WHITE PAPER

VISUALS IN E-LEARNING—
WHAT WE'VE LEARNED FROM COGNITIVE SCIENCE

Jolly T. Holden. Ed.D.

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INTRODUCTION

While the phrase "a picture is worth a thousand words" is often used to emphasize the importance of visuals, what is the *relative* value of the 1,000 words? To put it in perspective, a picture without relevancy is simply a picture that takes a thousand words to make it relevant to the *learner*. 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).

There are 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).

Since neuroscience has revealed 90% of what the brain processes is visual information, one's *primary learning modality is visual (*Hyerle, 2000). Jensen (2008), in his book on *Brain-Based Learning*, 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. It is no wonder, then, that 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).

WHAT IS MULTIMEDIA?

In its simplest form, multimedia is the presentation of material using words and pictures. More specifically, Richard Mayer (2011) has narrowed this definition to two forms: verbal and pictorial. Consequently, what Mayer refers to as multimedia learning is also more accurately called dual-code or dual-channel learning.

IMPLICATIONS FOR MULTIMEDIA DESIGN IN E-LEARNING

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 and/or 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. That said, 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 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.

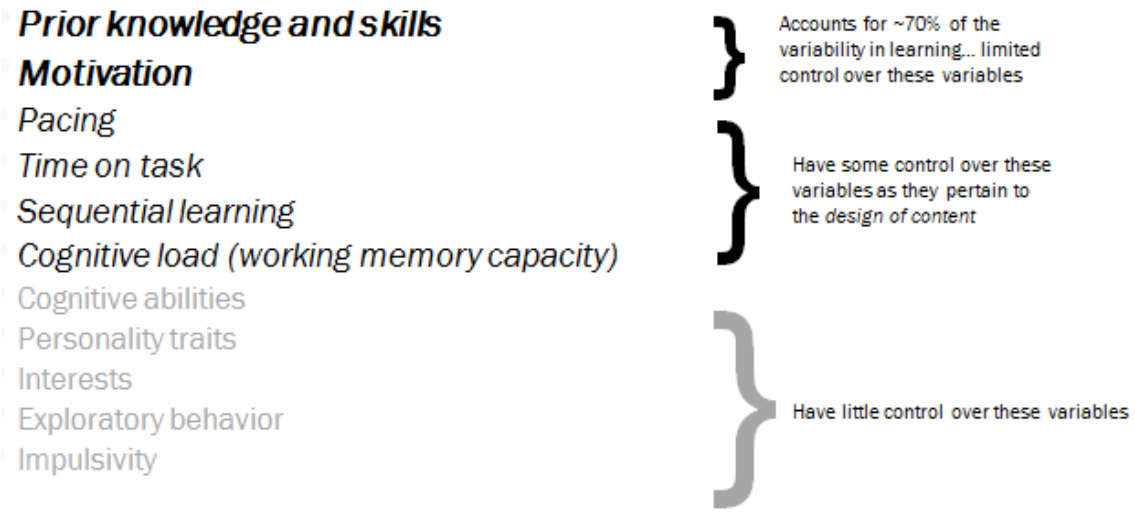
One of the reasons is the complexity of how the human brain functions as it relates to one's modalities in receiving information (visual, aural, kinesthetic) and how the brain processes

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.

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 media used, the richer and more secure will be the concepts we develop. Studies have shown that *how information is presented* determines the retention level of the information. 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.

Factors Affecting the Variability in Learning



MULTIMEDIA DESIGN PRINCIPLES FOR E-LEARNING

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 (Clark & Mayer, 2011).

- *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.

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.

MULTIMEDIA DESIGN THEORIES APPLICABLE TO E-LEARNING

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). 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. Focuses on the nature of learning in complex and ill-structured domains. The theory focuses on revisiting the same material, at different times, in rearranged contexts, for difference purposes, and from different conceptual perspectives in supporting knowledge acquisition (Driscoll, 2005). 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, and 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. The emphasis is placed upon the presentation of information from multiple perspectives and asserts that effective learning is context-dependent (Clark & Mayer, 2011).

Cognitive load theory. Cognitive load theory focuses on the strain that is put on working memory by the processing requirements of a learning task. Meaningful learning depends on active cognitive processing in learner's working memory. If learners encounter too many elements in the presentation of multimedia information (animation, graphics, sound, text), working 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).

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