White Paper

The Cognitive Science of Learning: Implications for eLearning Multimedia Design

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The Science of Learning

Since prior knowledge and learning are related, connecting new information to prior knowledge will facilitate the learning process. We learn better and faster when we relate new information to things we already know. Human learning is a constructive process in that humans construct meaning from existing knowledge structures that are individually defined. People take past experiences and make conceptual building blocks from them, upon which new knowledge is developed. The building metaphor is the basis for the constructivist philosophy of education.

What is Cognitive Science?

Cognitive science is the interdisciplinary study of the human mind and intelligence, embracing philosophy, psychology, artificial intelligence, neuroscience, linguistics, and anthropology. Broadly speaking, the goal is to characterize the nature of human knowledge -- its forms and content -- and how that knowledge is used, processed, and acquired.

Cognitive science intellectual origins are in the mid-1950s when researchers in several fields began to develop theories of mind based on complex representations and computational procedures. Active areas of cognitive research include language, memory, visual perception and cognition, thinking and reasoning, social cognition, decision making, and cognitive development.

What is Neuroscience?

Neuroscience is the study of how the nervous system develops, its structure, and what it does. Neuroscientists focus on the brain and its impact on behavior and cognitive functions.

Neurons are nerve cells built to process and transmit the electrical and chemical transitions of normal brain function. As core components of the central nervous system, neurons are mapped and studied by the medical profession

Neuroscience explains the process of your brain interpreting the information received from sensory input. That's the automatic function of one's nervous system. However, interpreting the information from sensory input is cognition

Cognitive Science and Learning Theories

Learning theories are conceptual frameworks that describe how information is absorbed, processed, and retained…in other words, how people *learn.* Therefore, it is essential to examine how information moves from sensory input, to short term memory, and to long term memory.

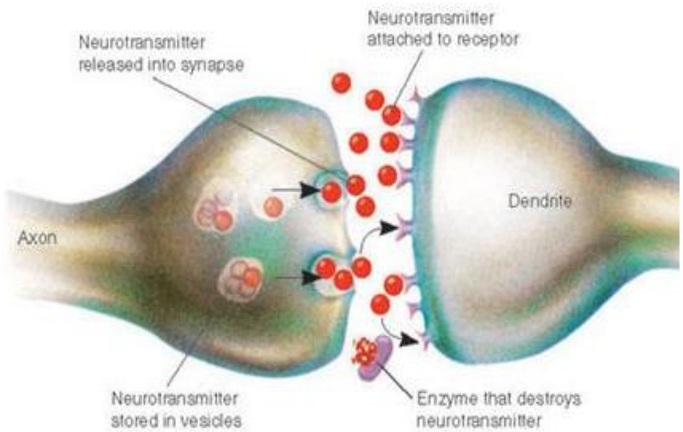
However, the challenge for teachers is *how* to move information from short term memory to long term memory for recall [and application]. Therefore, by exploring the *Cognitive Information Processing Model,* one can facilitate the transfer of information [from short term memory to long term memory] and increase learning and retention by integrating *cognitive learning strategies*.

The Neuroscience of How the Brain Learns

When exposed to new information from our senses (modalities), our brain needs to form an association between what we see and [sometimes] hear, which are then encoded by different groups of neurons in various parts of your brain. Each time that input is repeated (reinforced), those sets of neurons fire simultaneously, strengthening the synaptic pathway that connects them…effectively creating *memory* (How Does Our Brain Learn New Information? *Scientific American,* Nov., 2011*).*

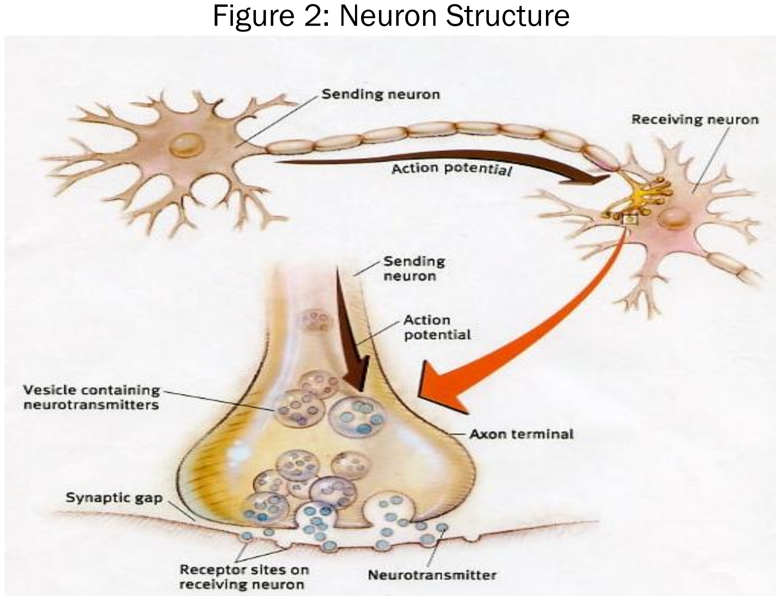
In scientific terms, learning is a neurobiological process indicated by the growth and strengthening of connections between neurons (Figure 1).

Figure 1: Synaptic Pathway



However, many different events can increase a synapse's strength when we learn new information. That process is called long-term potentiation where repeatedly stimulating two neurons at the same time fortifies the link between them. After a strong connection is established between these neurons, stimulating the first neuron will more likely excite the second (Figure 2). This effect can be achieved ("facilitated") by designing and integrating cognitive learning strategies.

Figure 2: Neuron Structure



Brain Research Discoveries [and their impact on learning]

The brain responds to reward due to several factors. Recent discoveries by neuroscientists reveals rewards are influenced by many factors, among them are context and individual differences. In the context of reinforcement learning, the individual learner's reward system responds to prediction error, which is the difference between the result an individual expects from their action and the outcome they actually get (Garrison, Erdeniz, & Done, 2013).

Learners use most areas of the brain. This runs contrary to the myth that individuals are using only 5 to 10 percent of their brain. There's no proof of this. Neuroscientists and neurologists have already presented evidence that refute this "10 percent" myth (Do People Only Use 10 Percent of Their Brains, 2008)

Cells that fire together, wire together. In other words, the "use-it-or-lose-it" phenomenon, or simply put, if you want to retain new information, you have to use it constantly or else lose it. When you stop practicing a new skill or a new language, for instance, your brain will eventually prune or eliminate certain pathways. You'll eventually lose a new skill unless you keep on practicing (Retrieval-Based Learning: Active Retrieval Promotes Meaningful Learning, 2012).

No one is neither right-brained nor left-brained. While it's true that some brain functions occur on either part of the brain, researchers have confirmed that personality traits have nothing to do with which side of their brain learners use more *(Nielsen, Zielinski, Ferguson, Lainhart, & Anderson, 2013.)*

The human brain can't multitask. The human brain cannot focus on several tasks at once. Multitasking simply splits the brain by frantically switching from one task to another. This results in significant inefficiency in filtering irrelevant information and simply doesn't work (Ophira, Nass, & Wagnerc, 2009).

Cognitive Information Processing Model

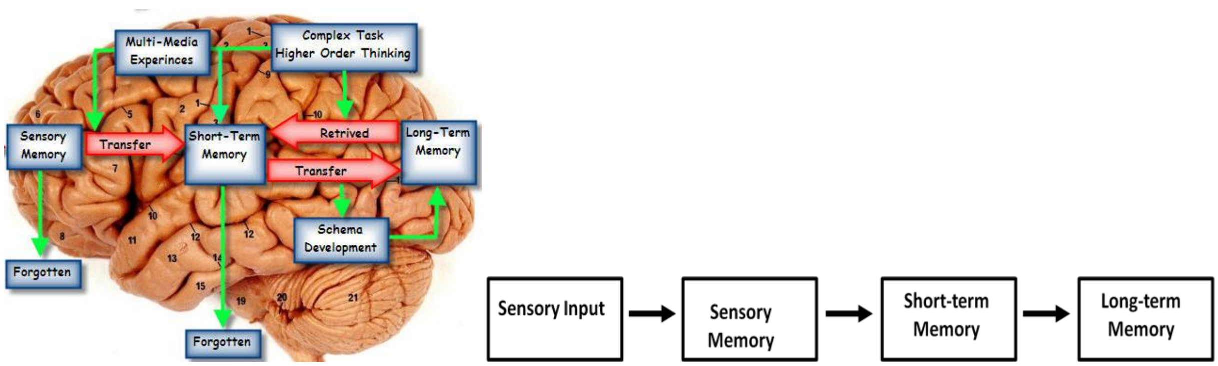
The cognitive information processing (CIP) model postulates that the learner's brain has internal structures that select and process incoming material, store and retrieve it, use it to produce behavior, and receive and process feedback on the results. A number of cognitive processes are involved in learning, including the "executive" functions of recognizing expectancies, planning and monitoring performance, encoding information, and producing internal and external responses. Consequently, it is essential to examine how information moves from sensory input, to short term memory, and on to long term memory. However, the challenge for instructors is *how* to move information from short term memory to long term memory for recall [and application]. Therefore, by exploring the *Cognitive Information Processing Model* (Figure 3), one can facilitate the transfer of information [from short term memory to long term memory] and increase learning and retention by integrating *cognitive learning strategies.*

The basic premise of the Cognitive Information Processing (CIP) model is that individuals mentally process their environment. This process consists of a number of stages in which the stimuli become information, which is given meaning by previous knowledge and current expectations. Cognitive strategies are employed to maintain the knowledge in short-term memory and translate it to a structure that enters long-term memory as a type of knowledge in the form of propositions, productions or schemas. Cognitive strategies are thought of as executive control mechanisms for learning. Monitoring the use of strategies is "metacognition." Cognitive strategies used in metacognition are called metacognitive strategies. The CIP model views learning when information is received from the environment via the senses (modalities), processed and stored into memory, and then output in some form of learned capability.

Memory

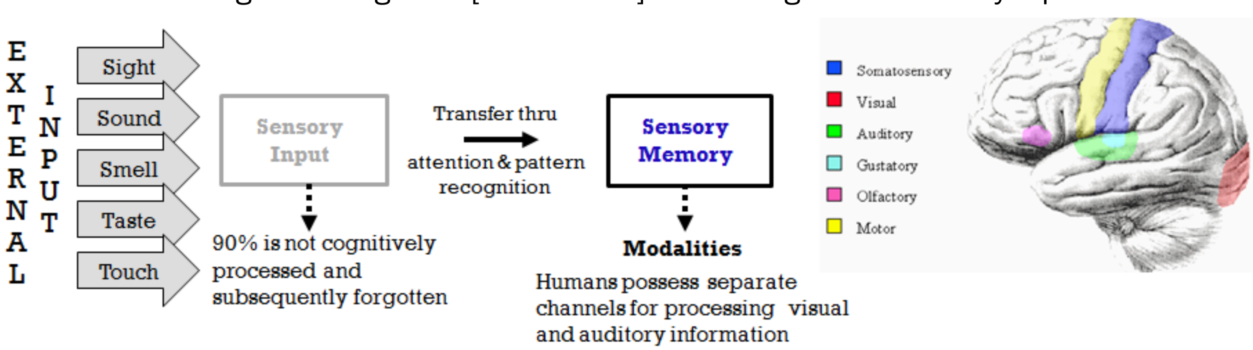
Humans have 3 types of memory***: sensory***, ***short term***, and ***long term***. In the simplest of terms, "learning" can be defined as the moving of "information" from short term memory (aka working memory) and consolidating it into long term memory (Schunk, 2004; Bruning, Schraw, Norby, & Ronning, 2004; Driscoll, 2005).

Figure 3: Cognitive [Information] Processing Model



The first stage, ***sensory memory,*** is associated with the senses (seeing, hearing, touching, etc.) where information is stored briefly for processing. Information is stored for only a fraction of a second before the subconscious decision is made concerning how to process the information. After entering sensory memory, a limited amount of information is transferred into short-term memory.

Figure 4: Cognitive [Information] Processing Model Sensory Input



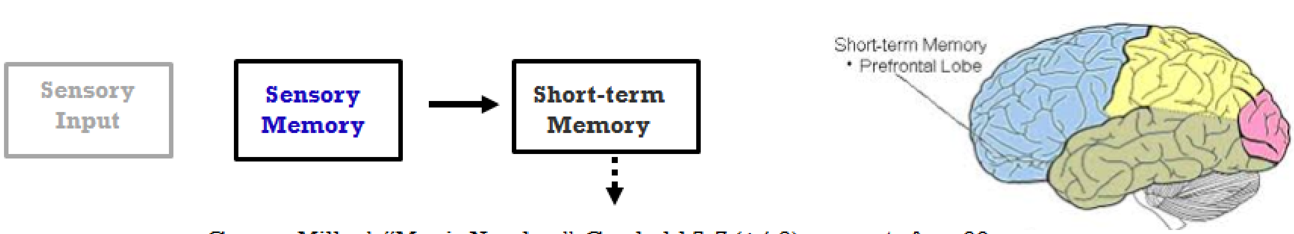
Sensory perception is very complex in that incoming stimuli are essentially bombarding the brain at any given moment in time. This incoming information would quickly result in sensory overload without the buffering mechanism that is referred to as sensory memory. As information is received by sensory receptors, the sensory memory begins to filter, or truly perceive, the information.

Short-term memory is the stage where further consciousness processing occurs, per se, actively thinking about what has occurred. Short-term memory receives information from sensory input and either discards it or processes it for storage into long-term memory. Short term memory is brief in duration (20-40 seconds), limited in capacity to 7 ±2 chunks of independent information (Miller's Law), and is vulnerable to interference and interruption, per se, the brain is easily distracted in that attention can be displaced.

Short-term memory is responsible for 3 operations:

1. **Iconic**. The ability to store images.
2. **Acoustic**. The ability to store sounds.
3. **Working Memory**. The ability to store information until it's put to use. Although working memory is often confused with short term memory, working memory refers to structures and processes used for temporarily storing and manipulating information, and is not only used for information storage, but also for the manipulation of information (Sossin, Lacaille, Castellucci, & Belleville, 2008).

Note: With respect to working memory, verbal/text memory and visual/spatial memory work together, without interference, into a framework (or *schema*) of understanding. Consequently, the development of schemata requires students to learn topics in ways that are relevant and meaningful to them, regardless of the modality.



George Miller's "Magic Number": Can hold 5-7 (+/-2) concepts for ~30-40 seconds before it decays… cognitive load can impede the transfer of information. Distractions & cognitive load decays information

The primary purpose of short-term memory is tri-fold: (1) to purge or release the new information from memory; (2) to maintain the information in working memory via simple rehearsal; or (3) to move (encode) the information from short term/working memory into long-term memory for later recall. While working memory holds limited information for a limited amount of time, by employing cognitive learning strategies the transfer of information from working memory to ***long term memory*** can be facilitated.

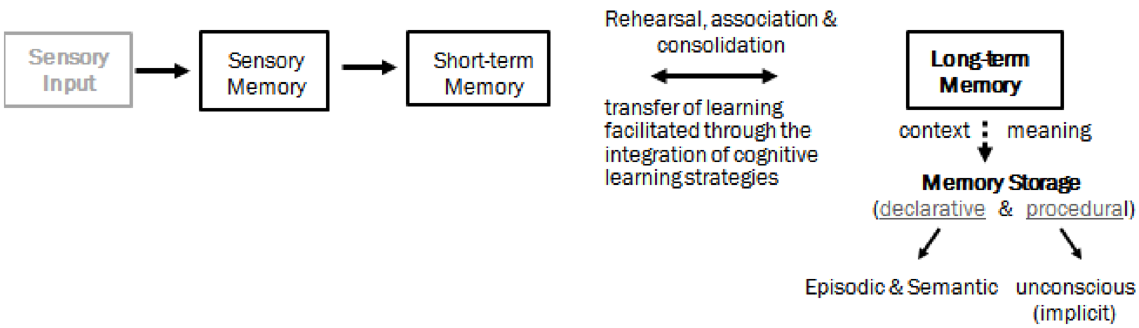
Long-term memory allows information [from short term memory] to be stored for extended periods of time, affects our perception and constitutes a framework where new information is attached. Information in Long-term memory is stored as a network of schemas, which then converts into knowledge structures. The challenge for an instructional designer is to activate those existing structures before presenting new information. Long-term memory consists of two types (Sossin, et al., 2008):

Explicit. Conscious memories that include our perception of the world, as well as our own personal experiences. Explicit memory consists of all those things you are aware of and that you can describe in words. This form of memory is also called declarative memory, because you can name and describe each of these remembered things explicitly.

Implicit: Unconscious memories (aka motor memories) that we use without realizing it and express it by means other than words. Also referred to as **non-declarative memory** because you are expressing memories of motor skills that do not require the use of language, e.g., riding a bike, juggling balls, tying shoe laces, etc.

Long-term memory is responsible for 3 operations

1. **Encoding**. The ability to convert information into a knowledge structure.
2. **Storage**. The ability to accumulate chunks of information.
4. **Retrieval**. The ability to recall things we already know (Sossin, et al., 2008).



Cognitive Learning Strategies

Transfer of learning means that something learned in one situation can be applied in another. Since transfer is the primary goal of instruction, it is imperative one must design for transfer. To that end, transfer is facilitated by the development of instructional strategies.

Scholars have identified learning to be primarily a social, dialogical process. Social learning theory suggests that most learning takes place in a social context where learner behavior is modeled by others. This modeling can occur through lecture, guided discussion, role-playing, case study, and other instructional strategies.

When articulating an instructional strategy, you must clearly relate the instructional strategy with the corresponding learning theory. For example, in each phase of learning activity, you would define and identify the key elements of the applicable learning theory and the appropriate instructional strategy that characterizes the specific learning theory. The student activities are the product of an instructional strategy that facilitates the attainment of the instructional objectives.

Cognitive learning strategies are methods used to help learners link new information to prior knowledge in facilitating the transfer of learning through the systematic design of instruction (Driscoll, 2005). Cognitive learning strategies focuses on how the learner processes the knowledge and supports the learner as they develop internal procedures that enable them to perform tasks that are complex, and can increase the efficiency with which the learner approaches a learning task.

The utility of cognitive learning strategies can be employed by trainers and/or instructional designers to facilitate the activation and retention of prior knowledge by focusing on *knowledge construction*.

Cognitive learning strategies primarily focuses on how the learner processes the knowledge, provides a structure for learning when a task cannot be completed through a series of steps (*scaffolding*).

Knowledge construction is a methodological approach which assumes that knowledge needs to be constructed. It occurs when learners explore issues, take positions, discuss positions in an argumentative format, and reflect and evaluate their positions. Knowledge construction involves active learning through participation and discourse, the opportunity to critically analyze information, dialogue with others about its meaning, reflect upon how the information fits within one's personal belief and value systems (*schema*), and arrives at a meaningful understanding of that information. In this process, information becomes transformed into knowledge.

Schema. The contents of long term memory are sophisticated structures that permit us to perceive, think, and solve problems, rather than a group of rote learned facts. These structures are known as schemas (a mental framework for understanding and remembering information) and permit us to treat multiple elements as a single element. Schema theory emphasizes the importance of generic knowledge that helps the formation of mental representations. There are four key elements of Schema:

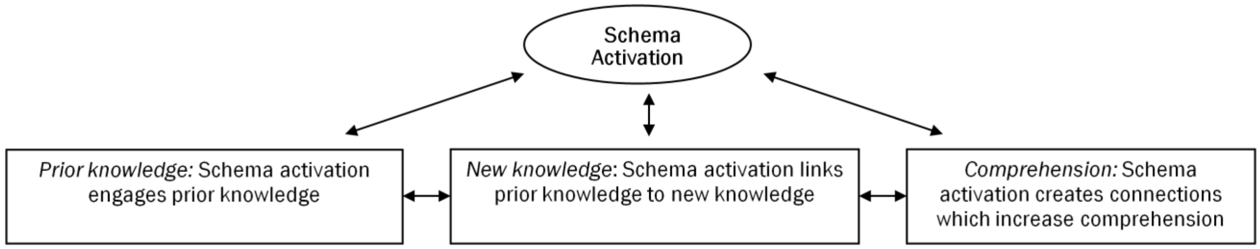
1. An individual can memorize and use a schema without even realizing of doing so.
2. Once a schema is developed, it tends to be stable over a long period of time.
3. Human mind uses schemata to organize, retrieve, and encode chunks of important information.
4. Schemata are accumulated over time and through different experiences.

Note: Sir Frederic Charles Bartlett (1886–1969) was a British psychologist, the first professor of experimental psychology at the University of Cambridge, and one of the precursors of cognitive psychology. The schema theory was one of the leading cognitivist learning theories and was introduced by Bartlett in 1932 and further developed in the '70s by Richard Anderson (Recker,1999).

Schemas are the cognitive structures that make up our knowledge base and assist us in knowledge construction, and are "activated" through the use of cognitive learning strategies.

> *Schema activation* refers to an array of activities designed to activate relevant knowledge in students' memory prior to encountering new information. Schema activation is the process of engaging prior knowledge, which is organized in the brain in schemata. Schema activation is an important scaffolding tool where learning depends upon the activation of old knowledge to provide an appropriate schema into which new knowledge can be incorporated (Driscoll, 2005, Schunk, 2004, & Bruning, et al., 2004).

Figure 5: Schema Activation



Scaffolding is a technique to increase the effectiveness of the instruction in that specialized instructional supports need to be in place in order to best facilitate learning when students are first introduced to a new subject. Scaffolding techniques can be classified into three major groups (Bruning, et al., 2004):

- *Verbal* scaffolding (e.g., paraphrasing, think-alouds, contextualizing)
- *Procedural* scaffolding (e.g., modeling, group instruction, peer assisted activities)
- *Instructional* scaffolding (e.g., using graphic organizers to help learners build background and organize text content).

Integrating Cognitive Learning Strategies into Multimedia Design

Cognitive learning strategies can be *represented* based on the information presented, and is used as tools to construct knowledge in new concepts (Driscoll, 2005, Schunk, 2004, Bruning, et al., 2004). Representative models include:

Organizing strategies must be supplemented by more powerful strategies, such as framing or concept mapping. However, chunking strategies are good preparation for other strategies (West, Farmer, & Wolff, 1999).

Chunking. Organization of information into meaningful units; makes it easier to use, store, and recall information; multiple chunks of information can be linked together; helps in overcoming working memory limitations; limits on the capacity of immediate memory affects the amount of information that we are able to receive, process, and remember.

Spatial strategies are an array of information organized by location in space and time. They assist in the recall of concrete arrays of information by using visual displays (grids, matrix, framework) of substantial amounts of information, and provide a big picture by which learners can use to assimilate information.

Bridging strategies helps learners to recall what they know and to transfer knowledge to new topics. It should be brief, abstract, and introduction of the new material and a restatement of prior knowledge. They provide learners with a structure of new information and encourage transfer and application by relating incoming information to concepts and ideas already in memory in such a way that new material is more memorable (West, et al., 1999).

Advance Organizer. A [bridging] strategy for metacognition in that it provides a "bridge" for students to transfer pre-existing knowledge to a new topic. Advance organizers can be used to link new with something already known, an introduction of a new lesson, unit or course, an abstract outline of new information and re-statement of prior knowledge, a structure for students of the new information, and an encouragement for students to transfer or apply what they know.

Metaphor. A figure of speech in which an expression is used to refer to something that it does not literally denote in order to suggest a similarity. A metaphor can be *comparative* in that it is an implicit statement that two apparently dissimilar objects do have in common features; it can be *interactive*, per se, similarities in the mind of the student between the vehicle and topic; or *relational*, per se, based on abstract connections of a logical or natural character; or an *attribute*, based on physical or perceptual similarities.

Analogy. Involves taking into consideration resemblances, between objects, situations or ideas which are similar. The intent is to transfer prior knowledge from a familiar situation to a new situation, per se, use of a familiar idea or concept to introduce or define a new idea or concept.

Simile. A figure of speech in which two unlike things are compared and share one common factor. This form of a cognitive strategy is essential because its ability to influence learning and memory. When using a simile the relationship is expressed using "is like" or "is similar to" or "as". A simile can use imagery as a bridge connecting the concept and the understanding, display better memory performance, e valuate their learning preference from the different formats the information is introduced, and imagine the concept, store and recall the image, and relate it to the subject.

General Purpose Strategies*.* Representative models include (West, et al., 1999):

Rehearsal. Allows for mastery of manageable chunks; enhances retention of modeled events; maintains information in short-term memory indefinitely and improve recall; represents miscellaneous ways of study; activities which help put material into short term memory by keeping it active so it can be more deeply processed for recall over long periods; reviewing, asking/answering questions, summarizing.

> Maintenance rehearsal is effective for short term retention and consists of using some memory strategy that keeps or maintains information in short-term memory.

> Elaborative rehearsal relates new information to previously known information. It is more of an active process that involves elaborating on new incoming information in some way and consists of information that one already knows.

Imagery. Mental visualization of objects, events, and arrays. Enabling internalized visual images that relate to information to be learned. Creating or recreating an experience in your mind .Imagery involves the primary learning modalities: visual and aural.

Mnemonics. Artificial aids to memory and meaningful practice which involves familiarizing oneself with a list. They act as a holding pattern while links are found to retain the information permanently. Repetition and association are two essential components to any memory technique. New knowledge is more effectively stored in the long term memory when it is associated with anything that is familiar. Demand active participation and a constant repetition of the material to be memorized.

Additionally, long term retention is improved as the spacing between repetitions increases. For example, by employing retrieval practice—asking questions repeatedly to retrieve information from the brain which is then immediately followed by feedback. To attend optimal retention, the learner should be engaged in repetition practice-repeat material often and continually. Also, spacing can improve retention (over hours, days, weeks); spacing combined with retrieval leads to better learning.

> "The so-called spacing effect—that practice sessions spaced in time are superior to massed practices in terms of long-term retention—is one of the most reliable phenomena in human experimental psychology" (Druckman & Bjork, 1991, p. 268, as cited in Clark & Mayer, 2011). Furthermore, "as long as eight years after an original training, learners whose prac-

tice was spaced showed better retention than those who practiced in a more concentrated time period" (Bahrick, 1987, p. 268, as cited in Clark & Mayer, 2011).

However, the spacing effect does not always result in better *immediate* learning, per se, only after a period of time are the benefits of spaced practice realized (Clark & Mayer, 2011).

Bottom line…using the above techniques activate more neurons. More neurons activated, the more likely retention (long term memory) is improved.

Multimedia Design for E-learning

What is Multimedia?

In its simplest form, multimedia is the presentation of material using both words and pictures. Words are the material is presented in *verbal form, e.g.,* printed or spoken text, and pictures are the material presented in *pictorial form, e.g.,* graphics, illustrations, graphs, photos, animation or video.

Learners can better understand an explanation when it is presented in words and pictures than when it is presented in words alone. By building connections between words and pictures, learners are able to create a deeper understanding than from words or pictures alone. This is the essence of the *cognitive theory of multimedia learning,* or more commonly referred to as dual-code or dual-channel learning (Clark & Mayer, 2011).

When translating learning theory into the design of content, integrating multimedia components can lead to effective learning. Continued research into neuroscience is discovering how the brain processes information and has revealed that significant increases in learning can be accomplished through the informed use of visual and verbal multimodal learning. Our brain is constantly searching its memory for context based on prior knowledge/experience. In the absence of visual cues, the brain creates "mental pictures" based upon one's schema to add context to what is printed/spoken. This view is more aligned with educational psychology, and is consistent with a cognitive theory of learning, which assumes that humans have separate information processing channels for verbal and pictorial knowledge.

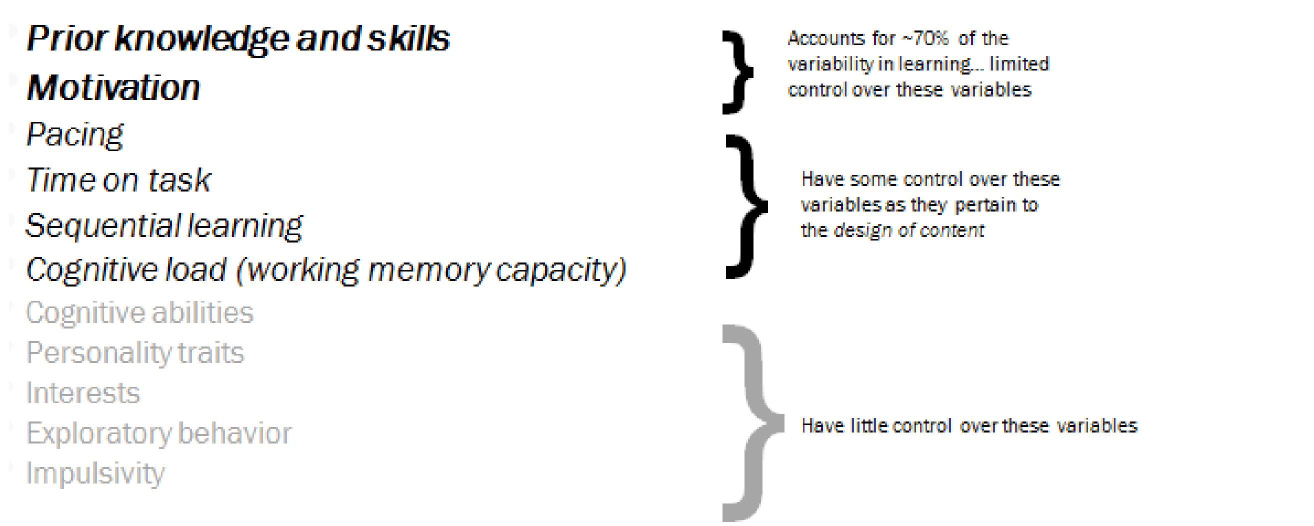
Note: Studies have shown that *how information is presented* determines the retention level of the information. Consequently, integrating multiple media in the design and delivery of instruction would *facilitate* the learning process

Basically, humans are *multi-sensory* in that the brain performs several activities at once when processing information (e.g., tasting and smelling, hearing and seeing), but are processed through different channels in our brain. The implicit assumption is that the information gained through one sensory modality is processed in the brain to be learned independently from information gained through another sensory modality.

The human dynamics of learning is a complex process that encompasses elements of behaviorist, cognitive and social learning theories. The variables that affect learning outcomes (Figure 5) are so pervasive that no single variable can account for variations in individual learning. Continued research into neuroscience is discovering how the brain processes information acquired through our primary learning modalities: visual, aural, and tactile. However, the challenge for trainers/instructional designers is to move information from short term memory to long term memory for recall [and application].

One of the reasons is the complexity of how the human brain functions as it relates to one's modalities in receiving information (visual, aural, kinesthetic) and how the brain processes that information (cognition).   An important finding from that research is that *learning* (retention) is generally *independent of the modality* used to acquire whatever is learned. To that end, trainers/instructional designers have some control over the variables that can affect learning when designing multimedia, but there are some variables which the designer has little or no control.

Figure 6: Factors Affecting the Variability in Learning



The Power of Visuals in E-learning

"A picture is worth a thousand words" is an often used phrase to emphasize the importance of visuals, but consider flipping the statement…it takes a thousand words to make the picture worthy. In other words, a picture without relevancy is simply a picture that takes a thousand words to make it relevant to the content. That said, emerging neuroscience and visualization research now reveals glimpses of the science behind the saying…visuals *do* matter (Multimodal Learning Through Media: What the Research Says, 2008).

The differences between the way the brain remembers words and remembers visuals. The brain has an extraordinary capacity to remember visual information. Memory experiments with visuals have shown that people can recall seeing hundreds, even thousands, of pictures. Pictures seem to operate as "chunks" and while the brain can hold only a few chunks in working memory at a time, visual images allow the brain to hold and enlarge the scope of those chunks. This is because visual processes evolved over millions of years, so the brain machinery in highly efficient in storing and recalling visual information (The Neuroscience of Learning: A New Paradigm for Corporate Education, 2010).

Although neuroscience has revealed 90% of what the brain processes is visual information, most learners are multi-modal and multi-sensory and adapt their strategies accordingly; consequently, one's *primary learning modality is visual (*Hyerle, 2000). That said, in his book on *Brain-Based Learning*, Jensen (2008) states that 80 –90% of information absorbed by the brain is visual in nature. What's more, the brain processes visual information 60,000 times faster than textual information. Consequently, the saying, "A picture is worth a thousand words" holds true. This means the learner will gain knowledge transfer by visual means. It is no wonder why most people say that they are visual learners. However, most learners are multi-modal and multi-sensory and adapt their strategies accordingly. In fact, studies have revealed that presenting material in two media—pictorial and verbal—is generally superior to presenting material in only a single medium—as long as the pictorial information is well designed and congruent (Clark & Mayer, 2011).

When designing multimedia for e-learning, visualization has become increasingly important. Our brains are wired to process visual input very differently from text, audio, and sound. Recent technological advances through functional Magnetic Resonance Imaging (fMRI) scans confirm a dual coding system through which visuals and text/auditory input are processed in separate channels, presenting the potential for simultaneous augmentation of learning. The bottom line is that learners using well-designed combinations of visuals and text learn more than students who only use text (Enns, 2004).

Visuals cause a faster and stronger reaction than words. They help learners engage with the content, and such emotional reactions influence information retention. This is because visual memory is encoded in the medial temporal lobe of the brain through the creation of new neurons. The medial temporal lobe is also the place where emotions are processed. The brain is set up in a way that visual stimuli and emotional response is easily linked through neural networking, and together the two form memories (Jensen, 2008).

Humans are predominantly processors of visual information. The implicit assumption is that the information gained through one sensory modality is processed in the brain to be learned independently from information gained through another sensory modality. This assumption is not valid in that focusing on one sensory modality flies in the face of the brain's natural interconnectivity (Geake, 2008). "*Separate structures in the brain are highly interconnected and there is profound cross- modal activation and transfer of information between sensory modalities. Thus, it is incorrect to assume that only one sensory modality is involved with information processing".* (Dekker, Lee, Howard-Jones & Jones, 2012).

Multimedia Design Principles for E-learning

You typically store memories in terms of meaning (context)-- not in terms of whether you saw (visual), heard (aural), or physically (tactile/kinesthetic) interacted with the information. Studies have shown that *how information is presented* determines the retention level of the information.

It often follows, then, that the more numerous and varied the media is used, the richer and more secure will be the concepts we develop. Cognitive science has revealed learners differ in their abilities with different modalities, but teaching to a learner's best modality doesn't affect learning outcomes. What does matter is whether *the learner is taught in the content's best modality*...people learn more when content drives the choice of modality.

> *Separate structures in the brain are highly interconnected and there is profound cross- modal activation and transfer of information between sensory modalities. Thus, it is incorrect to assume that only one sensory modality is involved with information processing* (Neuromyths in

education: Prevalence and predictors of misconceptions among teachers, frontiers in Educational Psychology, 2012)

Multimedia principle - People learn better from words and pictures than from words alone.

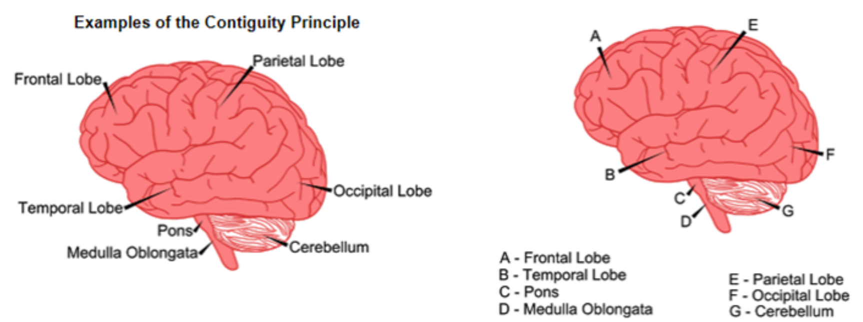
Modality Principle – People learn more deeply from multimedia lessons when graphics are explained by audio narration than onscreen text.

Contiguity Principle - Align words to corresponding graphics

- Spatial Contiguity Principle - People learn better when corresponding words and pictures are presented near rather than far from each other on the page or screen.
- Temporal Contiguity Principle - People learn better when corresponding words and pictures are presented simultaneously rather than successively (Clark & Mayer, 2011).

Figure 7: Contiguity Principle

(Contiguity Principle, n.d.)



In this example, the contiguity principle *is followed* because the labels for the parts of the brain are placed physically near the parts of the brain to which they correspond.

In this example, the contiguity principle *is violated* because the labels indicating the parts of the brain are physically separated from the image of the brain.

Principles for managing essential processing (Clark & Mayer, 2011)

- **Segmenting principle**: People learn better when a multimedia lesson is presented in learner-paced segments rather than as a continuous unit.
- **Pre-training principle**: People learn better from a multimedia lesson when they know the names and characteristics of the main concepts

Principles for reducing extraneous processing

- **Coherence principle**: People learn better when extraneous words, pictures, and sounds are excluded rather than included.
- **Redundancy principle**: People learn better from animation and narration than from animation, narration, and on-screen text.
- **The Redundancy Effect** is when information is presented through different cognitive processing channels (such as text and graphic) and repeat the exact same content.
- **Signaling principle**: People learn better when the words include cues about the organization of the presentation.

Cognitive Load Theory

Cognitive load theory focuses on the strain that is put on working memory by the processing requirements of a learning task (Driscoll, 2005). Meaningful learning depends on active cognitive processing in learner's short term memory.

Short term memory can only retain a certain amount of information simultaneously. The more information that is delivered at once, the more likely learners will not be able to process that information for transfer to long term memory. In other words, if learners encounter too many elements in the presentation of multimedia information (animation, graphics, sound, text), short term memory can be overwhelmed. The result is excessive cognitive load can impede learning (Clark & Mayer, 2011).

Mayer and Moreno (2003) conducted research into ways to reduce cognitive load in multimedia learning based on three assumptions:

- Humans possess separate information processing channels for verbal and visual material (Dual Channel).
- There is only a limited amount of processing capacity available via the visual (eyes) and verbal (ears) channels (Limited Capacity).
- Learning requires substantial cognitive processing via the visual and verbal channels (Active Processing).

Cognitive Load Theory proposes three types of cognitive load:

Intrinsic. This is the level of complexity inherent in the material being studied. There isn't much that we can do about intrinsic cognitive load; some tasks are more complex than others so will have different levels of intrinsic cognitive load.

Extraneous . This is cognitive load imposed by non-relevant elements that require extra mental processing e.g. decorative pictures, animations etc., that add nothing to the learning experience and is under the control of instructional designer. This form of cognitive load is generated by the manner in which information is presented to learners. Each of the cognitive loads are additive, and instructional design's goal should be to reduce extraneous cognitive load to free up working memory.

Germane. Germane load are elements that allow cognitive resources to be put towards learning i.e. assist with information processing, per se, dedicated to the processing, construction and automation of schemas. While intrinsic load is generally thought to be immutable, instructional designers can manipulate extraneous and germane load by limiting extraneous load and promoting germane load. Specifically, to facilitate the transfer of information from *working memory* to *long-term memory*, the information should be presented in such a way that it reduces extraneous cognitive load (non-relevant items), and, if possible, increases germane cognitive load (items that assist with information processing.

Mayer and Moreno (2003) proposed five ways to reduce cognitive load in an e-learning/computer-based training (CBT) module:

1. ***Present some information via the visual channel and some via the verbal channel***. If all of the content is processed visually i.e. via text, pictures or animations, the visual channel can

become overloaded. Using narration transfers some of the content to the verbal channel thereby spreading the load between the channels and improving processing capacity.

2. ***Break content into smaller segments and allow the learner to control the pace***. If the content is complex and the pace is too fast, the learner may not have enough time to process the information. Breaking complex content into smaller chunks and allowing the learner to control the speed of the learning lets them process the information more effectively.
3. ***Remove non-essential content***. Background music and decorative graphics may appear to make the eLearning more interesting. However, these elements require incidental processing and increase extraneous load. If the content doesn't support the instructional goal, it should be removed.
4. ***Words should be placed close as possible to the corresponding graphics***. When text is located away from the corresponding graphic, learners are forced to scan the screen in order to align the text to the graphic which requires additional cognitive processing. Placing the text close to the corresponding graphic improves the transfer of information.
5. ***Don't narrate on-screen text word-for-word***. When on-screen text is narrated, the same information is presented to learners via both channels. Rather than spreading the load, learners are forced to process the same information twice which means that there is a great deal of redundancy. If using narration, the on-screen text should be a summary.

Dual Coding Theory

Dual Coding Theory postulates that both visual and verbal information are processed differently using distinct channels within the human mind. According to this theory, the mind creates separate representations for the information processed in each channel. Both visual and verbal codes for representing information are used to organize incoming information into knowledge that can be acted upon, stored, and retrieved for subsequent use (Paivio, 1986).

Consequently, when content is presented through two different channels of memory representation (visual and auditory), working memory can be increased. Dual coding theory attempts to give equal weight to verbal and non-verbal processing in that cognition is unique and has become specialized for dealing simultaneously with language and with nonverbal objects and events (Driscoll, 2005). The theory assumes there are two cognitive subsystems, one specialized for the representation and processing of nonverbal objects/events (i.e., imagery), and the other specialized for dealing with language (Clark & Mayer, 2011).

Note: Recent research from Harvard's Medical School supports dual coding theory concepts in that presenting content in more than one way, e.g., visual and verbal, *is* helpful, *if* the information presented is complimentary and not conflicting (Kosslyn, & Kraemer, 2010).

Cognitive Flexibility Theory

The Cognitive Flexibility Theory relies upon the idea that learners must not only be able to manipulate the means by which knowledge and content are being represented, but also the processes that are in charge of operating those representations. The foundation of the Cognitive Flexibility Theory is that learners are better able to acquire and retain knowledge if they are encouraged to develop their own representation of it (Spiro, Feltovich, Jacobson,& Coulson, 1992).

Primarily, the theory focuses on the nature of learning in complex and ill-structured domains. It is a function of both the way knowledge is represented and the processes that operate on those mental representations. The theory is largely concerned with transfer of knowledge and skills beyond their initial learning situation. The emphasis is placed upon the presentation of information from multiple perspectives and asserts that effective learning is context dependent (Clark & Mayer, 2011).

- Stresses the importance of constructed knowledge in that learners must be given an opportunity to develop their own representations of information in order to properly learn.
- Accomplished by revisiting the same material, at different times, in rearranged contexts, and from different conceptual perspectives.

The main principles of the Cognitive Flexibility Theory are (Cognitive Flexibility Theory, n.d):

Knowledge is "context-dependent". Knowledge cannot be perceived out of context. It is the context that allows learners to see any possible relationships between various components of the subject matter presented. In addition, learning activities in any educational setting should be able to provide several different representations of the same instructional objectives in different contexts. Practically speaking, the Cognitive Flexibility Theory suggests that learners have the opportunity to better understand the specific concept or idea because of its practical application is clear to them.

Knowledge cannot be oversimplified. Instructional materials to be used must not oversimplify a topic neither in terms of content, nor in terms of structure. Simply stated, knowledge cannot be reduced to its basics. In terms of structure, problems should be presented to students in more complex and involving structures, rather than linear or simplified ones.

Knowledge is constructed. The instruction that takes place should be relevant, per se, there is an emphasis on the construction of knowledge rather than on how it is transmitted to learners. The Cognitive Flexibility Theory follows a constructivist approach to learning, according to which learners are actively engaged in the learning process and they are responsible for their own learning.

Knowledge is interconnected. In order for the learner to grasp what is being taught, the knowledge sources used should be interconnected through prior experiences rather than separated and compartmentalized. Specifically, this can be accomplished by using *advanced organizers* that represent the prerequisite knowledge before presenting new information.

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