retention of objects and their visual features, a second area is more parietal, presumably involving spatial aspects, while two frontal areas of activation have been associated with control functions \((\text{Henson, 2001})\). There is general acceptance that the frontal lobes play an important role in executive control, although opinions differ as to the extent to which different executive functions may be separately localisable. There is as yet little evidence as to the localisation of the episodic buffer, which seems likely to reflect a broadly distributed system which may possibly not give rise to activation in any one specific area \((\text{Shallice, 2002})\).
Localization:

Localization of brain functions in humans has become much easier with the advent of brain imaging methods (PET and fMRI). This research has confirmed that areas in the PFC are involved in working memory functions. During the 1990s much debate has centered on the different functions of the ventrolateral (i.e., lower areas) and the dorsolateral (higher) areas of the PFC. One view was that the dorsolateral areas are responsible for spatial working memory and the ventrolateral areas for non-spatial working memory. Another view proposed a functional distinction, arguing that ventrolateral areas are mostly involved in pure maintenance of information, whereas dorsolateral areas are more involved in tasks requiring some processing of the memorized material (Owen, 1997).

Brain imaging has also revealed that working memory functions are by far not limited to the PFC (Smith and Jonides, 1999). A review of numerous studies shows areas of activation during working memory tasks scattered over a large part of the cortex. There is a tendency for spatial tasks to recruit more right-hemisphere areas, and for verbal and object working memory to recruit more left-hemisphere areas. The activation during verbal working memory tasks can be broken down into one component reflecting maintenance, in the left posterior parietal cortex, and a component reflecting subvocal rehearsal,
in the left frontal cortex (Broca's area, known to be involved in speech production) \textit{(Smith et al., 1998)}.

The PFC has been found to be active in a variety of tasks that require executive functions. This has led some researchers to argue that the role of PFC in working memory is in controlling attention, selecting strategies, and manipulating information in working memory, but not in maintenance of information. The maintenance function is attributed to more posterior areas of the brain, including the parietal cortex. \textit{(Postle, 2006)}. Other authors interpret the activity in parietal cortex as reflecting executive functions, because the same area is also activated in other tasks requiring executive attention but no memory \textit{(Collette et al., 2006)}.

Working memory has been suggested to involve two processes with different neuroanatomical locations in the frontal and parietal lobes. First, a selection operation that retrieves the most relevant item, and second an updating operation that changes the focus of attention made upon it. Updating the attentional focus has been found to involve the transient activation in the caudal superior frontal sulcus and cortex. While increasing demands on selection selectively changes activation in the rostral superior frontal sulcus and posterior cingulate/precuneus \textit{(Bledowski et al., 2009)}. 
Effects of stress on working memory:

Working memory is impaired by acute and chronic psychological stress (Arnsten, 1998). Stress-induced catecholamine release in PFC rapidly decreases PFC neuronal firing and impairs working memory performance through feedforward, intracellular signaling pathways (Arnsten, 2009). Exposure to chronic stress leads to more profound working memory deficits and additional architectural changes in PFC, including dendritic atrophy and spine loss, (Radley et al., 2006) which can be prevented by inhibition of protein kinase C signaling (Hains et al., 2009).

Neural maintenance of working memory:

Much has been learned over the last two decades on where in the brain working memory functions are carried out. Much less is known on how the brain accomplishes short-term maintenance and goal-directed manipulation of information. The persistent firing of certain neurons in the delay period of working memory tasks shows that the brain has a mechanism of keeping representations active without external input. Keeping representations active, however, is not enough if the task demands maintaining more than one chunk of information. In addition, the components and features of each chunk must be bound together to prevent them from being mixed up. For example, if a red triangle and a green square must be
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remembered at the same time, one must make sure that "red" is bound to "triangle" and "green" is bound to "square". One way of establishing such bindings is by having the neurons that represent features of the same chunk fire in synchrony, and those that represent features belonging to different chunks fire out of synchrony (Raffone and Wolters, 2001). In the example, neurons representing redness would fire in synchrony with neurons representing the triangular shape, but out of sync with those representing the square shape. So far, there is no direct evidence that working memory uses this binding mechanism, and other mechanisms have been proposed as well (O'Reilly et al., 2003). It has been speculated that synchronous firings of neurons involved in working memory oscillate with frequencies in the theta band (4 to 8 Hz). Indeed, the power of theta frequency in the EEG increases with working memory load, (Klimesch, 2006) and oscillations in the theta band measured over different parts of the skull become more coordinated when the person tries to remember the binding between two components of information (Wu et al., 2007).
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C- LONG TERM MEMORY

Definition:

It is the memory in which information is stored permanently (Craik, 2000).

Table (1): Differences between short term memory and long term memory (Baddeley, 1966).

<table>
<thead>
<tr>
<th>Short term memory.</th>
<th>Long term memory.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1- Store information with strictly limited capacity and duration. (Information is not retained indefinitely).</td>
<td>1- Store much larger quantities of information for potentially unlimited duration (sometimes a whole life span).</td>
</tr>
<tr>
<td>2-Example: given a random seven-digit number we may remember it for only a few seconds before forgetting, suggesting it was stored in our short-term memory.</td>
<td>2-Example: we can remember telephone numbers for many years through repetition; this information is said to be stored in long-term memory.</td>
</tr>
<tr>
<td>3-Encodes information acoustically.</td>
<td>3-Encodes information semantically. (*)</td>
</tr>
<tr>
<td>4- Is supported by transient patterns of neuronal communication.</td>
<td>4- Are maintained by more stable and permanent changes in neural connections widely spread throughout the brain.</td>
</tr>
</tbody>
</table>
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<table>
<thead>
<tr>
<th>5- Dependent on regions of the frontal lobe (especially dorsolateral prefrontal cortex) and the parietal lobe.</th>
<th>5- The hippocampus is essential (for learning new information) to the consolidation of information from short-term to long-term memory, although it does not seem to store information itself. (***)</th>
</tr>
</thead>
</table>

(*) Baddeley (1966) discovered that after 20 minutes, test subjects had the most difficulty recalling a collection of words that had similar meanings (e.g. big, large, great, huge) long-term. Another part of long-term memory is episodic memory "which attempts to capture information.

(***) Without the hippocampus, new memories are unable to be stored into long-term memory, as learned from HM after removal of both his hippocampi, and there will be a very short attention span. Furthermore, it may be involved in changing neural connections for a period of three months or more after the initial learning.

Research has suggested that long-term memory storage in humans may be maintained by DNA methylation (Miller and Sweatt, 2007) or prions (Papassotiropoulos et al., 2005).

Long term memories are stored in the cerebral cortex. The verbal memories are lateralized to the left hemisphere. The visual memories are stored in the inferior region of the right temporal lobe. The visuo-spatial abilities are lateralized to the right hemisphere. Both prefrontal areas are responsible for performing arithmetic or repeating a list of words, as both are responsible for retrieval of part of memories from different areas of the brain (Ganong, 1996).
Types of Long Term Memory:

Information is stored permanently in long-term memory, which includes two components: declarative (DM) or explicit memory ("knows that") and nondeclarative (NDM) or implicit memory ("knows how"). Declarative memory can be further delineated into the episodic and semantic systems. The nondeclarative system includes procedural learning and priming (Craik, 2000).

Explicit and implicit memory are sometimes referred to as "declarative" and "procedural" memory, or "declarative" and "nondeclarative" memory respectively (Squire et al., 1993).

Explicit and implicit memories are sometimes referred to as "direct" and "indirect". That is to say, recall tests memory directly, while savings or priming test memory indirectly. It should be understood, though, that the direct-indirect distinction applies to memory tests and not to expressions of memory. Along the same lines, explicit and implicit memories are sometimes referred to as "intentional" and "incidental" respectively. That is to say, in recall tests subjects are instructed to intentionally remember some past event, while priming occurs incidentally when the subject is performing some non-memory task. The intentional-incidental distinction reminds us that there are two aspects of consciousness relevant to memory: conscious awareness and conscious control (Butler and Berry, 2001).
Declarative memory (sometimes referred to as explicit memory) is one of two types of long term human memory. It refers to memories which can be consciously recalled such as facts and knowledge its counterpart is known as non-declarative or procedural memory, which refers to unconscious memories such as skills (e.g. learning to ride a bicycle). Declarative memory can be divided into two categories: *episodic memory* which stores specific personal experiences and *semantic memory* which stores factual information (*Ullman, 2004*).

*Semantic memory* is that which stores general factual knowledge that is independent of personal experience. Examples include types of food, capital cities, lexical knowledge (vocabulary), etc. (*Tulving, 1972*).

Semantic memory refers to knowledge about factual information, such as the meaning of words. Semantic memory is independent information such as information remembered for a test. In contrast with episodic memory older adults and younger adults do not show much of a difference with semantic memory, presumably because semantic memory does not depend on context memory (*Wood et al., 2011*).

*Episodic memory* is that which stores specific events such as attending a class or flying to France. Retrieval of these memories can be thought of as mentally reliving the past events they concern. Episodic memory is believed to be the system
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that provides the basic support for semantic memory. "which attempts to capture information such as "what", "when" and "where"? With episodic memory individuals are able to recall specific events such as birthday parties and weddings (Tulving, 1972).

Episodic memory refers to memory for specific events in time, as well as supporting their formation and retrieval. Some examples of episodic memory would be remembering someone's name and what happened at your last interaction with each other (Ranganath et al., 2005). Older adults have worse episodic memories than younger adults because episodic memory requires context dependent memory (Spaniol et al., 2006).

Cohen and Squire (1980) drew a distinction between declarative knowledge and procedural knowledge. Procedural knowledge involves “knowing how” to do things. It included skills, such as “knowing how” to playing the piano, ride a bike; tie your shoes and other motor skills. It does not involve conscious (i.e. automatic) thought. For example, we brush our teeth with little or no awareness of the skills involved. Whereas, declarative knowledge involves “knowing that”, for example London is the capital of England, zebras are animals, your mums birthday etc. Recalling information from declarative memory involves some degree of conscious effort information is consciously brought to mind and “declared”.


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Procedural memory:

The type of memory that lets us perform some actions (such as writing, riding a bike and tie their shoes) without consciously thinking about these activities. Research into implicit memory indicates that it operates through a different mental process from explicit memory (Schacter, 1987).

Implicit memory/Procedural memory refers to the use of objects or movements of the body, such as how exactly to use a pencil, drive a car, or ride a bicycle. This type of memory is encoded and it is presumed stored by the cerebellum and the striatum. The basal ganglia are believed to mediate procedural memory and other brain structures and are largely independent of the hippocampus. Procedural memory is considered non-declarative memory or unconscious memory which includes priming and non-associative learning (Wood et al., 2011).

A characteristic of procedural memory is that the things that are remembered are automatically translated into actions, and thus sometimes difficult to describe (Schacter, 2011).

Priming Effects in Amnesia and Normal Memory:

Priming refers to the phenomenon that once an object has been perceived or processed, it can be more easily perceived or processed the next time it is encountered (Squire, 1992).
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Priming has relevance in the educational environment, particularly with regard to the use of advance organizers prior to the presentation of new to-be-learned information. Advance organizers might include reviewing the vocabulary prior to reading a chapter or book, reading the objectives at the beginning of chapters and/or the questions at the end of chapters prior to reading the chapters and discussing the to-be-learned material prior to having students read about it (Baddeley, 1996).

Studies of patients with the amnesic syndrome associated with bilateral damage to the hippocampus and related structures in the medial temporal lobe, or to the mammillary bodies and related structures in the diencephalon in an experiment in which amnesic patients were asked to study a list of familiar words. Compared to control subjects, the patients performed very poorly on standard tests of recall and recognition. However, when they were presented with three-letter stems or fragments, and asked simply to complete the cues with the first word that came to mind, amnesics and controls were equally likely to complete the cues with items from the studied list (Warrington and Weiskrantz, 1973).

This is a priming effect, in which the processing of one item influences the processing of another item. In positive priming, the prime facilitates processing of the target; in negative priming, the prime inhibits processing of the target.
this instance, the priming effect indicates that the studied items were encoded in memory, retained in storage, and influenced performance on the completion test. The fact that equivalent levels of priming occurred in neurologically intact subjects, who remembered the priming episode normally, and amnesic patients, who had very poor memory, indicates that priming can be dissociated from conscious recollection. The dissociation between priming and recall in amnesic patients indicates implicit memory can persist in the absence of explicit memory (Schacter, 1987).

**Figure 11:** Functional classification of memory systems (Squire et al., 1993 and van Strien et al., 2009).
Phenomena Associated with Long Term Memory

**Illusion-of-truth effect:**

Implicit memory leads to the illusion-of-truth effect, which suggests that subjects are more likely to rate as true those statements that they have already heard, regardless of their veracity (a person is more likely to believe a familiar statement than an unfamiliar one) (*Hasher et al., 1977*).

**Primacy and recency effects:**

**Primacy effect** is a situation in which recall of information is enhanced when individuals have no information stored in STM and their attention to new stimuli is at its peak), as happens, for example, in more easily recalling words presented at the beginning of a list (*Tulving, 1972*).

**Recency effect** is a situation in which recall of the most recently presented information is also enhanced as happens, for example, in more easily recalling the words presented at the end of a list (*Tulving, 1972*)
Models of Memory

Models of memory provide abstract representations of how memory is believed to work. Below are several models proposed over the years by various psychologists. There is some controversy as to whether there are several memory structures. Models include:

I- Working memory models include:

1- Baddeley and Hitch's working memory model.

2 - Cowns model.

II- Multi Store Model of Memory - Atkinson and Shiffrin, 1968.

The multi store model (Atkinson and Shiffrin, 1968) is a classic model of memory. It is sometimes called the modal model or the dual process model.

Atkinson and Shiffrin (1968) suggest that memory is made up of a series of stores (Figure 12).
The multi store model (Atkinson and Shiffrin 1968) describes memory in terms of information flowing through a system.

- Information is detected by the sense organs and enters the **sensory memory**.

- If attended to this information enters the **short term memory**.

- Information from the STM is transferred to the **long-term memory** only if that information is rehearsed.

- If rehearsal does not occur, then information is forgotten, lost from short term memory through the processes of displacement or decay.
Weaknesses of multi store model: *(Zlonoga and Gerber, 1986).*

- The model is **oversimplified**, in particular when it suggests that both short-term and long-term memory each operate in a single, uniform fashion. We now know is this not the case. It has now become apparent that both short-term and long-term memory are more complicated than previously thought. For example, the Working Model of Memory proposed by Baddeley and Hitch (1974) showed that short term memory is more than just one simple unitary store and comprises different components (e.g. central executive, visuo-spatial etc.).

- The model also shows all the memory stores as being a single unit whereas research into this shows differently. For example, short-term memory can be broken up into different units such as visual information and acoustic information. Patient KF proves this. Patient KF was brain damaged and had problems with his short term memory. He had problems with things such as spoken numbers, letters and words and with significant sounds (such as doorbells and cats meowing). Other parts of short term memory were unaffected, such as visual (pictures). It also shows the sensory store as a single unit whilst we know that the sensory store is split up into several different parts such as taste, vision, and hearing.
In the case of long-term memory, it is unlikely that different kinds of knowledge, such as remembering how to play a computer game, the rules of subtraction and remembering what we did yesterday are all stored within a single, long-term memory store. Indeed different types of long-term memory have been identified, namely episodic (memories of events), procedural (knowledge of how to do things) and semantic (general knowledge).

The model suggests rehearsal helps to transfer information into LTM but this is not essential. Why are we able to recall information which we did not rehearse (e.g. swimming) yet unable to recall information which we have rehearsed (e.g. reading your notes while revising). Therefore, the role of rehearsal as a means of transferring from STM to LTM is much less important than Atkinson and Shiffrin (1968) claimed in their model.

However, the models main emphasis was on structure and tends to neglect the process elements of memory (e.g. it only focuses on attention and rehearsal).

The multi store model has been criticized for being a passive/one way/linear model.

Long-term memory (LTM) is memory in which associations among items are stored, as part of the theory of a dual-store memory model. The division of long term and short
term memory has been supported by several double dissociation experiments (Wood et al., 2011). According to the theory, long-term memory differs structurally and functionally from sensory memory, working memory, short-term memory, and intermediate-term memory. While short-term and working memories persist for only about 20 to 30 seconds, information can remain in intermediate-term memory for 5 to 8 hours and in long-term memory indefinitely. This differs from the theory of the single-store retrieved context model that has no differentiation between short-term and long-term memory. Long term memory is an important aspect of cognition. LTM can be divided into three processes: encoding, storage, and retrieval. Encoding of long-term memory occurs in the medial temporal lobe and damage to the medial temporal lobe is known to cause anterograde amnesia (Axmacher et al., 2010).

III- Single-store memory model:

An alternative theory is that there is only one memory store with associations among items and their contexts. In this model, the context serves as a cue for retrieval, and the recency effect is greatly caused by the factor of context. Immediate and delayed free-recall will have the same recency effect because the relative similarity of the contexts still exist. Also, the contiguity effect still occurs because contiguity also exists between similar contexts (Howard and Kahana, 2002).
Meta-Memory

The term ‘meta-memory’ refers to an individual’s awareness of his or her own memory processes and the ways in which storage and retrieval of information can be enhanced. Efficient learners appear to know a great deal about how best to internalize important information, how to offset the effects of forgetting, and what strategies to use to maximize recall (Byrnes, 2001).
Types of Memory

Meta-memory increases with age, but for some students with learning difficulties, time and effort may need to be spent within intervention programs to raise children’s awareness of their own memory processes and how these can be monitored and made more effective. In particular, as students get older it becomes possible and desirable to teach the effective use of mnemonic strategies as part of study skill development (Forness et al., 1997).

Forgetting

It is perfectly natural to forget information. We cannot, and do not need to, remember everything. As Haberlandt (1999) points out: forgetting fulfills a selective function by uncluttering our memories and thereby increasing the chance of recalling important information.

The most common reasons for failing to remember something important include:

- The information was of no personal significance.
- Failing to give the information sufficient attention when it is first encountered.
- Not rehearsing the information with the intention of remembering it.
Types of Memory

- Decay or fading of information over time; sometimes described as ‘passive loss of memory trace’.

- New or conflicting information interfering with storage and recall of earlier information. The term ‘proactive interference’ is used for situations where something you already know prevents you from easily assimilating and recalling something new. ‘Retroactive inhibition’ refers to new information preventing the easy recall of prior knowledge.

- Lack of relevance or meaningfulness, in the sense that the new information was not linked effectively with other stored information. It could be said that the information had not been effectively accommodated into existing schemata.

- Failure to use imagery to assist storage and retrieval.

- Inability of the learner to ignore distractions during learning.

- Detrimental emotional states, such as stress and anxiety.

Many of the above factors account for problems in recall that students with learning difficulties exhibit. It is widely acknowledged that students with learning disabilities lack good attention to task and do not use effective study and memorisation strategies (Ormrod, 2003). The problems are
most evident in students with attention deficit and hyperactivity disorder (ADHD).

The duration and nature of typical lessons in school also influence learning and remembering. It is said that human attention span, and the active use of working memory, begin to weaken significantly after about 10 to 20 minutes (Sousa, 2001a). To hold students’ attention and to optimise their processing and assimilation of information the activities used within the lesson should change at frequent intervals. Variety and active involvement both help students to learn and remember. Gage and Berliner (1998) indicate that the more teachers can get physical, auditory, and visual stimuli combined with the meaningful presentation of information, the more likely that the information will be learned and retrieved easily. Physically active, multisensory learning is more likely to result in longer and fuller retention than passive learning. The challenge for the teacher is to find ways of ensuring that students do store and remember important information and skills.
Types of Learning

Definition:

Learning is commonly defined as a process that brings together cognitive, emotional, and environmental influences and experiences for acquiring, enhancing, or making changes in one's knowledge, skills, values, and world views (Illeris, 2000).

Types of learning:

Conventional psychology has identified at least four different types of learning that occur in normal waking consciousness: (a) Classical (respondent) conditioning, (b) operant (instrumental) conditioning, (c) observational (vicarious) learning, and (d) cognitive (information-processing) learning (Neher, 1990).

A-Classical conditioning:

Conditioning is regarded as a fundamental process of learning. Conditioning is based upon spontaneous associative processes whereby two stimuli become joined together in experience. Two main types of associative learning are respondent (classical) conditioning and operant (instrumental) conditioning. Respondent conditioning is regarded as a nonconscious, involuntary, automatic form of associating two
stimuli together, whereas operant conditioning is viewed as a conscious, voluntary, deliberative form of associating a response with its consequence such that the behavior tends to be repeated following pleasant consequences or diminished in frequency following unpleasant consequences (Walsh and Vaughan, 1980).

Respondent conditioning is the form of learning that occurs when two stimuli (US-CS) are associated together in experience. Greatly oversimplified, Pavlovian conditioning has four key elements: (a) an unlearned unconditioned stimulus (US), (b) an unlearned, unconditioned response (UR), (c) a to-be-conditioned neutral stimulus (CS), and (d) a to-be-learned conditioned response (CR). The association between the US and the UR is biologically wired-in because it is an involuntary, physiological reflex, is therefore Respondent conditioning, in other words, builds upon the reflexes we are born with. If you eat bad food (US), you get sick (UR). Cold temperatures (US) produce shivering (UR). A sudden, loud noise (US) results in a pounding heart (UR). The connection between the US and the neutral CS is the to-be-learned association. The neutral CS can be anything you can imagine – a mailbox, a room, the smell of a perfume, a building, and a person. Repeated pairings of an US-UR reflex with a neutral CS will gradually cause the CS alone to produce a modified version of the UR in the absence of the US. This modified UR is called a CR and tends to be
similar, but not identical, to the UR (less intense, slower to appear). For example, suppose Diana became sick (UR) with the flu (US), after she ate egg rolls and Moo Gu Gai Pan (CS). Now, if she tries to eat Moo Gu Gai Pan (CS) or even thinks about it, she feels sick to her stomach (CR), because she has associated her experience of being sick with the flu (US-UR) with her once favorite Chinese dinner (CS). Most US-UR reflexes have a pleasurable or aversive emotional component, and through respondent conditioning that pleasurable or aversive component becomes connected to the CS to elicit what is called a “conditioned emotional response” (CER) (Garcia et al., 1989). When the US and the CS are no longer paired, extinction of the CR occurs, although the CR may resurrect spontaneously in response to the CS long after the conditioning process has been concluded a phenomenon called "spontaneous recovery." Stimuli and responses can be differentiated (or discriminated) and generalized across comparable situations so that stimuli similar in form or appearance to the original US can elicit prior conditioned responses. Memories themselves can become “conditioned” in this way. For instance, there may be some past experience that occurred where things did not turn out quite the way the individual would have liked them. As a result, when a visual image of that past experience comes into mind and the person thinks about it, he or she gets the same kind of feelings that he or she had as a result of that experience (Rescorla, 1988).
**B- Operant (instrumental) conditioning:**

Operant conditioning is the type of learning that occurs when we associate a response (behavior) with a stimulus (a consequence, effect, or outcome). The stimulus here is no longer defined as a part of the physical environment or physical organism that elicits a response, either reflexively or through classical conditioning. The stimulus situation merely "sets the occasion" for the behavior to occur. The behavior causes the consequences, which in turn, causes the behavior to either reoccur or not reoccur in the same situation in the future. Operant conditioning has three key elements: Antecedent (A) context cues or stimuli that set the occasion for behavior, the operant or instrumental behavior (B) emitted, and the consequences (C) that follow or are caused by the behavior. A stop sign (A) sets the occasion for stepping on the brake (B) that stops the car (C). Operant conditioning is “learning from consequences.” Consequences can be reinforcing as when some pleasurable stimulus is presented or some aversive stimulus is removed following behavior, in which case the behavior increases in frequency in similar contexts. If the telephone rings repeatedly (A), you answer it (B), and a friend always speaks (C), this A-B-C series of events increases the probability of you answering the telephone the next time it rings (behavior increases). On the other hand, consequences can be punishing as when some pleasurable stimulus is removed or some
Types of Learning

aversive stimulus is presented following behavior, in which case the behavior decreases in frequency in similar situations. If the telephone rings repeatedly (A), you answer it (B), and no one ever answers (Sp), the probability of your answering the telephone the next time it rings diminishes (behavior decreases) \cite{Skinner1974}.

Operant conditioning can be quite complex involving primary and secondary reinforcers and punishers, prompts and fading, shaping, token reinforcement and contingency contract programs. Operant conditioning intertwines in intricate ways with respondent conditioning in natural settings of everyday life \cite{Baldwin2001}. Respondent conditioned reflexes can be modified by operant conditioning, for instance. With the help of operant conditioning, Diana can learn to enjoy her favorite Chinese food again, Yvonne learns to drive more carefully on icy roads, and Beth learns to take a shower without feeling frightened.

C-Latent learning, insight learning, and observational learning.

Latent learning is the capacity to form inner mental representations of their outer physical environment \cite{TolmanHonzik1930}.
In **Insight learning:**

Insight learning is the ability to suddenly “get the point” of a problem-solving situation and arrive at a solution (*Kohler, 1970*).

**Observational learning:**

Observational learning is the learning in which new behaviors are learned and old behaviors are inhibited or disinhibited, as a result of observing other people’s behavior. The observed behaviors may be modeled or imitated later depending on the consequences the model receives for his or her behavior, the competence and likeability of the model, the nature and complexity of the modeled behavior, contextual cues, and other factors (*Bandura, 1986*).

**D-Information processing:**

The processing of information begins at the level of *sensation*, in the so-called *sensory register*. The individual is bombarded constantly by stimuli in the environment (sounds, colours, textures, aromas) and these are either attended to or ignored. An individual can only attend to limited amounts of information at one time, so many sensations are not actively processed. Information in the sensory register lasts very briefly less than a second for visual stimuli; perhaps two or three seconds for auditory information. Information that is *attended*
to and thus *perceived* then moves into short-term or working memory for processing. If the information is relevant to the learner at that moment, and particularly if it links with what the learner already knows, it will pass in some encoded form (for example, visual images, words) into longer-term memory. Cognitive psychologists usually refer to the information ‘stores’ involved at various stages in processing information as *sensory register, short-term memory, working memory, and long-term memory* (Figure 14). Attention and memory are intimately involved in all deliberate acts of learning; and weaknesses in attention and memory are implicated in many cases of learning failure (*Ormrod, 2003*).
Figure 14: Architecture of the human information processing system (Farnham-Diggory 1992).
Types of Learning

While there are several different types of information processing, two important groups are (Table 2) (National center of learning disabilities, 2008).

Table 2: Visual and auditory processing (National center of learning disabilities, 2008).

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<thead>
<tr>
<th>1- Visual Processing</th>
<th>2- Auditory Processing</th>
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<td>Visual Discrimination</td>
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<td>Visual Sequencing</td>
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<td>Visual Memory</td>
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<td>Visual Motor Processing</td>
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<td>Visual Closure</td>
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<td>Spatial Relationships</td>
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<td>Auditory Discrimination</td>
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<td>Auditory Memory</td>
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<td>Auditory Sequencing</td>
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Categories of learning:

There have been many and varied attempts to categorise examples of learning.

The most obvious categories that appeal to common sense comprise:

- Knowledge
- Skills
- Attitudes and values
Types of Learning

These three broad categories or domains have provided the basic framework for planning a wide variety of learning objectives within school curricula, as reflected in the vast literature on educational programming and curriculum design (Gunter et al., 2002).

Most schools would readily acknowledge their responsibility to facilitate learning in the three domains. There are other more detailed ways of analysing learning that subdivide the three broad domains into specific categories of learning. For example (Gagne and Wager, 2002) developed a taxonomy for categorising different forms of learning. His early model was complex and contained a variety of sub-types such as signal learning, stimulusresponse learning, discrimination learning, chaining, verbal association, rule learning and concept learning. These categories served a useful purpose in contexts where psychologists were carrying out controlled experiments in human learning, but the categories were more difficult to apply in school contexts where most episodes of learning involve simultaneous and integrated use of several subtypes of learning within one task or lesson.

Mastropieri and Scruggs (2002) still advocate a very similar taxonomy of learning for use when designing effective instruction for students with special needs. Their taxonomy comprises: discrimination learning, factual learning, rule
Types of Learning

learning, procedural learning, conceptual learning, and problem solving and thinking.

In a later analysis, (Gagne et al., 1992) moved toward a much broader system of classification using five main categories of learning: physical skills, information, intellectual skills, cognitive strategies, and attitudes.

Physical (psychomotor) skills:

Psychomotor skills are learned capabilities that involve the coordination of brain, muscles, hand and eye. Psychomotor skills include such diverse activities as cutting with a pair of scissors, getting dressed, swimming, walking, eating with a spoon, using a computer keyboard, writing, riding a bicycle, and driving a car. Children, without direct teaching, acquire very many physical skills through imitation and trial and error, but most of the physical skills associated with performance in school need to be directly taught and frequently practised. It is generally accepted that very large amounts of practice are needed in order that motor skills can eventually be performed with a high degree of automaticity.

In the early stages of teaching a new motor skill, modelling, imitation, and precise verbal instruction are extremely important. Sometimes direct physical movements is required, when helping a young child or a child with a physical disability to form the numeral 7 for example; or an older child
to experience the movement for a backhand stroke in tennis. It is also clear that corrective feedback is necessary to help learners improve their motor skill performance. Some of this feedback comes from the instructor, but an even more essential component of feedback must come from the learner’s own internal self-monitoring of performance, resulting in self-correction (*Howe, 1998*).

**Acquiring information:**

This type of learning involves the acquisition of factual information (knowledge) that the learner is able to state and use. Examples include factual knowledge such as, ‘Paris is the capital of France’; ‘7 + 2 = 9’. This type of knowledge is known as *declarative knowledge* to differentiate it from *procedural knowledge* which involves knowing the steps in carrying out a procedure. A sound knowledge-base of information provides much of the raw material utilised in the performance of intellectual skills for example, thinking and reasoning usually require the retrieval and application of some factual information (*Hirsch, 2000*).

When used in combination with cognitive strategies and intellectual skills, information enables an individual to reason, reflect, solve problems, explain, and generate new ideas. Information is of most value (and is most easily accessed) when it links with related information also stored in the learner’s
Types of Learning

memory. Isolated fragments of information are often easily forgotten or are difficult to access. Information is more readily remembered when it is linked directly to prior learning and when students are encouraged to process it actively. Students acquire huge amounts of factual information incidentally in daily life, particularly in this era of communication technology. In school, teachers still need to set high priority on making sure students are building a deep and relevant knowledge base. A teacher’s task is to make key information available to students and to help them make appropriate connections with prior knowledge and experience. Sometimes, important curriculum information needs to be conveyed to students by direct teaching and through use of appropriate texts and computer programs. At other times, information is readily acquired through students’ independent study, group work, and discussion. The currently popular constructivist theory of learning suggests that the acquisition of information occurs best when learners actively engage in exploratory modes of learning. Some instances of learning difficulty can be traced to lack of automaticity in the retrieval of essential declarative knowledge, or in the application of procedural knowledge. A learner who lacks automaticity has to expend inappropriately large amounts of concentrated effort in recalling information or remembering the simple lower-order steps in a cognitive process. He or she is therefore hampered in engaging in higher-order thinking. An example might be difficulty in comprehension when reading
due to lack of automaticity in word recognition and phonics. The reader’s efforts have to be focused on basic decoding of the print on the page rather than reading for meaning. Similarly in mathematics, poor automaticity with recall of simple number facts, or a weakness in recalling steps in a multiplication algorithm, will distract the student from reflecting logically upon the features of a contextual problem. A student’s failure to perform well, or a teacher’s failure to teach well, may be due to inadequate declarative knowledge, inadequate procedural knowledge, or both’ (Gage and Berliner, 1998).

Developing intellectual skills:

Intellectual skills represent the cognitive abilities that enable individuals to interact successfully with their environment and tackle new tasks effectively. Intellectual skill development involves the acquisition of concepts, rules, routines, and symbol systems. Learning an intellectual skill usually means learning how to perform the cognitive processes involved in thinking, reasoning and problem solving (Gagne, 1984) indicates that much human behaviour is ‘rule-governed’.

Basic rules include principles such as understanding that printed language in English is sequenced from left to right, that in oral language words must be produced in a particular sequence to obey the rules of grammar, that traffic lights operate in set sequence, and that birds and animals can be
Types of Learning

classified into species according to their specific characteristics. Learners create higher-order rules as they attempt to work out solutions to problems. They draw upon concepts and basic rules already known and combine them in new ways. For example, a preschool child solves the problem of how to assemble the track for a new toy train by combining prior knowledge about the ways in which some objects can be linked together with prior knowledge that the tracks provided for other moving toys often form a circle. In carrying out this task the child has combined fragments of prior knowledge and utilised previous experience in a unique way to solve a new problem. In doing so the child has acquired a set of principles that might be used again in similar circumstances (in other words, can be generalised or transferred).

Teaching lower-level intellectual skills (discriminations, simple concepts, symbol recognition) usually involves direct explanation, demonstration, and guided practice. Basic rules are also best taught through direct instruction, followed by application. However, higher-order rules have to be constructed by the learner, who therefore needs to be given opportunity to solve problems and apply accumulated knowledge to new situations. This level and type of learning suggests the need for an enquiry or problem-solving classroom approach. What is learned in this domain of intellectual skills is mainly procedural skills – knowing how, rather than knowing that (Gagne et al., 1992).
Learning cognitive and metacognitive strategies:

Cognitive strategies can be regarded as mental plans of action that learners develop to help them approach any learning task or problem. An effective cognitive strategy enables learners to plan what they will do and then monitor and modify their own thoughts and actions as they proceed. We refer to this ability to ‘think about our own thinking’ as metacognition (Kershner, 2000). For example, a student trying to solve a problem may think, ‘This isn’t working out correctly – I had better try a different way’. This student is effectively monitoring and adapting his or her own performance. The child who thinks, ‘I need to write this down to help me remember it’, is also illustrating a metacognitive self-regulating strategy.

Metacognitive processes that supervise and control our cognition are sometimes termed internal executive processes (Gourgey, 2001). These executive processes enable us to plan, monitor and evaluate performance throughout the execution of a task. It is now believed that all academic and intellectual tasks, like writing an essay, reading with comprehension, solving a mathematical problem, analysing data for a project, are most easily and effectively accomplished through the application of cognitive and metacognitive strategies. It is also believed that many learning difficulties are caused by students’ lack of appropriate cognitive strategies and relative absence of metacognition (Bradshaw, 1995).
It is proving to be possible to teach students to use cognitive strategies more efficiently, thus resulting in an improved rate of success. In general, cognitive strategies are taught by direct explanation and modelling, with the teacher ‘thinking aloud’ as he or she demonstrates an effective strategy for a given task. The learners are encouraged to observe and develop similar ‘self talk’ to help them apply the new strategy effectively (Graham and Harris, 2000a).

Developing attitudes, beliefs and values:

Gagne et al. (1992) define an attitude as an internal state that affects an individual’s choice of personal action toward some object, person, or event. Many of the most important goals of education deal with the development of positive and productive attitudes, beliefs and values in students. They may be acquired through a combination of observing a model displaying the particular attitude, reflecting upon the outcomes from the actions of self and others, from peer group pressure, and to some degree through active persuasion and the use of incentives (rewards). Once they are acquired, attitudes tend to be reinforced when others agree with and support them. Some of the most significant beliefs and attitudes learners develop are associated with their own competence and efficacy as learners; and these beliefs are shaped by the extent to which they succeed or fail in school (Eccles et al., 1998).
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While the five categories of learning identified by Gagne et al. (1992) are extremely useful for analyzing learning in a school context and for identifying appropriate methods to facilitate learning in the five domains.

There are other ways of classifying human learning into:

1- Intentional learning and incidental learning:

Good and Brophy (2002) make an important distinction between two broad categories of learning, intentional and incidental learning. Intentional learning operates in a situation where the learner is deliberately setting out to acquire some particular knowledge, skill or strategy, and is putting focused effort into the task. Incidental learning, on the other hand, occurs when an individual is not making any conscious effort to acquire information or skill but is merely exposed by chance to some experience such as passively observing the actions of another person, watching a film, or over-hearing a conversation. It is believed that many of the attitudes, beliefs, and values we hold are acquired mainly through incidental learning rather than from deliberate instruction. Some contemporary classroom approaches rely fairly heavily on children’s incidental learning capacity to acquire basic skills and concepts. Advocates of these approaches regard incidental learning as preferable to direct instruction because it is considered to be a more ‘natural’
way of acquiring information and skills (Gilles, 2006). Similarly, it has been argued that basic number skills and concepts will be discovered effectively through activity-based, problem-solving methods, rather than from direct teaching, drill and practice but indirect methods used exclusively are inappropriate for the types of learning involved in the initial acquisition of basic literacy and numeracy skills (Hirsch, 2000). Many psychologists and educators now believe that important facts and skills are taught most effectively in the early stages by direct instruction (Kauffman, 2002).

The current view is that effective teaching of basic academic skills requires a careful combination of student-centred activity and direct teaching. It is also believed that certain students make significantly more progress when directly taught than when left to discover important concepts for themselves (Graham and Harris, 1994). One potential cause of learning difficulty for some students is lack of direct instruction in curriculum areas where and when it is most needed.

2- Observational learning:

Observational learning, as the term implies, is learning that occurs when a person observes and imitates someone else’s responses or behaviour, or when information and concepts are acquired without active participation. In many instances learning by observation and imitation is a quick and effective
process, and many typical lessons in classrooms rely on some degree of observation and modelling by the learners. Learning by observation requires the activation of four processes (*Santrock, 2001*):

- **Attention**: the learner must obviously be attending to the actions of the model and taking in the information presented.

- **Retention**: the learner must store the observed actions or information in memory.

- **Reproduction**: the learner can recall and imitate (albeit imperfectly) what they have seen.

- **Reinforcement or incentive**: the learner needs to be motivated to want to reproduce and carry out the observed behavior or recall the information.

Observational learning can be intentional or incidental. When modeling and imitation are used as teaching strategy for example, when teaching a new skill to students with intellectual disability the behaviour to be learned may need to be broken down into several smaller steps with each step demonstrated and rehearsed many times to facilitate the eventual development of the complex skill or behaviour.
3- **Rote learning versus meaningful learning:**

Most psychologists and educators differentiate between rote learning and meaningful learning. In recent years it has become popular to criticize the use of rote learning methods, partly because the learner may commit to memory information which is not understood and is therefore of no functional value. Material that is forced into memory by drill-type repetition without understanding tends to remain isolated within the learner’s long-term memory, rather than being connected with prior knowledge (*Rosenshine, 1995*). For this reason, information stored by rote is not easily retrieved when needed. Rote-memorized material is also easily forgotten unless rehearsed frequently, and is unlikely to generalize to new contexts. Students who lack effective learning strategies frequently resort to rote learning, even when its use is not appropriate. There is an important difference between rote learning and memorization. It should be mentioned that in some cultures (for example, Chinese) memorizing important information that is understood by the learner is regarded as a necessary and effective way of mastering subject matter and of eventually deepening understanding (*Watkins and Biggs, 2001*). Such use of memorization is not strictly speaking learning by *rote* but rather is an example of appropriate *over learning*. 
In meaningful learning, new information and new concepts are connected with the learner's prior knowledge. Meaningful learning thus contributes in a major way to the development of what (Gagne et al., 1992) refer to as ‘intellectual skills’ and ‘cognitive strategies’. Intellectual skills and strategies build upon each other to form increasingly elaborate mental structures that permit the operation of higher-order cognitive processing required in problem solving, planning and decision-making (Gredler, 2001).

Learning Hierarchies

Gredler (2001) defines a learning hierarchy as, ‘An organized set of intellectual skills from simple to complex that indicates the set of prerequisites for each capability to be learned’. Such hierarchies are frequently represented on paper as flow-charts, with the learning outcome or goal identified at the top and the essential prior learning stages sequenced in descending order of complexity to the most basic at the bottom. The flow chart produced when we analyse tasks in this way can serve as a useful tool for diagnosing points of difficulty, can help teachers sequence instruction effectively. Task analysis is extremely useful and is very widely used by teachers working in special education settings. In the wider context, it is reported that teacher effectiveness that a key characteristic of highly effective teachers is that they do sequence the learning of a new topic into easy steps (Kauchak and Eggen, 2003).
For example, in arithmetic the ability to carry out the written algorithm for long division is built upon the ability to carry out the simple division process. Ability to perform simple division is built upon an understanding of the concept of sharing or sub-dividing groups of real objects, together with the skill of counting objects, and the ability to recognise and write numerals.

The process and Sequence of Learning:

Learning occurs over a period of time, and moves through different stages, rather than occurring as a result of a single moment of experience. Most types of learning take more time to accomplish if the learner has an intellectual impairment (Block, 1973).

The stages through which a learner progresses when acquiring new knowledge, skills and strategies can be summarised as follows: (Mastropieri and Scruggs, 2002).

1- Attention to task.

2 – Acquisition.

3- Application.

4- Fluency (automaticity).

5- Maintenance.
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6- Generalization.

7- Adaptation.

Individual difference among learners is the time they need to take at each stage.

Attention to task: Underpinning all stages of learning is attention. Many learning problems begin at the point of attention (Rooney, 2002). Howse et al. (2003) report that at-risk children tend to display much poorer ability to regulate their own attention, are easily distracted, and do not stay cognitively alert during a task. Failing to give attention to the task or to the content of a lesson makes it virtually impossible for the student to acquire and store the related knowledge, skills and strategies.

Acquisition, application and fluency:

The first stage in acquiring a new skill may reflect a high error rate until the learner has had adequate successful practice. For example, a very young child using the ‘mouse’ to move the cursor carefully on the computer screen may at first have very great difficulty in coordinating hand and eye (acquisition phase). After sufficient practice, the actions become more controlled, and eventually the child can move the cursor automatically without deliberate thought (fluency phase).

Teaching strategies involving frequent practice, application and reinforcement are necessary to ensure fluency.
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and automaticity. Many learning difficulties can be traced to lack of practice, or to inappropriate practice in the form of decontextualised exercises.

The acquisition phase in learning frequently takes much longer than many teachers realise, and some learning problems are the direct result of students being moved too rapidly through the acquisition and application stages (Mastropieri and Scruggs, 2002).

**Maintenance:** Forgetting (decay) occurs if the learner does not make use of the stored information or skill for any purpose or if the learner is required to learn more material of a very similar nature (interference) (Snowman and Biehler, 2003). Constant practice through application and regular rehearsal and review ensure that the skill is maintained over time.

**Generalization:** Generalization occurs when the student recognizes any situation or problem where the same information, skill or strategy can be applied. This is the most difficult level of learning, and it requires that teaching must occur across different contexts and with frequent reviews and revision (Gresham, 2002). Students with learning difficulties, particularly those with intellectual disability, have great trouble in generalizing new knowledge and skills. For example, students will need to be shown how to apply a measurement technique taught in mathematics to tasks set in geography.
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lessons. Teaching for generalization is an essential feature of effective instruction, particularly for students with intellectual disability or learning difficulty.

Adaptation: Adaptation occurs when the learner has fully mastered the concept, skill, or strategy and can modify it to suit the changing demands of different situations and new contexts. It represents the highest level of mastery and is essential for independence in learning (Henson and Eller, 1999).

Theories of Learning

Theories of learning are usually categorised as behavioural, cognitive, or neobehavioural.

I-Behavioral theory

Behavioural learning theorists consider that all behaviour is learned and that learning occurs as a result of the effect of one’s behaviour on the environment. A learner’s actions and responses are in some way either rewarded or punished, and thereby strengthened or weakened. One underlying principle within behavioural theory is that when an action or response produces a pleasant or rewarding outcome that behaviour is likely to be repeated (Thorndike’s Law of Effect) and the more the response is repeated the more it is strengthened (Thorndike’s Law of Exercise) (Tan et al., 2003 and Thorndike, 1927). In contrast, responses that bring displeasure
or pain are likely to weaken and fade. These principles govern much of what goes on in various ways in typical classrooms.

II- Cognitive theories of learning

Cognitive learning is an internal mental phenomenon. (Eggen and Kauchak, 2003) state that from a cognitive perspective, learning is a change in ‘mental structures’. Cognitive learning theories deal with the issue of how people process and store information to gain an understanding of themselves and the environment, and how their thinking and reasoning influence their actions and reactions (Henson and Eller, 1999). Cognitive psychology explores interrelationships among variables involved in learning, such as perception, attention, memory, language, motivation, concept development, reasoning and problem solving. Cognitive theories underpin the currently popular constructivist approach to learning and are influencing classroom practice to a very significant degree. Constructivist theory sees learners as active participants in the process of learning, seeking to interpret and make meaning from multiple sources of information by linking them with what is already known (Eysenck and Keane, 2000).
III- Neobehaviourism

Neobehavioural (or cognitive-behavioural) theories of learning are positioned somewhere between behavioural and cognitivist explanations, combining essential elements of both. Tan et al. (2003) state that the term neobehaviourism covers theories and models based on the belief that changes in behavior (learning) are the net result of environmental influences interacting with innate predispositions and processes within the learner.

It is believed that learners do not passively respond to reinforcement and other environmental feedback, as extreme behaviourists assume; and nor do they simply process information without involvement of feelings, beliefs and emotions as perhaps the cognitivists assume. Environmental influences on learning are mediated by many different internal factors. Emotions evoked during learning affect both the ways people learn, their memories of events, their perceptions of their own ability, and their future attitude toward engaging in similar activities (Howe, 1998).

Representing Information in Long-term memory:

Information storage is often categorized as declarative knowledge (facts, definitions, propositions, rules, etc.) or procedural knowledge (knowing how to perform a cognitive
task or action). Declarative knowledge may be encoded in memory in verbal form and can be retrieved when necessary. It can also be stored as images and patterns of linked information (such as ordered lists; figures; models, etc.), or as *schemata*. Mental schemata (or schemas) are organised bodies of knowledge we build up about particular objects, situations or phenomena (*Ormrod, 2003*). *Sweller (1999)* suggests that schemata are essential to cognitive functioning because they permit us to store multiple elements of information as a single, easily accessed whole. Long-term memory holds huge numbers of automated schemata for indefinite periods, perhaps represented in specific neural networks within the brain. One definition of learning consists of the acquisition of *increasingly automated schemata held in long-term memory*.

*Sweller (1999)* further indicates that schemata not only allow us to hold a great deal of material in long-term memory, they massively reduce the burden on working memory, allowing us to accomplish intellectual tasks that otherwise would be impossible. Schemata can be thought of as the highly functional ‘cognitive networks’ or ‘mental representations’ that are acquired as a result of experience.

*Santrock (2001)* defines a schema as comprising linked concepts, knowledge, and information about that already exist in a person’s mind. When a learner is making sense of a learning experience, separate units of information or concepts
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become closely interconnected and form the raw material used in thinking, reasoning and imagining. Well-developed schemata contain knowledge that can be used to interpret new experiences (Eggen and Kauchak, 2003). Children have been acquiring schemata since birth because the ability to do so is part of our basic cognitive architecture (Sweller, 1999). Schemata constantly change as learners make sense of a wider and wider range of experiences and as they link new information with prior knowledge. It is believed that a learner establishes highly effective schemata as new relationships are recognized between previously disconnected information (Nuthall, 1999). The taking in of new information (the process of assimilation) usually results in some restructuring of the existing schema (the process of accommodation).

A simple example of the expansion of a schema is that which occurs when you move to live in a new town. At first you may know only one route from your flat to the bus station. Gradually, through exploration your knowledge of the area increases and you add to your ‘route-to-the-bus schema’ routes from the flat to the shops and from the bus station to the shops. You then discover a quicker route to the bus station via the park; and in doing so you recognize that a tower you have previously only seen from your window actually belongs to a building that shares a boundary with the park. You also find a bus stop that allows you to walk through the park when you
return from work, and so on. You have literally created a mental ‘map’ that has steadily expanded and become refined with experience, and has become increasingly functional. According to schema theory, during our lifetime we develop an indefinite number of such schemata connected with all our meaningful learning. For example, we develop schemata connected with particular objects, with the number system, with the grammar of our language, with interpreting text, with codes of social behavior, with the classification of types of animals, and so on. Schemata associated with particular events are often called scripts (Ayers et al., 2000).

**Metacognition and Self-regulation:**

Metacognition is the ability to think about one’s own thought processes, self-monitor, and modify one’s learning strategies as necessary. Children who have metacognitive awareness are able to plan how best to tackle tasks and monitor their efforts. It is considered that metacognition helps a learner recognise that he or she is either doing well or is having difficulty learning or understanding something. A learner who is monitoring his or her own ongoing performance will detect the need to pause, to double-check, perhaps begin again before moving on, to weigh up possible alternatives, or to seek outside help (Kershner, 2000).
For children who are developing normally, metacognitive awareness and the intentional use of task-approach strategies improves steadily throughout the school years (*McDevitt and Ormrod, 2002*).

Metacognition often involves inner verbal self-instruction and self-questioning talking to one’s self in order to focus, reflect, control or review. Training in self-regulation involves teaching students to tell themselves specifically what they need to do and how they need to monitor and self-correct during the task. One example is the scaffolding that effective teachers provide for students through the modeling of ‘thinking aloud’ that later influences students’ own use of inner language. The teaching of verbal self-instruction is considered very important in helping all students become better self-regulated and metacognitive (*Chan, 1991*).
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Memory is essential for every learning and adaptation process. Acquisition of a new behavior requires the possibility to compare what is perceived with what is already known (Rotta et al., 1996).

According to (Jensen, 1998): Learning and memory are like two sides of a coin to neuroscientists. You can’t talk about one without the other. After all, if you have learned something, the only evidence of the learning is memory.

Individuals with learning disabilities usually have adequate long-term memories. If there is poor long-term memory, it may be difficult for the child to recall dates, names, and facts on tests (Bender, 2008).

When engaged in a learning task, the learner must make use of working memory capacity, and hence a load is placed upon that memory. Instruction places at least two kinds of demands upon the learner: those demands inherent in the learning (intrinsic load), and those demands resulting from instructional design (extrinsic load) (Paas et al., 2003).
Working Memory and Learning

Working memory processes appear to function mainly in the prefrontal cortex of the brain. Working memory is sometimes conceptualized as ‘mental working space for thinking’. It involves those perceptual and cognitive processes that enable a person to hold visual and verbal information in an active state while processing it for a particular purpose or integrating it with other information (Demetriou et al., 2002). In relation to learning, (Sweller, 1999) reported that the only factor determining ease or difficulty of understanding may be the working memory load imposed by the material’. The cognitive load on working memory increases when the elements of a problem or task interact and need to be processed simultaneously. Working memory, where all conscious cognitive processing occurs, is involved in all acts of thinking, reasoning and problem solving (Paas et al., 2003). For example, working memory is a key factor involved in reading comprehension and in understanding and communicating through spoken language. Working memory enables us to maintain continuity in our attention and thoughts from one moment to the next in our daily lives. Limitations in working memory are often implicated in difficulties in reading, writing, mathematics and problem solving (Swanson, 2002). Working
memory capacity is also known to be restricted in persons with intellectual disability (Numminen et al., 2002).

A good example of an everyday activity that uses working memory is mental arithmetic. Imagine, for example, attempting to multiply two numbers (e.g., 43, 27) without being able to use a pen and paper or a calculator. To do this successfully, it is necessary to store the two numbers, and then systematically apply multiplication rules, storing the intermediate products that are generated as we proceed through the stages of the calculation. Without working memory, we would not be able to carry out this kind of complex mental activity in which we have to both keep in mind some information while processing other materials. Carrying out such mental activities is a process that is effortful and error prone. A minor distraction such as an unrelated thought springing to mind or an interruption by someone else is likely to result in complete loss of the stored information, and so in a failed calculation attempt. Multiplying larger numbers (e.g., 142 and 891) “in our heads” is for most of us out of the question, even though it does not require greater mathematical knowledge than the earlier example. The reason we cannot do this is that the storage demands of the activity exceed the capacity of working memory (Geary, 1993)
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Most of the children with school problems have relative weaknesses in their auditory short-term memory, and because much of the information that is presented in the classroom is presented in an auditory/verbal format, this weakness leads to significant functional problems for them. Deficits in working memory may be manifested in a number of ways in the school setting. Students may have trouble with solving math calculation problems that involve multiple steps. They often have tremendous trouble with word problems in math because they are unable to keep all the information on their mental "plate" while they are deciding what information is most relevant and what process they need to use to solve the problem. They may have functional problems with reading comprehension because they fail to remember the sentences they just read while reading the sentence they are reading. Writing composition is often a difficult task for them. It requires them to retrieve their ideas from long-term memory while simultaneously recalling rules about capitalization, punctuation and grammar and writing their ideas down. They must remember the teacher's questions while searching long-term memory for the answer. Students who have difficulty with working memory also experience problems with many higher order thinking tasks such as problem solving and comparing and contrasting ideas (Thorne, 2008; Menghini et al., 2011).
The information needs to enter working memory before it can be stored into long-term memory. e.g. in vision, the speed with which information is stored into long-term memory is determined by the amount of information that can be fit, at each step, into working memory. In other words, the larger the capacity of working memory for certain stimuli, the faster these materials can be learned (Nikolić and Singer, 2007).

There is extensive evidence that working memory is linked to key learning outcomes in literacy and numeracy. Working memory capacity, but not IQ, predicts learning outcomes two years later (Gathercole and Alloway, 2008). This suggests that working memory impairments are associated with low learning outcomes and constitute a high risk factor for educational under achievement for children. In children with learning disabilities such as dyslexia, ADHD, and developmental coordination disorder, a similar pattern is evident (Conway et al., 2007).

Alloway et al. (2005) in their study investigates whether working memory skills of children are related to teacher ratings of their progress towards learning goals at the time of school entry, at 4 or 5 years of age. A sample of 194 children was tested on measures of working memory, phonological awareness, and non-verbal ability, in addition to the school-based baseline assessments in the areas of reading, writing,
mathematics, speaking and listening, and personal and social development. Various aspects of cognitive functioning formed unique associations with baseline assessments; for example complex memory span with rated writing skills, phonological short-term memory with both reading and speaking and listening skills, and sentence repetition scores with both mathematics and personal and social skills. Rated reading skills were also uniquely associated with phonological awareness scores. The findings indicate that the capacity to store and process material over short periods of time, referred to as working memory, and also the awareness of phonological structure, may play a crucial role in key learning areas for children at the beginning of formal education.

Individual differences in the capacity of working memory appear to have important consequences for children’s ability to acquire knowledge and new skills (Alloway et al., 2004).

Impairments of working memory are closely associated with learning deficits, as well as daily classroom activities. Without early intervention, memory deficits cannot be made up over time and will continue to compromise a child’s likelihood of academic success. So working memory makes a vital contribution to classroom learning (Alloway, 2006).
Gathercole et al. (2008) employed two studies because classroom activities in children with low working memory skills observed to be very poor. In Study 1, 5- and 6-year-old completed one task involving recalling spoken sentences and counting the numbers of words, and another task involving the identification of rhyming words in spoken poems. Poorer performance of low than average working memory children was obtained on the recall measure of both tasks. In Study 2, 5- and 6-year-old children heard spoken instructions involving the manipulation of a sequence of objects, and were asked either to perform the instructions or repeat them, in different conditions. The accuracy of performing but not repeating instructions was strongly associated with working memory skills. These results indicate that working memory plays a significant role in typical classroom activities that involve both the storage and mental manipulation of information.

Working memory and reading:

Reading disabilities can be characterized by marked difficulties in mastering skills including word recognition, spelling, and reading comprehension. Current evidence suggests that although verbal short-term memory is significantly associated with reading achievements over the early years of reading instruction, its role is as part of a general phonological processing construct related to reading.
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development rather than representing a causal factor *perse* (*Wagner et al., 1997*).

With respect to verbal working memory tasks, it is well established that children with reading disabilities show significant and marked decrements on such tasks relative to typically developing individuals (*Swanson, 1999*). In typically developing samples of children, scores on working memory tasks predict reading achievement independently of measures of verbal short-term memory (*Swanson, 2003*) and phonological awareness skills (*Swanson and Beebe-Frankenberger, 2004*). This dissociation in performance has been explained as the result of limited capacity for simultaneous processing and storage of information characteristic of working memory tasks, rather than a processing deficiency or specific problem with verbal short-term memory in poor readers. It is important to note that studies have found that working memory skills of children with reading disabilities do not improve over time, indicating that a sustained deficit, rather than a developmental lag, best explains their memory impairment. It is thus fair to argue that learners with sever deficiency in working memory would have problem in reading, meaning dyslexia, and thus would prefer visual learning (*Swanson and Sachse-Lee, 2001*).

Simple interventions (e.g. rehearsal training) have been shown to improve working memory performance:impaired
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reading ability is related to phonological memory codes, and that children with reading difficulties tend to rely more on visual memory (*Hulme, 1981*).

Children unable to develop letter-sound associations due to a severe phonological memory deficit. The intervention, which involved verbal repetition and identification of spoken letters, produced a limited but significant improvement in letter-reading skills; however, no improvement was seen for more complex reading experiences (*Kipp and Mohr, 2008*).

Children with reading disabilities are also thought to have deficits in attention processing which can make it difficult to determine which information is relevant to keep in mind (*Swanson 1993*). *Swanson et al. (2010)* suggested that children with reading disabilities have trouble preventing extraneous information from entering working memory, and are therefore more likely to consider alternative interpretations or strategy choices that are not central to the task at hand.

**Working memory and mathematics:**

There is growing evidence that mathematical deficits could result from poor working memory abilities. For example, low working memory scores have been found to be closely related to poor computational skills (*Wilson and Swanson, 2001*), and reliably differentiate children with mathematical
deficits from same-age controls (Geary et al., 1999). Weak verbal working memory skills are also characteristic of poor performance on arithmetic word problems (Swanson and Sachse-Lee, 2001). Common failures include impaired recall on both word and number-based working memory stimuli and increased intrusion errors (Passolunghi and Siegel, 2001). As with reading deficits, mathematical abilities do not improve substantially during the course of schooling, suggesting that such deficits are persistent and cannot be made up over time (Geary, 1993).

Verbal working memory plays a crucial role in mathematical performance when children are younger. However, as they get older, other factors such as number knowledge and strategies play a greater role (Thevenot and Oakhill, 2005). This view is supported by recent evidence that working memory is a reliable indicator of mathematical disabilities in the first year of formal schooling (Gersten et al., 2005).

Visuo-spatial memory is also closely linked with mathematical skills. It has been suggested that visuospatial memory functions as a mental blackboard, supporting number representation, such as place value and alignment in columns, in counting and arithmetic (D’Amico and Gharnera, 2005). Children with poor visuo-spatial memory skills have less room
in their blackboard to keep in mind the relevant numerical information (Heathcote, 1994).

Specific associations have been found between visuospatial memory and encoding in visually presented problems and in multi-digit operations (Logie et al., 1994). Visuo-spatial memory skills also uniquely predict variability in performance in nonverbal problems in pre-school children (Rasmussen and Bisanz, 2005). In contrast, the role of verbal short-term memory is restricted to temporary number storage during mental calculation (Hechet, 2002) rather than general mathematical skills (Reukala, 2001).

**Working memory in children’s arithmetic strategy:**

Working memory resources play a role in children’s simple-arithmetic performance. This assertion is mainly based on studies showing a working-memory deficit in mathematically disabled children (Swanson and Beebe-Frankenberger, 2004).

This impairment has often been attributed to limitations in working memory, and especially to limitations in the executive working-memory component (Passolunghi and Siegel, 2004).

**Working memory and general learning difficulties:**
Deficits in working memory appear to be unique to learning difficulties. They found that children identified as having general learning difficulties that included both literacy and mathematics performed poorly in all areas of working memory, whereas children with problems of a behavioral or emotional nature performed normally on all of the memory assessments (Pickering and Gathercole, 2004).

Any pupil who requires extra support to succeed in a regular classroom is a child who has special education needs. The term ‘special educational needs’ reflects a broad spectrum of problems, including physical or sensory difficulties, emotional and behavioral difficulties, or difficulties with speech. As many children at some point during their school years have special educational needs, it is important to identify the cognitive mechanisms that underlie these learning difficulties. Children with special educational needs had working memory deficits that varied in severity according to stage of the Code of Practice for special educational needs. In particular, children with statements of special educational needs performed at significantly lower levels than children at the School Action stage on such tasks. The magnitude of working memory deficits of the special needs children were never observed in a sample of over 600 children without learning difficulties (Alloway et al., 2005).
Working memory in the classroom:

Marked working memory deficits affect classroom activities *(Gathercole et al., 2005)*.

The children in class were asked to identify the rhyming words in a text read aloud by the teacher. They had to wait until all four lines had been read before telling the teacher the two words that rhymed: *tie*, and *fly*. This task involves matching the sound structures of a pair of words, and storing them. Common failures for these children with working memory impairments included forgetting lengthy instructions, place-keeping errors (e.g., missing out letters or words in a sentence), and failure to cope with simultaneous processing and storage demands *(Gathercole and Alloway, 2005)*. One explanation for these failures is that the concurrent storage and processing demands of the activity were beyond the working memory capacities of these children. Although the classroom teachers viewed their main problems as relating to lack of attention and motivation (e.g., “He doesn’t listen to a word I say”), it is important to note that the children showed no consistent evidence of attentional deficits using the Conners’ Teacher Rating Scale (1997), a diagnostic test based on teacher ratings of behaviour. Why does working memory constrain learning? One suggestion is that working memory provides a resource for the individual to
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Integrate knowledge from long-term memory with information in temporary storage (Swanson and Saez, 2003).

A child with weak working memory capacities is therefore limited in their ability to perform this operation in important classroom-based activities. A related suggestion is that poor working memory skills result in pervasive learning difficulties because this system acts as a bottleneck for learning in many of the individual learning episodes required to increment the acquisition of knowledge. As low working memory children often fail to meet working memory demands of individual learning episodes, the incremental process of acquiring skill and knowledge over the school years is disrupted (Gathercole, 2004).

Working memory and Attention

Attention is a key component in cognitive functioning and is the foundation for memory and information processing (Johnson and Robert, 2004).

Numerous cognitive processes come into play as one reads a paper. In fact, it takes little introspection to realize the necessity for visual, language, working memory, and declarative memory (among other) systems in the reading.
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process. However, the proper operation of all these systems would not be possible without a function that allowed the appropriate selection of stimuli, maintenance of concentration, and interactions with space and time. That cognitive function is attention. Indeed, it could be argued that while most other cognitive systems can operate somewhat independently of one another (e.g. patients with aphasia can still see just as well as patients with pure amnesia can still speak) none of them could function at anywhere near normal levels without the appropriate attentional interactions. Without attention, coherent thought itself would be impossible *(Gitelman, 2003).*

As memory has a limited capacity, it is crucial to understand which information is selected for encoding. Likewise, because attention operates in a world that is relatively stable over time, it is useful to rely on past experience to optimize selection. In fact, some aspects of attention and memory might even reflect the same processes. For example, memory retrieval might reflect a form of selective attention to internal representations *(Badre, 2005).* Classic psychologists such as William James stated long ago that ‘we cannot deny that an object once attended to will remain in the memory, while one inattentively allowed to pass will leave no traces behind’ *(James, 1890).*

Selective attention is a primary determinant of the relationship between working memory and general learning
ability: A single factor (i.e., general intelligence) can account for much of an individual's performance across a wide variety of cognitive tests. However, despite this factor's robustness, the underlying process is still a matter of debate (Kolata et al., 2007).

Research suggests a close link between the working memory capacities of a person and their ability to control the information from the environment that they can selectively enhance or ignore. Such attention allows for example for the voluntarily shifting in regard to goals of a person's information processing to spatial locations or objects rather than ones that capture their attention due to their sensory saliency (such as an ambulance siren). The goal directing of attention is driven by "top-down" signals from the PFC that bias processing in posterior cortical areas (Desimone and Duncan, 1995) and saliency capture by "bottom-up" control from subcortical structures and the primary sensory cortices (Yantis and Jonides, 1990). The ability to override sensory capture of attention differs greatly between individuals and this difference closely links to their working memory capacity. The greater a person's working memory capacity, the greater their ability to resist sensory capture. The limited ability to override attentional capture is likely to result in the unnecessary storage of information in working memory suggesting not only that having a poor working memory affects attention but that it can also limit the capacity of working memory even further. (Low
attention <-> low working memory) (Fukuda and Vogel, 2009). Attention control is fundamental to all learning. Language learning requires a mature level of attention. Although the mechanism of attention is not entirely understood, there is widespread agreement that attention is a limited capacity processing system that can flexibly allocate resources to modulate signal detection and response for controlled action. With respect to language processing, attention plays an important role in mediating the selection of competing candidates so that, for example, the correct word can be activated (Kurland, 2011).

Children with attention-deficit hyperactivity disorder (ADHD) are impaired on one or more components of working memory (WM) independent of comorbid language learning disorders, and WM impairments are more strongly related to symptoms of inattention than to symptoms of hyperactivity-impulsivity (Martinussen and Tannock, 2006).

Attention and Learning

In learning, attention is one of the most important of our attributes. Good attention skills enable us to maintain our focus even when there are distractions around us or in our thoughts. A major problem that interferes with the learning of children is their difficulty in paying attention (Lovaas et al., 1981). Attention deficit results in inconsistent perception of stimuli.
hampering the development of strong neural connections and weakens the working memory necessary for processing multiple perceptions (Alexander and Slinger-Constant, 2004).

There are several kinds of attentional problems. Poor attention may be related to poor motivation (Lovaas et al., 1981). Short attention span may be the marked clinical aspect of presentation of cases with LDs (McGee and Share, 1988). The children's attentional problems may also lie in an overly narrow attention to external cues. Here, the children focus on small details and are unable to see the whole picture. They have overselected their attention. Overselective attention can occur "between the senses". The child may focus on one channel of input (say the visual cue) while ignoring the other channel (the auditory cue). Overselection may also occur within a stimulus dimension. For example, with visual cues, which may have shape, size, and color, the child may pay attention to only one or two of these dimensions, but not all three. The same problem shows up with auditory cues. For example, in order to learn language, the child should pay attention to several cues in voice such as the loudness, pitch, and form of a verbal utterance. A child will not understand much language unless he can focus on several auditory cues given simultaneously. The children may overselect certain details of the teaching situation and this
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interferes with their transfer or generalization of that learning to new situations (Lovaas et al., 1981).
Memory Deficits in Learning Disability Children

Problems with memory can occur with short-term or working memory, or with long-term memory. Most memory difficulties occur in the area of short-term memory, which can make it difficult to learn new material without many more repetitions than usual.

Variety of memory problems are evidenced in the learning-disabled. These include problems in receptive memory, sequential memory, rote memory, short term memory, and long term memory. **Receptive memory** (sensory memory) refers to the ability to note the physical features of a given stimulus to be able to recognize it at a later time. The child who has receptive memory difficulties invariably fails to recognize visual or auditory stimuli such as the shapes or sounds associated with the letters of the alphabet, the number system, etc. **Sequential memory** refers to the ability to recall stimuli in their order of presentation. Many dyslexics have poor visual sequential memory and this will affect their ability to read and spell correctly. Some also have poor auditory sequential memory and therefore may be unable to repeat longer words orally without getting the syllables in the wrong order. **Rote memory** refers to the ability to learn certain information as a habit pattern, such as the alphabet, the number system,
multiplication tables, spelling rules, grammatical rules, etc (Bender, 2008).

Memory problems in learning disabilities include:

1- Short term memory (Working memory).
2- Long term memory.
3- Visual memory, visual processing disorders.
4- Auditory memory, auditory processing disorders.
5- Phonological memory.

**Short Term Memory (working memory)**

Most of the children with school problems have relative weaknesses in their auditory short-term memory, and because much of information that is presented in the classroom is presented in an auditory/verbal format, this weakness leads to significant functional problems for them. Deficits in working memory may be manifested in a number of ways in the school setting. Students may have trouble with solving math calculation problems that involve multiple steps. They often have tremendous trouble with word problems in math because they are unable to keep all the information on their mental "plate" while they are deciding what information is most relevant and what process they need to use to solve the problem. They may have functional problems with reading comprehension because they fail to remember the sentences
they just read while reading the sentence they are reading. Writing composition is often a difficult task for them. It requires them to retrieve their ideas from long-term memory while simultaneously recalling rules about capitalization, punctuation and grammar and writing their ideas down. They must remember the teacher's questions while searching long-term memory for the answer. Students who have difficulty with working memory also experience problems with many higher order thinking tasks such as problem solving and comparing and contrasting ideas. Pupils with short term memory find it difficult to remember instructions, number or word patterns. Some learners have ‘fluctuating memories’ when they can complete a task in one session but cannot repeat it in future sessions. This causes difficulties when assessing children. Memory can also affect pupils ability to sequence, something which makes progress in maths and learning phonics difficult (Thorne, 2008).

We use working memory to do multi-task, or to think about more than one thing at a time. Kids whose LDs reflect working memory problems may have trouble carrying out multi-step instructions (i.e., keeping in mind steps while one completes the first instruction) or completing mental arithmetic problems. This type of memory can interfere with reading comprehension because it can be hard to keep track of story characters and plot lines while sounding out new words.
Working memory impairments demonstrated by having the participants listen to long series of numbers and letters and then repeat them back in a different order (letters in alphabetical order and numbers in numerical order). In poor working memory, it can be harder to perform Multi-tasking, listening to a teacher, pulling out relevant information, taking notes, figuring out a tip, following multiple step instruction (*Menghini et al.*, 2011).

**Long-term Memory**

Individuals with learning disabilities usually have adequate long-term memories. If there is poor long-term memory, it may be difficult for the child to recall dates, names, and facts on tests. Children with long term memory difficulties may not even learn after many repetitions and much practice and appear to start again each time. It is important to recognize that this is due to ‘perseveration’, which is a specific memory difficulty. Memory difficulties do not correlate with an individuals intelligence. Children with long term memory difficulties may not even learn after many repetitions and much practice and appear to start again each time (*Bender*, 2008).

Many children are seen by ophthalmologists because of scholastic difficulties in school initially attributed to eyesight when, in fact, the problem often is a result of a disorder of the brain processing vision. Visual processing is the main brain
function allowing normal perception of what is being viewed. Ophthalmologists as well as patients must realize that with normal 20/20 eyesight interpretation of what is seen may be dysfunctional because of faulty brain processing of that which is seen by normal eyes. Abnormal Visual Processing as well as auditory processing disorders eventually lead directly to learning disorders in children and young adults (Koller, 2012).

Information storage involved at various stages in processing information as sensory register, short-term memory, working memory, and long-term memory. While there are several different types of information processing, two important groups are Visual Processing and Auditory processing disorders

**Visual Processing and Auditory Processing Disorders**

It include:

**Visual Processing:** Visual processing disorders are the visual system mechanisms and processes responsible for the following behavioral phenomena (National Center for Learning Disabilities, 1999).

- Visual Discrimination
- Visual Sequencing
- Visual Memory
- Visual Motor Processing
- Visual Closure
- Spatial Relationships

**Auditory Processing:** To learn auditorily, a child should have normal hearing sensitivity. In addition, there are many auditory skills that enable the child to make use of what heard for further processing and hence, decoding of the auditory signal (*Katz et al., 1992*).

- Auditory Discrimination.
- Auditory Memory.
- Auditory Sequencing.

**Table 3:** Auditory and visual processing and their disorders.  
(*National center of learning disabilities, 2008*).

<table>
<thead>
<tr>
<th>Processing Area</th>
<th>Skill</th>
<th>Possible Difficulties Observed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Visual Discrimination</strong></td>
<td>Using the sense of sight to notice and compare the features of different items to distinguish one item from another</td>
<td>Seeing the difference between two similar letters, shapes or objects. Noticing the similarities and differences between certain colors, shapes and patterns.</td>
</tr>
<tr>
<td><strong>Visual Figure Ground</strong></td>
<td>Discriminating a shape or printed character from its</td>
<td>Finding a specific bit of information on a printed page full of</td>
</tr>
</tbody>
</table>
### Memory Deficits in Learning Disability Children

<table>
<thead>
<tr>
<th>Discrimination</th>
<th>background.</th>
<th>words and numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Seeing an image within a competing background.</td>
</tr>
</tbody>
</table>

### Visual Sequencing

- The ability to see and distinguish the order of symbols, words or images
- Using a separate answer sheet.
- Staying in the right place while reading a paragraph.
- Example: skipping lines, reading the same line over and over.
- Reversing or misreading letters, numbers and words.
- Understanding math equations.

### Visual Motor Processing

- Using feedback from the eyes to coordinate the movement of other parts of the body
- Writing within lines or margins of a piece of paper.
- Copying from a board or book. Moving around without bumping into things.
- Participating in sports that require well-timed and precise movements.
### Memory Deficits in Learning Disability Children

<table>
<thead>
<tr>
<th></th>
<th>There are two kinds of visual memory:</th>
<th>Remembering the spelling of familiar words with irregular spelling.</th>
</tr>
</thead>
</table>
| **Visual Memory** | -Long-term visual memory is the ability to recall something seen some time ago.  
-Short-term visual memory is the ability to remember something seen very recently | Reading comprehension.  
Using a calculator or keyboard with speed and accuracy.  
Remembering phone numbers. |
| **Visual closure** | The ability to know what an object is when only parts of it are visible. | Recognizing a picture of a familiar object from a partial image.  
Example: A truck without its wheels.  
Identifying a word with a letter missing.  
Recognizing a face when one feature (such as the nose) is missing. |
 Memory Deficits in Learning Disability Children
Spatial
relationships

The ability to
understand how
objects are
positioned in space
in relation to
oneself. This
involves the
understanding of
distance (near or
far), as well as the
relationship of
objects and
characters described
on

Getting from one place
to another Spacing
letters and words on
paper Judging time.
Reading maps.

Paper or in a spoken
narrative.
Auditory
discrimination

The ability to notice,
compare and
distinguish the
distinct and separate
sounds in words.
This skill is vital for
reading.

Learning to read
Distinguishing
difference between
similar sounds.
Example: Seventy and
seventeen.
Understanding spoken
language, following
directions and
remembering details.
Seems to hear but not
listen.

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| **Auditory figure-ground** | The ability to pick out important sounds from a noisy background. | Distinguishing meaningful sounds from background noise.  
Staying focused on auditory information being given.  
Example: following verbal directions |
|---|---|---|
| **Auditory memory** | There are two kinds of auditory memory:  
- Long-term auditory memory is the ability to remember something heard some time ago.  
- Short-term auditory memory is the ability to recall something heard very recently. | Remembering people's names.  
Memorizing telephone numbers.  
Following multi-step directions.  
Recalling stories or songs. |

Central auditory processing disorder (CAPD) can be a congenital or an acquired condition (for example; resulting from ear infections and head injuries). People with CAPD have a disorder in processing auditory information within the brain. The written word is a representation of verbal language, thus CAPD can extend into reading and writing. As a consequence, CAPD has been recognized as one of the major causes of
dyslexia. Prevalence of CAPD in children diagnosed with Learning Disabilities (LDs) is estimated to be as high as 30–50% (King et al., 2002; Ramus, 2003).

**Manifestations of central auditory processing disorders:**

Children who have CAPD are known to exhibit such characteristics as the following (Bishop and Adams, 1990; Chermak and Musiek, 1992):

1. Most cases are males (75%).
2. Inconsistent response to auditory stimuli.
3. They ask frequently for repetition.
4. Defective auditory localization (far or near, soft or loud).
5. Difficulty hearing in noisy situations.
6. Difficulty following long conversations especially on the telephone.
7. Difficulty learning a foreign language or challenging vocabulary words.
8. Difficulty remembering spoken information (i.e., auditory memory deficits).
9. Difficulty taking notes.
10. Difficulty in directing, sustaining, or dividing attention.

11. Easy distractibility by either irrelevant auditory or visual stimuli.

12. Hyperactivity (90%).

13. Difficulty with organizational skills.


15. Difficulty with reading and/or spelling.

16. Difficulty processing nonverbal information (e.g., lack of music appreciation).

**Manifestations of visual processing disorders:**

Children with visual processing disorders may exhibit the following characteristics (*Bloom, 1990*):

1- Complain eyes hurt and itch, rub eyes, complain print blurs while reading.

2- Might has severe problems with overhead light.

3- Turns head when reading across page or holds paper at odd angles.

4- Closes one eye while working, may yawn while reading.

5- Slow reading speed; poor comprehension.
6-  Poor spelling (due to visual sequencing deficits).

7-  Difficulty visualizing math problems, difficulty using a keyboard or calculator.

8-  Difficulty learning by demonstration or by video.

9-  Difficulty extracting information from pictures, graphs, diagrams.

10- Difficulty blending information from both eyes for depth perception.

11- Directionality problems in reading and math, confusion of similarly shaped letters, such as b/d/p/q (due to problems with spatial relations).

12- Inability to recognize an object/word if only part of it is shown and difficulty filling in missing parts of pictures (due to visual closure problems).

13- Inability to consistently recognize letters, numbers, symbols, words, or pictures.

14- Problems with whole/part relationships.

15- Poor visual-motor coordination leading to holding pencil too tightly; often breaking pencil point, illegible handwriting, slow, inaccurate copying, difficulty using
separate answer sheet, poor directional sense, difficulty with eye-hand coordination, clumsiness.

16- Visual figure-ground problems leading to trouble tuning in to any one item on a crowded board, page, etc., difficulty finding specific information in a dictionary or phone book, skipping words or lines, or reading same line twice, trouble seeing an image within a competing background.

**Visual Memory Deficits**

Visual memory refers to the ability to take in visual information and to hold it in mind. Visual information can be stored with a limited capacity in short-term memory and can be converted to longer-term storage if actively rehearsed. Visual memory is the Memory for visual information, Can be abstract information or meaningful.

Kids whose LDs reflect visual memory problems may have trouble remembering the differences between letters (e.g., ‘d’ and ‘b’ – both circles and sticks but one has to remember which side of the circle the stick is on). In school, they may struggle with visual-based subjects, such as mapping in geography, or labeling diagrams in science. Sometimes, kids with visual memory problems have trouble remembering faces. Visual memory impairments demonstrated by having the participants look briefly at an array of visual objects and then recall as many objects as they can remember. Visual memory is
the function of memory that allows you to successfully turn images into pictures in your mind to reserve and recall later. Unfortunately, children that suffer from various visual processing disorders may also have visual memory problems. This, in turn, affects their school work, ability to follow instructions and how they learn. If your child has visual memory problems, finding better ways to offer instructions and playing memory games can help improve her ability to remember and follow instructions and assignments (Ireland, 2010).

**Phonological Memory**

*According to Baddeley and Hitch model (1974)*, the phonological loop is the principal concern today. It consists of two subcomponents, a phonological store and a subvocal rehearsal process. The store holds verbal material in a phonological form, possibly corresponding to phonemes or perhaps to subphonetic features. Phonological material held in the store is subject to decay within about two seconds. The duration of storage can, however, be prolonged by the subvocal rehearsal of the contents of the phonological store. Subvocal rehearsal involves covert articulation in real time of information held in the phonological store. So providing that the entire contents of the phonological store can be rehearsed within about two seconds, the material can be stored indefinitely, although somewhat effortfully.
It should be noted that information may gain access to storage capacity of the phonological loop in one of two ways. The direct route involves auditory input: all spoken language that is perceived gains obligatory access to the phonological store. The indirect route is available for information which is not presented in spoken form, but which can be recoded internally into a phonological code by accessing stored knowledge of its label. Examples of such inputs are the printed forms of familiar words, and pictures denoting objects with familiar verbal labels. For such inputs, the subvocal rehearsal process generates the phonological form, which is then stored in the phonological store in the same way as spoken language inputs. In this way, the phonological loop can be used to store internally generated phonological sequences as well as sequences of spoken stimuli.

Primary function of phonological short-term memory is to support the long-term learning of the sound structures of new words, which is a key process involved in vocabulary acquisition. Beside the role of the phonological loop in the acquisition of language. There is a strong role in the acquisition of literacy. There is a close links between short-term memory and reading (Baddeley et al, 1998).

There are certainly links between reading development and the phonological loop. It has variously been speculated that these links reflect the role of short-term memory in learning
letter-sound associations and in storing segments generated by a phonological recoding strategy prior to blending. Interest in short-term memory and literacy development has, however, been dramatically overshadowed by the even stronger associations found between phonological awareness and reading ability. These have led to a sustained interest in the possibility that the core cognitive skill required for a child to learn to become a proficient reader is the metalinguistic awareness of the phonological structure of spoken language (Coswami and Bryant, 1992).

Development of awareness of the phonological structure of spoken language is itself strongly stimulated by literacy instruction, probably due to the explicit focus in alphabetic orthographies at least on exploiting the regularities between spelling patterns and the units of sounds constituting individual words. As the very strong empirical links found between phonological awareness and reading ability reflect this fact that phonological awareness is itself a beneficiary of reading development, it is easy to inflate the importance of the high correlations found in the literature (Morais et al., 1979).

Adequate temporary storage of the phonological form of a novel word is the first crucial step towards building a stable long-term representation of its structure. The long-term specification is typically built up over multiple exposures to new words, but the better the short-term trace on each occasion,
the greater the degree of learning. Children with relatively weak phonological memory skills will therefore require more frequent exposures to interpretation has been borne out by several independent studies in recent years which have demonstrated that severe nonword repetition deficits are a key feature of specific language impairment (*Montgomery, 1995*).

Poor phonological short-term memory skills during childhood make specific difficulties in acquiring language and scholastic abilities. In studies, young children’s scores on phonological memory tests such as digit span and nonword repetition have consistently been shown to be closely related to vocabulary knowledge both in the native language and in second languages. Children with low phonological memory perform relatively poorly in learning unfamiliar phonological structures under controlled laboratory conditions. Links between phonological memory and word learning extend to a number of special developmental populations. Children with deficits in phoneme awareness have poor phonological recoding in working memory. These children have problems with following more than two directions at a time and with math facts, and many have problems with ordered concepts such as the alphabet, months, seasons, and days of the year. Severe deficits on phonological memory tasks are characteristic of Specific Language Impairment, a disorder of language
development in the absence of general intellectual or sensory problems (*Gathercole and Baddeley, 1990a*).

The linkage of attention to memory has long been recognized and recent developments on this linkage mainly focus on its role in mental activities like working memory, verbal learning and memory and visual learning and memory. Children with ADHD have shown significant impairment in terms of verbal learning and memory (*Cowan, 2011*).

**Biochemical and Molecular Deficits in Learning disabilities**

Brain-derived neurotrophic factor (BDNF) modulates both short-term synaptic function and activity-dependent synaptic plasticity in hippocampal and cortical neurons. We have recently demonstrated that endogenous BDNF in the hippocampus is involved in memory formation. Examining the role of BDNF in the parietal cortex (PCx) in short-term (STM) and long-term memory (LTM) formation of a one-trial fear-motivated learning task in rats. Bilateral infusions of function-blocking anti-BDNF antibody into the PCx impaired both STM and LTM retention scores and decreased the phosphorylation state of cAMP response element-binding protein (CREB). In contrast, intracortical administration of recombinant human BDNF facilitated LTM and increased CREB activation. Moreover, inhibitory avoidance training is associated with a
rapid and transient increase in phospho-CREB/total CREB ratio in the PCx. Thus, our results indicate that endogenous BDNF is required for both STM and LTM formation of inhibitory avoidance learning, possibly involving CREB activation-dependent mechanisms. The present data support the idea that early sensory areas constitute important components of the networks subserving memory formation and that information processing in neocortex plays an important role in memory formation (*Alonso et al.; 2005*).

The cAMP-responsive element-binding protein (CREB) has been implicated in the activation of protein synthesis required for long-term facilitation, a cellular model of memory in Aplysia. In studies with fear conditioning and with the water maze show that mice with a targeted disruption of the α and δ isoforms of CREB are profoundly deficient in long-term memory. In contrast, short-term memory, lasting between 30 and 60 min, is normal. Consistent with models claiming a role for long-term potentiation (LTP) in memory, LTP in hippocampal slices from CREB mutants decayed to baseline 90 min after tetanic stimulation. However, paired-pulse facilitation and posttetanic potentiation are normal. These results implicate CREB-dependent transcription in mammalian long-term memory (*Bourtchuladze et al., 1994*).

Using the flight simulator system, the operant conditioned visual flight orientation behavior in Drosophila was
studied. It was demonstrated that the visual learning performance is associated with age; flies learn more reliably at 3-4 days than at 1-2 days of age; the cAMP level of brain is also increasing with age; the brain cAMP content of nonlearner flies of wild type is much higher than that of normal flies; the cAMP level of brain increased abnormally after being fed with caffeine, and the learning performance decreased. These results imply that a moderate range of cAMP level is necessary for the visual learning and memory process. Abnormally high or low level of cAMP causes defects of learning and memory ability (Wang et al, 1998).

Long-term memory (LTM) formation requires: DNA transcription, RNA translation, and the trafficking of newly synthesized proteins quantitative proteomic method was used to identify novel memory-associated proteins in neural tissue taken from animals that were trained in vivo to form a long-term memory. The results confirm the involvement of previously identified memory proteins such as: protein kinase C (PKC), adenylate cyclase (AC), and proteins in the mitogen-activated protein kinase (MAPK) pathway (David et al., 2010).

Little is known about the neuronal mechanisms that subserve long-term memory persistence in the brain. The components of the remodeled synaptic machinery, and how they sustain the new synaptic or cellwide configuration over time, are yet to be elucidated. In the rat cortex, long-term
associative memories vanished rapidly after local application of an inhibitor of the protein kinase C isoform, protein kinase M zeta (PKMζ). The effect was observed for at least several weeks after encoding and may be irreversible. In the neocortex, which is assumed to be the repository of multiple types of long-term memory, persistence of memory is thus dependent on ongoing activity of a protein kinase long after that memory is considered to have consolidated into a long-term stable form (Reut et al., 2007).
Assessment of Memory Deficits in Learning Disability

The memory demands for school and college-age students are tremendous. Students are constantly bombarded with new information that they are expected to learn relatively quickly. Thus, the assessment of memory is a critical component of a student's learning profile and should be included in a neurodevelopment or psychoeducational evaluation (Postle, 2006).

I- Assessment of Auditory Memory

Methods of Testing Echoic Memory:

1- Partial & Whole Report:

Echoic memory is measured by behavioural tasks where participants are asked to repeat a sequence of tones, words, or syllables that were presented to them, usually requiring attention and motivation. The most famous partial report task was conducted by presenting participants with an auditory stimulus in the left, right, and both ears simultaneously. Then they were asked to report spatial location and category name of each stimulus. Results showed that spatial location was easier to recall than semantic information when inhibiting information
from one ear over the other. Consistent with results on iconic memory tasks, performance on the partial report conditions were far superior to the whole report condition. In addition, a decrease in performance was observed as the interstimulus interval (ISI) (length of time between presentation of the stimulus and recall) increased (Darwin, 1972).

2- Auditory Backward Recognition Masking:

Auditory backward recognition masking (ABRM) is one of the most successful tasks in studying audition. It involves presenting participants with a brief target stimulus, followed by a second stimulus (the mask) after an (ISI). The amount of time the auditory information is available in memory is manipulated by the length of the ISI. Performance as indicated by accuracy of target information increases as the ISI increased to 250 ms. the mask doesn’t affect the amount of information obtained from the stimulus, but it acts as interference for further processing (Bjork, 1996).

3- Mismatch Negativity:

A more objective, independent task capable of measuring auditory sensory memory that does not require focused attention are mismatch negativity (MMN) tasks, which record changes in activation in the brain by use of electroencephalography (EEG). This records elements of auditory event-related potentials (ERP) of brain activity elicited
150-200ms after a stimulus. This stimulus is an unattended, infrequent, "oddball" or deviant stimulus presented among a sequence of standard stimuli, thereby comparing the deviant stimulus to a memory trace (Sabri et al., 2004).

4- Central auditory processing testing: There are numerous auditory tests that the audiologist can use to assess central auditory function. These fall into two major behavioral tests and electrophysiologic tests. The behavioral tests are often broken down into four subcategories, including monaural low-redundancy speech tests, dichotic speech tests, temporal patterning tests, and binaural interaction tests. Electro physiologic tests are measures of the brain’s response to sounds. Some electrophysiologic tests are used to evaluate processing lower in the brain (auditory brainstem response audiometry), whereas others assess functioning higher in the brain (middle latency responses, late auditory evoked responses, auditory cognitive or P300 responses) (Smoski et al., 1992).

The following tests are designed to test the individual auditory abilities important for learning:

- Auditory attention: Attention can be defined as —the length of time a subject maintains an orientation to the stimulus. Auditory attention can be tested by Wepman Auditory Discrimination Test (Wepman, 1958), Competing Environmental Sounds Test (Katz, 1977), Speech-
Assessment of Memory Deficits in Learning Disability

Intelligibility-In-Noise (SPIN) test —Arabic version (*Tawfik and Shalaby, 1995*).

- **Auditory figure-ground**: test the ability to delineate a sound administered using tape recorded speech in the presence of competing background noise e.g. competing sentences test (*Willeford, 1977*).

- **Auditory discrimination**: To differentiate among sounds of different frequency, duration or intensity (*Foss and Hakes, 1993*). One example is Wepman auditory discrimination test (*Wepman, 1958*) which uses minimal pairs (e.g. lake & make).

- **Auditory closure**: To understand the whole word or message when part is missing (*Kirk et al., 1969*). It can be tested through monaural low-redundancy speech tests and Illinois Test of Psycholinguistic Abilities —Arabic version (*El-Sady et al., 1996*).

- **Auditory blending**: To synthesize isolated phonemes into words (*Kirk et al., 1969*). This can be tested by Illinois Test of Psycholinguistic Abilities —Arabic version (*El-Sady et al., 1996*).

- **Auditory analysis**: Auditory analysis test (*Rosner and Simon, 1971*) entails assessment of the ability to identify phonemes or syllables embedded in words or to form a new
word when a phoneme or syllable is removed from a larger word e.g. _gate‘ without _g‘ is _ate‘.

- **Binaural fusion:** The Masking Level Difference (MLD) test has been found to be a sensitive test for binaural interaction problems in CAPD children (*Roush and Tait, 1984*).

- **Temporal processing:** This can be assessed by Frequency Pattern Test, Duration Pattern Test, Pitch Pattern Sequence Test and Auditory Fusion Test.

- **Auditory memory:**
  - Memory span can be tested by Wepman and Morency Auditory Memory Span Test (*Wepman and Morency, 1973*) in which single syllable nouns are presented in progressively increasing series from two or six words and the child is asked to repeat in the order presented, three trials at each level are given.
  - Sequential memory can be tested using the auditory sequential memory subtest of the Illinois Test of Psycholinguistic Abilities —Arabic version || (*El-Sady et al., 1996*). This test utilizes digits; the child must recall the exact order of the given stimuli. The number of digits presented range from two to six.

- **Tests to discover the preferred ear (Dichotic Listening Tests):**
Assessment of Memory Deficits in Learning Disability

It was found that 45-60% of dyslexic children are left or mixed eared for speech which means that more language than usual is being handled by the right hemisphere (Hornsby, 1984).

In the everyday clinical practice the approach most frequently used is to base a diagnosis of CAPD on a criterion of failure in at least two of the central auditory tests administered. The alternative practice is to consider as CAPD positive each child that is failing at least one of the tests administered given the fact that each test used evaluates a different component of auditory processing (Bellis, 2003).

Iliadou et al. (2009) found that in a target group of children suspected of learning disabilities three tests, namely the speech in babble left ear perception, the duration pattern test of the left ear and the frequency pattern test of the right ear, were more efficient in distinguishing between a subject with normal auditory processing and one with an Auditory Processing Disorder. They suggested that these tests can be used as a screening approach for children suspected with Learning Disabilities, however this does not imply that testing with this screening battery provides the whole auditory processing profile of the children tested as each test evaluates a different auditory processing ability. Due to the fact that the prevalence is high in this specific group, screening for children experiencing the disorder would require less time spent for evaluation. The proposed screening battery approach would
require approximately 15 min to be administered and it would quite successfully divide the children suspected of learning disabilities into those that have normal auditory processing abilities and those that would require further evaluation and possible management.

II- Assessment of visual memory

1) Assessment of visual acuity (*Hornsby, 1984*).

2) Tests for visual perception as testing the ability to copy words from the blackboard (*Alder, 1983*).

3) Ophthalmo-kinesis: Dyslexics show longer fixations, smaller saccades, and a greater number of regressions (*Kowler and Anton, 1987*).

4) Determination of the preferred eye: Where the child is asked to look through a hole in a card held by both of his hands close to his face, the child will use his preferred eye. Most dyslexics have preferred left eye (*Hornsby, 1984*).

5) The visual sequential memory subtest of the Illinois test of psycholinguistic abilities - Arabic version (*El-Sady et al., 1996*) to evaluate visual memory. It involves the ability to reproduce memory from sequences of visually received stimuli.

Figures used in the visual sequential memory test are shown in figure (15).

III- Assessment of working memory

It can be assessed through many tasks such as:

1) Forward digit span (*Baddeley and Hitch, 1974*). It is one of the subtests of Illinois Test of Psycholinguistic Abilities Arabic version (*El-Sady et al.*, 1996).

2) Backward digit span (*Carroll, 1993*). It is one of the subtests of Arabic Dyslexia Assessment Test (*Aboras et al.*, 2008).

A backwards digit span task requires that a person listens to a string of digits and then reproduces them in reverse sequence. It is more difficult and requires more processes besides immediate recall. Theoretically, the backwards digit task is of interest as a spatial reasoning task because it requires rotation or transformation of the sequence (*Carroll, 1993*). Right-hemisphere dysfunction reduces backwards digit span performance while left-hemisphere dysfunction reduces
forward digit span performance (Rapport et al., 1994), although this difference does not occur in all types of disorders.

3) Nonsense word repetition (Gathercole et al., 1991). Gathercole et al. (1991) suggested that nonsense word repetition may be a more sensitive measure of phonological working memory than simple verbal memory span measures, as it avoids the possibility of using lexical and semantic cues to assist recall.

4) Reading span "complex span" used to test working memory capacity. It is a dual-task paradigm combining a memory span measure with a concurrent processing task. Subjects read a number of sentences (usually between 2 and 6) and try to remember the last word of each sentence. At the end of the list of sentences, they repeat back the words in their correct order (Daneman and Carpenter, 1980).

5) Preload task of working memory (Baddeley et al., 1985). Prior to presentation of the task, the child is instructed that he would be presented digits and words and that he had to remember these items in the sequential order they were presented, but to recall the words first then the digits.
Memory tests from the Working Memory Test Battery for Children (WMTB-C) (Pickering and Gathercole, 2001):

I- The three verbal short-term memory measures (VSTM) that correspond to the phonological loop in the Baddeley working-memory model are:

Digit recall test, the word recall test (In each of these tests, the child hears a sequence of verbal items (digits and one-syllable words, respectively), and has to recall each sequence in the correct order and nonword list recall (recall of spoken lists of monosyllabic nonwords).

Measurement of phonological memory capacity by nonword repetition. In this task, the child simply hears a made-up word such as "doppelate", and attempts to repeat it back. The accuracy of the repetition attempt is scored. As children cannot fall back upon their stored knowledge about the sound pattern to support their repetition attempt, they are forced to rely upon the temporary representation of the nonword in the phonological store. Repetition accuracy increases with word length, as would be expected if scores on this measure tap the limited storage capacity of the phonological loop. Nonword Repetition requires the use of an audiocassette recorder to ensure standardized administration, particularly as the items become more difficult (Gathercole et al., 1991).
II-The three verbal working memory measures (VWM) associated with the central executive in the Baddeley working-memory model are:

The listening recall test, backward digit recall test, and counting recall test.

In the listening recall test:

The child is presented with a series of spoken sentences, has to verify the sentence by stating “true” or “false,” and recalls the final word for each sentence in sequence.

In the backward digit recall test:

The child is required to recall a sequence of spoken digits in the reverse order.

In the counting recall test:

The child is presented with a visual array of red circles and blue triangles. She or he is required to count the number of circles in an array and then recall the tallies of circles in the arrays that were presented.

III- Two measures of the visuo-spatial short-term memory (VSSTM) are the block recall test and the visual patterns test, corresponding to the visuo-spatial sketchpad in the Baddeley working-memory model.
In the block recall test:

The child views nine cubes, randomly located on a board, and has to tap a set sequence in the correct order.

In the visual patterns test

The child views a two-dimensional grid of black and white squares for 3 s, and has to mark the black squares on an empty grid.

*Wagner et al., (1999)* recently offered the Comprehensive Test of Phonological Processing (CTOPP) as a measure of phonological coding. Phonological coding abilities may help school psychologists to more accurately differentiate students with learning disabilities from students who may be experiencing academic failure as a result of other causes.

Phonological coding consists of the analysis and synthesis of phonemes (the smallest unit of recognized sounds). Beginning readers who have deficits in phonological coding seem to have difficulty naming letters of the alphabet, identifying sounds for alphabet letters, segmenting words into phonemes and syllables, and applying knowledge of letter-sound correspondence to decode words. Phonological coding is an oral language skill. It involves analysis such as recognizing that the first sound of the word *ball* (/b/) can be replaced with /t/ to produce the word *tall*. Phonological coding abilities
associated with this process of changing ball to tall include letter-sound correspondence, phonemic awareness and segmentation, and working with information in phonological memory. It also involves the synthesis of sounds into words. Since the most common forms of severe reading problems are caused by deficits in one or more aspects of phonological coding, school psychologists should consider including measures specifically designed to address this cognitive-linguistic process in their assessment of cognitive functioning.

Wagner et al., (1999) developed the CTOPP in a manner consistent with their theoretical assumptions about the nature of phonological coding deficits. They present a three-part model which consisting of the following:

(a.) Phonological awareness: analysis and synthesis of the sound structure of oral language. The order of progression of phonological awareness starts with syllables and moves toward smaller units of speech sounds (Adams, 1990). Phonological awareness provides individuals with the ability to break words into syllables and component phonemes, to synthesize words from discrete sounds, and to learn about the distinctive features of words (Torgesen and Wagner, 1998).
(b.) Phonological memory: coding information phonologically for temporary storage in working or short-term memory. Phonological short-term memory involves storing distinct phonological features for short periods of time to be "read off" in the process of applying the alphabetic principle to word identification.

(c.) Rapid naming: efficient retrieval of a series of names of objects, colors, digits, or letters from long-term memory. Rapid naming of verbal material is a measure of the fluid access to verbal names, in isolation or as part of a series, and related efficiency in activating name codes from memory (Wagner et al., 1999).

Phonological memory composite includes Memory for Digits and Nonword repetition. Though similar to the Digit Span test, Memory for Digits is presented via audiocassette recorder at a faster rate of presentation (two digits per second) and with a specification of forward-only recall. These modifications were meant to stress the efficiency of the phonological loop, i.e., "brief verbatim storage of auditory information" (Wagner et al., 1999), avoiding the involvement of other cognitive processes, such as rehearsal and elaboration. On Digit Span, many students "think through" the backward recall of numbers or refresh the phonological loop through rehearsal, calling on other cognitive strategies. The modifications on the CTOPP attempt a purer measure of the
underlying phonological process that is not confounded by other cognitive operations.

**IV- Assessment of Long and Short term memory**

Here subjects are given three digits or six digits then a word list is presented. The subject is required to recall the words in their correct order and then recall the digits in their correct order of presentation. The type of words to be recalled should be variable (high imagery words versus low imagery words). In this test, long terms as well as short term memory are assessed as their affection affects the reading ability (*Siegel and Linder, 1984*).

**Tests for procedural memory:**

1- **Pursuit rotor task:**

A device used to study visual-motor tracking skills and hand-eye coordination by requiring the participant to follow a moving object with a cursor or use a stylus to follow the target on a computer screen or a turntable. With the computer screen version, the participant follows a dot on a circular path like the one shown below.
Assessment of Memory Deficits in Learning Disability

Figure 16: Screenshot of a computerized version of the pursuit rotor task (Allen et al., 2004).

The pursuit rotor task is a simple pure visual-motor tracking test that has consistent results within age groups. This displays a measurement of procedural memory as well as demonstrates the participant's fine-motor skills. The pursuit rotor task tests the fine-motor skills which are controlled by the motor cortex (Allen et al., 2004). The results are then calculated by the participant's time-on and time-off the object. Amnesic participants show no impairment in this motor task when tested at later trials. It does however seem to be affected by lack of sleep and drug use (Dotto, 1996).

2- Serial reaction time task:

This task involves having participants retain and learn procedural skills that assess specific memory for procedural-motor skill. These skills are measured by observing the speed and accuracy of the participant's ability to retain and acquire new skills. The reaction time is the time it takes for the
participant to respond to the designated cue presented to them. Participants with Alzheimer’s disease and amnesia demonstrate a long retention time which indicates that they are able to retain the skill and demonstrate effective performance of the task at a later point in time (Balota et al., 1993).

3- Mirror tracing task:

This task looks at the integration of the senses more specifically as it is a visual motor test where the participants learn a new motor skill involving hand-eye coordination. Evidence is shown for procedural memory as amnesic participants are able to learn and retain this task. Drawing the image is the work of your procedural memory; once you figure out how to draw the image in the mirror you have little difficulty the second time. Individuals with Alzheimer’s disease are not able to recall the skills acquired in a mirror tracing task, but they acquire the procedural performance ability regardless (Corkin et al., 1993).

4- Weather prediction task:

Specifically, this task uses experimental analysis of weather prediction. As a probability learning task, the participant is required to indicate what strategy they are using to solve the task. It is a cognitively-oriented task that is learned in a procedural manner. It's designed using multidimensional stimuli, so participants are given a set of cards with shapes and
then asked to predict the outcome. After the prediction is made participants receive feedback and make a classification based on that feedback. For example, the participant can be shown one pattern and then asked to predict whether the pattern indicates good or bad weather. The actual weather outcome will be determined by a probabilistic rule based on each individual card. Amnesic participants learn this task in training but are impaired in later training control (Packard and Poldrack, 2003).

Techniques Used to Assess Infants’ Memory:

Infants do not have the language ability to report on their memories, and so, verbal reports cannot be used to assess very young children’s memory. Throughout the years, however, researchers have adapted and developed a number of measures for assessing both infants’ recognition memory and their recall memory. Habituation and operant conditioning techniques have been used to assess infants’ recognition memory and the deferred and elicited imitation techniques have been used to assess infants’ recall memory.

Techniques used to assess infants’ recognition memory:

- **Visual paired comparison procedure (relies on habituation)**: Infants are first presented with pairs of visual stimuli, such as two black-and-white photos of human faces, for a fixed amount of time; then, after being
familiarized with the two photos, they are presented with the “familiar” photo and a new photo. The time spent looking at each photo is recorded. Looking longer at the new photo indicates that they remember the “familiar” one. Studies using this procedure have found that 5- to 6-month-olds can retain information for as long as fourteen days (Fagan, 1974).

- **Operant conditioning technique**: infants are placed in a crib and a ribbon that is connected to a mobile overhead is tied to one of their feet. Infants notice that when they kick their foot the mobile moves; the rate of kicking increases dramatically within minutes. Studies using this technique have revealed that infants’ memory substantially improves over the first 18-months. Whereas 2- to 3-month-olds can retain an operant response (such as activating the mobile by kicking their foot) for a week, 6-month-olds can retain it for two weeks, and 18-month-olds can retain a similar operant response for as long as 13 weeks (Rovee-Collier, 1999).

**Techniques used to assess infants’ recall memory:**

- **Deferred imitation technique**: an experimenter shows infants a unique sequence of actions (such as using a stick to push a button on a box) and then, after a delay, asks the infants to imitate the actions. Studies using
deferred imitation have shown that 14-month-olds’ memories for the sequence of actions can last for as long as four months (*Meltzoff, 1995*).

- **Elicited imitation technique**: is very similar to the deferred imitation technique; the difference is that infants are allowed to imitate the actions before the delay. Studies using the elicited imitation technique have shown that 20-month-olds can recall the action sequences twelve months later (*Bauer, 2002*).

**Techniques used to assess older children and adults' memory:**

Researchers use a variety of tasks to assess older children and adults' memory. Some examples are:

- **Free recall** - during this task a subject would be asked to study a list of words and then sometime later they will be asked to recall or write down as many words that they can remember. Earlier items are affected by retroactive interference, or RI, which means the longer the list, the greater the interference, and the less likelihood that they are recalled. On the other hand, items that have been presented lastly suffer little RI, but suffers a great deal from proactive interference, or PI, which means the longer the delay in recall, the more likely that the items will be lost (*Baddeley, 1976*).
• **Recognition** - subjects are asked to remember a list of words or pictures, after which point they are asked to identify the previously presented words or pictures from among a list of alternatives that were not presented in the original list (*Baddeley, 1976*).
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► General techniques for improving attention and memory (Mastropieri and Scruggs, 1993):

1) Increase Attention: Students will not remember something that they did not pay attention to in the first place. Strategies for enhancing attention include intensifying instruction, teaching enthusiastically, using more visual aids and activities, and reinforcing attending.

2) Enhance Meaningfulness: Find ways to relate the content being discussed to the student's prior knowledge.

3) Minimize Interference: Avoid digressions and emphasize only the critical features of a new topic.

4) Promote Active Manipulation: Students remember content better when they experience it for themselves.

5) Promote Active Reasoning: Students remember better if they actively think through new information, rather than simply repeating it.
6) Increase the Amount of Practice: Students should be taught the necessity of "over learning" new information. Often they practice only until they are able to perform one error-free repetition of the material.

7) Review material right before going to sleep at night. Any task that is performed after reviewing and prior to sleeping interferes with consolidation of information in memory.

8) Note taking is an activity that may help students register information in memory as well as to consolidate it.

9) All students would benefit from self-testing.

10) Draw diagrams or flow charts of the steps/events.

11) Information is remembered better when it is rehearsed using multiple sensory modalities.

12) Use the test questions that require recognition memory rather than recall (e.g., multiple choices and/or matching) 
(Mastropieri and Scruggs, 1993).

► More Specific Strategies for Enhancing Memory and Reducing Memory Problems:

1- Mnemonic strategies:
Defined in broad terms, a mnemonic is a device, procedure, or operation that is used to improve memory. Defined in narrow terms, a mnemonic is a specific reconstruction of target content intended to tie new information more closely to the learner's existing knowledge base and, therefore, facilitate retrieval. There are a variety of mnemonic techniques, including keywords, acronyms, spelling mnemonics, phonetic mnemonics, number-sound mnemonics, and Japanese “Yodai” methods. Mnemonic strategies have been proven to be extremely effective in helping people remember things (Mastropieri and Scruggs, 1989; Bulgren et al., 1994).

Examples of mnemonic techniques include:

*The keyword method:*

A keyword is a word that sounds like the new word and is easily pictured. For example, to remember that “barrister” is another word for “lawyer”, the keyword “bear” that sounds like the word “barrister” is created. Then the picture of a bear who is acting as a lawyer in a courtroom, for example, is created.

*Letter strategies:*

Letter strategies, which involve using letter prompts to remember lists of things, are the most familiar to students.
Acronyms are most helpful when the first letters of a list can be used to create an entire word (Mastropieri and Scruggs, 1994).

Spelling mnemonics:

These are used to help remembering the spelling of words. For example, to avoid confusion between "hear" and "here", remember “you HEAR with your EAR” (Mastropieri and Scruggs, 1994).

2- Students who have working memory problems may need to use a "staging" procedure that allows them to focus on one aspect of writing at a time. With this procedure, they would first generate ideas, then organize them, and finally attend to spelling and mechanical and grammatical rules (Kail and Hall, 2001).

3- Building sequential memory:

- Activities to build visual sequential memory: You can use memory cards, photos, toys or other objects. Do not say anything (auditory overrides visual). Start with a sequence of two. Let the child see the sequence for a second or two then cover the items with a blanket and he would tell you what he saw in the same order. When the child performs accurately 75% at any particular level, this means he is ready for the next level.
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- **Activities to build auditory sequential memory:** This activity is auditory. Do not give any visual clues. Use a monotone voice with a one second pause between each direction. Do not use extra words. When they get up to 6 or 7, add variety by doing them reversed. This teaches visualization. You say a sequence backwards and the child repeats it to you forward. Ex.: red, purple. Yellow…they’d say yellow, purple, and red. This activity is great to teach spelling. Spelling requires visualization and processing (*Levine, 1994*).

**Remediation of attention and memory disorders:**

* **Training attention:**

  - Training auditory attention through story telling: The child was instructed to listen carefully to passage read by the clinician and to raise his hand immediately after a target word was presented

  - Training visual attention using visual abilities cards.

* **Activities to build auditory memory (short term and working memory):**

1) Forward Digit span:

   A monotone voice was used with a one second pause between numbers. The child had to repeat the sequence in the
same order. A sequence of two was first introduced and the sequence gradually increased to 6 or 7. When the child performed accurately 75% at any particular level, this meant he/she was ready for the next level.

If the child found difficulty to repeat the sequence correctly at any level, we proceeded to the following facilitation steps:

- Chunking (with intoned voice) plus repeating the last number twice.
- Chunking without repetition of last number.
- Repetition without chunking (with a one second pause between numbers).
- Complete withdrawal of facilitation.

2) Backward Digit span:

This task is more complex than the forward digit span, since the information must be processed more times prior to being retrieved, thus placing greater demands on the working memory.

3) Word list repetition:

The child was instructed to repeat (in the same order) lists of words orally presented at one second intervals. The list
increased gradually in length from 2 words to 6 words. The following principles were considered in constructing the word lists:

- Always started with monosyllabic then proceeded to disyllabic and lastly multisyllabic words.

- Retrieval of words belonging to the same semantic category was easier than retrieval of words from different semantic categories.

- Phonologically similar words are more difficult to retrieve than phonologically dissimilar words.

If the child found some difficulty to repeat the sequence correctly at any level, the same order of facilitation techniques mentioned with digit span forward was also followed.

4) The child was instructed to repeat (in the same order) the first sound of words orally presented at one second intervals. The list increased gradually in length from 2 words to 6 words.

5) Listen and do exercises: The child was asked to follow multistep commands increasing gradually in length.

* Activities to build visual sequential memory:
Using picture cards, photos, toys or other objects without saying anything (auditory overrides visual). A sequence of two was first introduced then the child was asked to see the sequence for a second or two. The items were then covered and the child was asked to tell what he/she saw in the same order. When the child performed accurately 75% at any particular level, this meant he/she was ready for the next level.

**Accommodations for visual processing disorders:**

By the following:

- Use large print books.

- Use books on tape, e-books or screen reader.

- Avoid shiny white paper.

- Suggest use of tracking tools when reading: For many children, a “window” made from cutting a rectangle in an index card helps keep the relevant numbers, words, sentences, etc. in clear focus while blocking out much of the peripheral material which can become distracting. As the child’s tracking improves, the prompt can be reduced. For example, after a period of time, one might replace the “window” with a ruler or other straightedge, thus increasing the task demands while still providing additional structure.
This can then be reduced to, perhaps, having the child point to the word s/he is reading with only a finger.

- Give instructions in written and oral form. Read problems aloud.

- Suggest that student compare notes with other students.

- Use reader on tests.

- Use 1.5 line spacing.

- Allow student to write answers on test, not a separate paper (Bloom, 1990).

Ireland, 2010 suggest four steps for helping children with visual memory problems:

**Step 1:**

Fill a tray with five or six small, recognizable items from around the house and allow your child to look at the tray and observe the objects. After one or two minutes, take the tray away and remove one of the objects. Then ask your child which object is missing. He'll need to recall his visual memory of the tray to decide.

**Step 2:**
Utilize the spoken word as often as possible, and ask that your child's teachers do the same at school. While a child with visual memory problems may balk at written directives, hearing the instructions may be more effective. That's why a child with visual memory problems may be seen reading instructions aloud to try and grasp and remember the instructions on an audible level.

**Step 3:**

Offer hands-on activities where your child is doing something rather than simply seeing something. When your child sees something done, a visual memory problem can erase both the image and the concept soon after. Giving your child the chance to experience an activity like cooking, playing or acting things out can instill the concepts deeper in your child's mind through experience rather than visual pictures.

**Step 4:**

Alter handouts and instructions so they are easier to read and remember. While a list of instructions or a paper filled with words and pictures is confusing, a paper that clearly offers borders and dividers can help your child easily pick out the most important information. Ask your child's teacher to add things like text boxes and darkened margin lines so your child
can more easily understand a worksheet, and implement the same changes at home for better understanding and more recall,

**Accommodations for auditory processing disorders:**

By the following:

- Supplement lectures with written material, visual cues, handouts, and manipulatives.
- Show rather than explain.
- Speak slowly and clearly.
- Reduce and/or space directions (give them one at a time); give cues such as —ready? Ask individuals or class to repeat instructions.
- Give directions both orally and visually. Limit background noise while giving directions or teaching new information.
- Vary pitch and tone of voice; alter pace, stress key words.
- Allow 5-6 seconds for students to respond to questions.
- Avoid asking students to listen and write at the same time.
- Help students strengthen note-taking skills. Suggest they compare notes later with others.
- Suggest that students record study material for later playback.

- Encourage students to ask for clarification when necessary.

- Encourage students to sit where they can hear best.

- Make students aware of quiet places for study.

- Acoustic modifications can be made to the classroom (e.g., carpeting, acoustic ceiling tiles, window treatments) which should help to minimize the detrimental effects of noise on the child's ability to process speech in the educational setting (Bloom, 1990).

**Working Memory Training**

One theory of attention-deficit hyperactivity disorder states that ADHD can lead to deficits in working memory. Studies suggest that working memory can be improved by training in ADHD patients through computerized programs (Klingberg et al., 2002). Working memory training increases a range of cognitive abilities and increases IQ test scores. This suggests that working memory underlies general intelligence (Olesen et al., 2004).

**Management of ADHD:**
There are several effective and clinically proven options to treat people with ADHD. Combined medical management and behavioral treatment is the most effective ADHD management strategy, followed by medication alone, and then behavioral treatment \textit{(Jensen, 2005)}.

Training with a working memory task (the dual n-back task) improves performance on a very specific fluid intelligence test in healthy young adults \textit{(Jaeggi et al., 2008)}. Improving or augmenting the brain’s working memory ability increases fluid intelligence is backed by some and questioned by others \textit{(Chooi and Thompson, 2012)}.

Working memory is enhanced through exposure to excess neural activation. The brain map of an individual, he argues, can be altered by this activation to create a larger area of the brain activated by a particular type of sensory experience. An example would be that in learning to play guitar, the area activated by sensory impressions of the instrument is larger in the brain of a player than it is in a nonplayer \textit{(Klingberg, 2009)}.

There is evidence that optimal working memory performance links to the neural ability to focus attention on task-relevant information and ignore distractions \textit{(Zanto and Gazzaley, 2009)}. That practice-related improvement in working memory is due to increasing these abilities \textit{(Berry et al., 2009)}.
The key to enhancing one’s working memory is to practice attention control. Absentmindedness is one of the “seven sins of memory”. Also show kids what to do more than once, breaking tasks into individual steps and avoid work settings that have high demand for multi-tasking, such as office reception or keeping track of short orders in a busy coffee shop (Schacter, 2001). In a study of brain activity showed that working memory is closely related to the parietal lobe, the superior frontal gyrus, and the middle frontal gyrus. The first two areas are also active when the subject of an experiment practices controlled attention. Working memory and attention control are thus inseparable functions of our brains (Klingber, 2009).

Working memory performance may also be increased by high intensity exercise. A study was conducted with both sedentary and active females 18–25 years old in which the effects of short-term exercise to exhaustion on working memory were measured. While the working memory of the subjects decreased during and immediately after the exercise bouts, it was shown that the subjects' working memory had an increase following recovery. However, much of the success of working memory training studies has been called into question. Working memory training studies are accused of poor experimental design. The majority of training studies utilize a
no-contact control group making it impossible to determine whether any benefit of training is due to actual improvement or a Hawthorne effect (Shipstead et al., 2010).

Ideal solution for impairments of working memory would be to remediate these memory impairments directly, there is little evidence that training working memory in children with low working memory skills leads to substantial gains in academic attainments. However, we suggest that the learning progress of children with poor working memory skills can be improved dramatically by reducing working memory demands in the classroom (Turley-Ames and Whitfield, 2003).
Methods of classroom management in children with working memory impairments:

First, it is important to ensure that the child can remember what he or she is doing. On many occasions, children with low working memory simply forget what they have to do next, leading to failure to complete many learning activities. Children’s memory for instructions will be improved by using the instructions that are as brief and simple as possible. Instructions should be broken down into individual steps where possible. One effective strategy for improving the child’s memory for the task is frequent repetition of instructions. For tasks that take place over an extended period of time, reminding the child of crucial information for that particular phase of the task rather than repetition of the original instruction is likely to be most useful. Finally, one of the best ways to ensure that the child has not forgotten crucial information is to ask them to repeat it. Our observations indicate that the children themselves have good insight into their working memory failures (*Turley-Ames and Whitfield, 2003*).

Second, in activities that involve the child in processing and storage information, working memory demands and hence task failures will be reduced if the processing demands are decreased. For example, sentence writing was a source of
particular difficulty for all of the children with low working memory that we observed. Sentence processing difficulty can be lessened by reducing the linguistic complexity of the sentence. This can be achieved in a variety of ways, such as simplifying the vocabulary, and using common rather than more unusual words. In addition, the syntax of the sentence can be simplified, by encouraging the child to use simple structures such as active subject-verb-object constructions rather than sentences with a complex clausal structure. The sentences can also be reduced in length. A child with poor working memory skills working with short sentences, relatively unfamiliar words and easy syntactic forms are much more likely to hold in working memory the sentence form and to succeed in a reasonable attempt at writing the sentence (Turley-Ames and Whitfield, 2003).

Third, the problem of the child losing his or her place in a complex activity can be reduced by breaking down the tasks into separate steps, and by providing memory support. External memory aids such as useful spellings displayed on the teacher’s board or the classroom walls and number lines are widely used in classrooms. In our observational study, however, we found that children with poor working memory function often chose not to use such devices, but gravitated instead towards lower-level strategies with lower processing requirements resulting in
reduced general efficiency. For example, instead of using number aids such as Unifix blocks and number lines that are designed to reduce processing demands, these children relied on more error-prone strategies like simple counting instead. In order to encourage children’s use of memory aids, it may be necessary to give the child regular periods of practice in the use of the aids in the context of simple activities with few working memory demands (Turley-Ames and Whitfield, 2003).

Difficulties in keeping place in complex task structure may also be eased by increasing access to useful spellings. This will also help prevent them losing their places in writing activities. Reducing the processing load and opportunity for error in spelling individual words will increase the child’s success in completing the sentence as a whole. However, reading of information from spellings on key words on the teachers’ board was itself observed to be a source of error in low memory children in our study, with children commonly losing their place within the word. Making available spellings of key words on the child’s own desk rather than a distant class board may reduce these errors by making the task of locating key information easier and reducing opportunities for distraction. It may also be beneficial to develop ways of marking the child’s place in word spellings as a means of
Management of Memory Deficits in Learning Disability Children


Management of Phonological Memory Deficits

Phonological awareness is an auditory skill that is developed through a variety of activities that expose students to the sound structure of the language and teach them to recognize, identify and manipulate it. Listening skills are an important foundation for the development of phonological awareness and they generally develop first. Therefore, the scope and sequence of instruction in early childhood literacy curriculum typically begins with a focus on listening, as teachers instruct children to attend to and distinguish sounds, including environmental sounds and the sounds of speech. Early phonological awareness instruction also involves the use of songs, nursery rhymes and games to help students to become alert to speech sounds and rhythms, rather than meanings, including rhyme, alliteration, onomatopoeia, and prosody. While exposure to different sound patterns in songs and rhymes is a start towards developing phonological awareness, exposure in itself is not enough, because the traditional actions that go along with songs and nursery rhymes typically focus on helping students to understand the meanings of words, not attend to the
sounds. Therefore, different strategies must be implemented to aid students in becoming alert to sounds instead. Specific activities that involve students in attending to and demonstrating recognition of the sounds of language include waving hands when rhymes are heard, stomping feet along with alliterations, clapping the syllables in names, and slowly stretching out arms when segmenting words. Phonological awareness is technically only about sounds and students do not need to know the letters of the alphabet to be able to develop phonological awareness (Richmond, 1998).

Students in primary education sometimes learn phonological awareness in the context of literacy activities, particularly phonemic awareness. Some research demonstrates that, at least for older children, there may be utility to extending the development of phonological awareness skills in the context of activities that involve letters and spelling. A number of scholars have been working on this approach (Kurtz, 2010).

Van Kleek et al. (1998) demonstrated that training in phonemic awareness results in improved phonological memory, unlike an alternative training program in rhyming. Many teachers find that work with concrete manipulatives and mnemonic devices aids memory. Providing children with appropriate "assistive technology" can scaffold for poor memory, whether that technology is as simple as number lines.
and math facts tables or as advanced as using calculators and electronic reminder systems.

Although all children with severe reading disabilities require extensive practice for success, those with poor orthographic memories require phenomenal amounts of practice. Computer technology, repeated readings, and using visualization tricks for spelling may all be helpful additions to programs for such children. Children with stronger orthographic memories and high vocabularies can look like miracles with the speed of their progress, once the phonological deficits are remedied and they are given lots of opportunity for practice to get their new skills applied and automatic (Van Daal and Reitsma, 1993).
Summary

Memory is the process by which that knowledge of the world is encoded, stored and later retrieved, learning is the process by which we acquire knowledge about the world so memory is closely related to learning and both are usually considered together.

From information processing perspective there are three main stages in the formation and retrieval of memory:

- *Encoding* or registration (processing and combining of received information)
- *Storage* (creation of a permanent record of the encoded information)
- *Retrieval* or recall (calling back the stored information in response to some cue for use in a process or activity).

Brain parts involved in neuroanatomy of memory and learning include:

A- Subcortical structures include hippocampus, amygdalae, basal ganglia and cerebellum.

B- Cortical structures includes frontal, parietal and temporal lobes.
Learning and memory are attributed to changes in neuronal synapses, thought to be mediated by long-term potentiation and long-term depression.

Memory is classified according to the duration of memory retention (depending on how long information is stored) into sensory register, short term or working memory, and long term memory.

Sensory memory include iconic (visual) memory, echoic (auditory) memory and haptic memory.

Working memory consists of three basic stores: the central executive, the phonological loop and the visuo-spatial sketchpad and episodic buffer.

Long-term memory includes two components: declarative (DM) or explicit memory ("knows that") and nondeclarative (NDM) or implicit memory ("knows how").

Declarative memory can be divided into two categories: episodic memory and semantic memory. Non-declarative is known as procedural memory.

There are four different types of learning that occur in normal waking consciousness, depending on whether the outer physical environment or inner mental processes are focused upon the primary cause of the physical organism's observed performance (a) classical (respondent) conditioning, (b) operant
(instrumental) conditioning, (c) observational (vicarious) learning, and (d) cognitive (information-processing) learning.

There is now extensive evidence that working memory is linked to key learning outcomes in literacy and numeracy. Impairments of working memory are closely associated with learning deficits, as well as daily classroom activities. Without early intervention, memory deficits cannot be made up over time and will continue to compromise a child’s likelihood of academic success.

Variety of memory problems are evidenced in the learning-disabled. These include problems in receptive memory, sequential memory, rote memory, short term memory, and long term memory.

Assessment of memory deficits in learning disability include assessment of receptive memory (auditory and visual memory), sequential memory, short term memory (working memory), and long term memory.

**General techniques for improving attention and memory include:**

1) Increase Attention.

2) Enhance Meaningfulness.

3) Minimize Interference.
4) Promote Active Manipulation.

5) Promote Active Reasoning: Students remember better if they actively think through new information, rather than simply repeating it.

6) Increase the Amount of Practice 7) Review material right before going to sleep at night. 8) Note taking.

9) All students would benefit from self-testing.

10) Draw diagrams or flow charts of the steps/events.

11) Information is remembered better when it is rehearsed using multiple sensory modalities.

12) Use the test questions that require recognition memory rather than recall (e.g., multiple choices and/or matching).
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