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Instructional Message Design:
Theory, Research, and Practice

Chapter 2: Cognitive Load Theory and Instructional Message Design

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Chapter 2: Cognitive Load Theory and Instructional Message Design

Bethany Emory

Key Points

- Cognitive processing is required for all learning tasks, and is separated into components of intrinsic, extraneous and germane cognitive load
- Working memory and long-term memory vary greatly in their functions and capacity
- The effects of all types of cognitive load can vary based on learner expertise
- Message design can significantly decrease the level of extraneous cognitive load in all formats of instructional materials

Abstract

Although theoretical in basis, Cognitive Load Theory (CLT) is pragmatic in nature. Its goal, as it relates to instructional message design, is to present information in a way that enables the learner to process it as efficiently as possible and add it to their brain as learned information. This process relies on the brain for memory, which is separated into two component parts – working memory and long-term memory. Both of these forms of memory are required to connect new information to information that is known – which are essential

elements in the learning process. To do this, information that detracts from processing is discouraged, information that assists in processing is encouraged, and any complexity inherent to the learning is presented at a level that is appropriate (Chandler & Sweller, 1991; Sweller, 2008; Sweller, van Merrienboer, & Paas, 1998).

Introduction

In order to appreciate the effect of cognitive load on message design, we will begin by describing the processes in the brain, which help us to remember, and ultimately to learn. We will then explore the research that went into the development of seven heuristic guidelines useful in designing instruction focused on effective cognitive processing. Finally, we will apply these heuristic ideas to the forms of static media (such as text and images) and animated media (such as audio and video recording and simulations).

You may be asking how this chapter will aid in developing a message design knowledge base. The answer will vary, depending on your level of expertise as you begin this exploration. For those readers who have completed prior study in learning theory or instructional design, you may wish to jump to the final section of the chapter for pragmatic examples prior to moving on to chapters specific to your goals. For those who are new to the arena of learning theory and instructional design (regardless of audience), the theory may provide insight into approaches you have implemented successfully in the past or provide guidance into some new approaches you may choose in the future.

Memory

Memory is the process by which the brain first encodes, stores, then recalls information (Mellanby & Theobald, 2014). Cognitive theory suggests that there are two centers of memory aided through cognitive structures. Long-term memory, whose primary process is organization and storage and working memory, whose primary process is encoding and processing (Mellanby & Theobald, 2014; Sweller, van Merrienboer, & Paas, 1998). Connections between the two areas are supported through organizational structures called schemas (or schemata) (Sweller, van Merrienboer, & Paas, 1998). These structures of learned patterns aid in organizing information and facilitating its transfer between working and long-term memory.

Long Term Memory

Long-term memory serves as the information store for all results of learning. Although long envisioned as a repository, long-term memory serves equally to organize and recall key pieces of information during the learning process (Baddeley, 1995; Mellanby & Theobald, 2014; Sweller, 2008). Sweller (2008) suggests that it is "…the central structure of human cognitive architecture" (p.371).

Information is transmitted to the long-term memory through encoding and organizing processes of the working memory. These same processes rely on appropriate retrieval of information to categorize new information and is an essential element in learning (Sweller, 2008). Continual cognitive functions, including auditory and visual communication, ensure information remains current, retrievable, and relatable (Sweller, 2008). Long-term memory interacts with the working memory and serves as a support for the association of new knowledge within structures of existing knowledge, commonly referred to as schemas (van Merriënboer & Sweller, 2005). These organizational structures assist the brain in retrieving information and connecting this information in complex ways (Sweller, 2008; van Merriënboer & Sweller, 2005). Schema assist both the long-term storage and retrieval of information, as well as its ability to be encoded (van Merriënboer & Sweller, 2005).

Working Memory

Although sometimes referred to as short-term memory, working memory represents the encoding mainstay of the brain. One of the seminal researchers in the field, Alan Baddeley (2000), defines working memory as "a limited capacity system allowing the temporary storage and manipulation of information necessary for such complex tasks as comprehension, learning and reasoning" (p.418). Baddeley's model has developed over the years, and currently includes four component parts. Figure 1 illustrates the relationship between these cognitive elements.

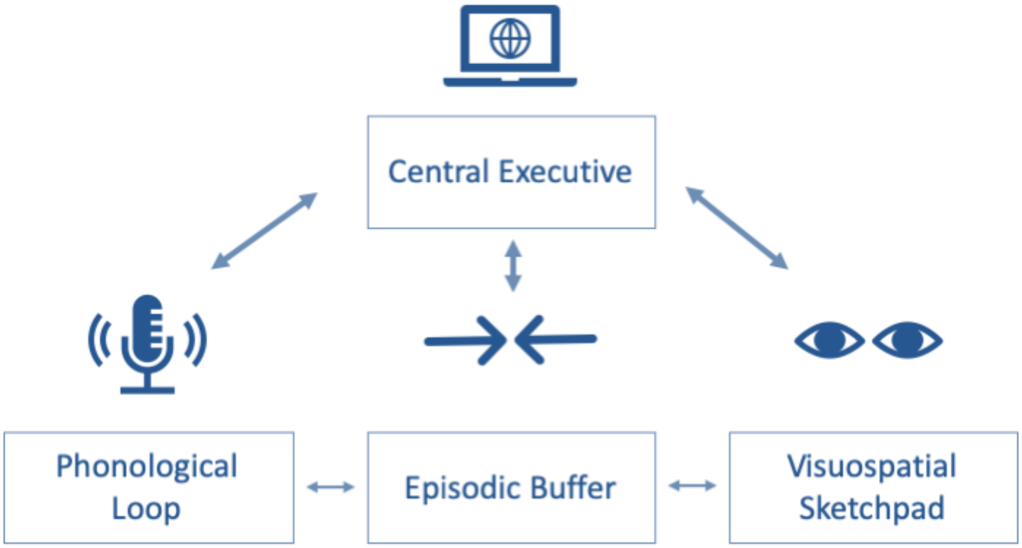

Figure 1. Graphical representation of the components of working memory Adapted from "The episodic buffer: a new component of working memory?" by Alan Baddeley (2000, p. 421).

The central executive serves as the processing core. This component focuses attention and allows for encoding of new information (Baddeley, 1995, 2000; Jonides et al., 2008). The central executive is supported by cognitive areas which aid in the processing of new information. These are the phonological loop, visuospatial sketchpad, and episodic buffer (Baddeley, 1995, 2000, 2003; Jonides et al., 2008).

The phonological loop stores auditory-verbal information for a matter of seconds, unless this time frame is altered by some form of repetition or processing (Baddeley, 1995). The ability to retain information within the phonological loop has been proven to be affected by similarity of the items as well as the item length (Baddeley, 1995, 2000; Sweller, 2008). In addition, memory can be limited by suppression of the auditory processes such as rehearsal, resulting from the repetition of an extraneous word or sound throughout the process of encoding, or allowing external noises to distract (Baddeley, 1995). Consider for example, when watching a recorded interview, the effect of background music on your processing of the information. This effect can often be the result of an overload within the phonological loop (Baddeley, 1995).

The visuospatial sketchpad is the second reinforcement to the central executive and functions similarly to the phonological loop, however it stores visual information (Baddeley, 1995, 2003). Visual, spatial, and forms of kinesthetic information are stored here throughout the encoding process (Baddeley, 1995; Sweller, 2008). Similar to the suppression effect in the phonological loop, the visuospatial sketchpad can be clogged by unnecessary visual information (Baddeley, 2003). Consider the habit of closing one's eyes when trying to remember, this has been correlated with a reduction of visual interference (Vredeveldt & Vredeveldt, 2011).

The final piece of the Baddeley model of working memory is the episodic buffer. This component is most similar to the central executive as it serves to create a complex memory by integrating contents of the phonological loop and the visuospatial sketchpad (Baddeley, 2000). Baddeley (2000) described this buffer as "… episodic in the sense that it holds episodes whereby information is integrated across space and potentially extended across time" (p. 421). Although this function is temporary, similar to other working memory processes, it has been shown to assist in forming connections to similar information in the long-term memory (Baddeley, 2000).

Early Research Supporting Cognitive Load Theory

In the late 1950s an educational psychologist from Harvard named George Miller began to notice some consistencies in the ability of the working memory to encode information. He began to conduct research into the phenomena and became plagued by the number seven (Miller, 1956). Although the number would vary slightly, in numerous experiments this number would emerge as the amount of information that could be encoded by the working memory – causing Miller (1956) to refer to it as "The Magical Number Seven Plus or Minus Two" (p.81). As his work progressed, he theorized that this number applied to two separate functions within working memory, absolute judgements, and immediate memory (Miller, 1956).

Miller's research built upon works exploring the recall of items such as auditory tones, taste sensations, and colors. Although he found that the brain could process different topics and stimuli simultaneously, its ability to transfer that information into long-term memory was always limited in quantity to seven units of information, plus or minus two (Miller, 1956). Miller stated simply (1956): "There seems to be some limitation built into us either by learning or by the design of our nervous systems, a limit that keeps our channel capacities in this general range. (p.86)"

In regard to absolute judgments, Miller was referring to the amount of information that a person can transmit correctly after receiving it into their short-term memory. The value is binary, as it is either correct or incorrect (Miller, 1956). Potential for correct transmission increases exponentially as the number of inputs increase (Miller, 1956). For example, if a student hears one word, they can transmit that information correctly or not – resulting in two alternatives per bit of information. Miller proposed that there were two alternatives for one bit of information, where two bits were provided, there were four alternatives, where there were three, eight and so on (Miller, 1956). Miller identified the learner's channel capacity – or highest level of correctly transmitted information before performance waned, at six alternatives (Miller, 1956). He found that increasing the number of inputs failed to increase the correct transmittal (or output) of information (Miller, 1956).

For the realm of immediate memory, the researcher sought to clarify the number of items of information that a person could retain in short term memory. Miller proposed the concepts of bits of information and chunks of information (Miller, 1956). Bits were seen as the component parts of chunks.

In terms of modern instructional design theory, Morrison, Ross, Kalman, and Kemp (2011) describe information as falling into four categories – facts, concepts, principles and rules, and procedures. In relation to bits and chunks, a bit might equate to an individual fact, especially when this fact is not related to other items that had been previously learned. In other words, the learner may not have an initial schema to which a new fact (a bit) can be attached. If, however many facts were described using a concept, this concept (or schema of bits) would represent a chunk of information and may make the bits easier to remember. If again, those concepts were joined to develop a principle or rule of behavior, then the chunk would expand to encompass both the component facts and concepts contained within. Given this broader definition, the limitation of items which can be processed within working memory becomes far more complex.

As a result, this magic number was revisited in 2010 by a researcher named Nelson Cowan. In his work Cowan proposed that this magical number was in fact closer to four than seven (Cowan, 2010). The difference lies primarily in the ability of working memory to isolate items or chunks, and how this pattern differed in more practical applications versus simpler examples explored in earlier works. For example, although one may be able to remember seven chunks of information, the brain will require part of its processing capacity to form those chunks (Cowan, 2010). How the brain processes this information is explored further in the next section. His work brought to light studies that revealed the effect of instructional strategies, such as rehearsing, and the effects of distractors (Cowan, 2010). However, the limitation can be seen as both a strength and a weakness.

For those who viewed the limitation as a weakness, it was believed that the brain simply functioned most effectively with no more than four concepts due to the number of neurons available. In this view, when too much information was presented, some content was simply not able to be incorporated into schemas and was lost (Cowan, 2010).

When viewing the limitation as a strength, it is believed that when learners are presented information at the optimum level of content items it allows the brain to function at the most efficient processing level. This logical structure allows the brain to discern between what is important and what is not and to apply cognitive resources appropriately (Cowan, 2010).

Cognitive Load Theory

In the late 1980s and early 1990s John Sweller was researching problem solving skills and published a seminal article which introduced the management of cognitive load as a potential means to assist novices to solve problems (Sweller, 1988). He built upon research based on the world of chess that showed that the largest difference between novices and experts when working problems, was that experts could envision successful solution steps based upon experience where novices could not (Sweller, 1988). He used the word schema to place the problem-solving steps in relation to similar steps in previously encountered problems. Sweller documented that novice students who would often resort to a means-end analysis of a problem, often overwhelmed the capacity of their short-term memory to recognize those important problem-solving steps inherent in schema creation (Sweller, 1988). In many ways they were focusing all of their attention on coming to a solution, rather than developing the skills that could help them apply the same processes in the future. As a result, the findings of this initial research indicate that cognitive processes that are not related to learning (or the acquisition of knowledge) were detrimental.

This research continued, with Sweller and Paul Chandler completing an exploration of unnecessary cognitive processing in relation to static images including charts, graphs, and illustrations (Chandler & Sweller, 1991). The pair completed six experiments within industrial settings to gauge the effects of different placements of text material used in support of these images. The experiments were conducted on varying topics and explored the integration of textual information and its effect on instructional efficiency and student learning. In this early work, the Redundancy and Split Attention Effects began to take form (Chandler & Sweller, 1991). Split attention theory suggests effective placement of text and images when both are necessary to comprehend the concept that they are used to illustrate (Chandler & Sweller, 1991; Kalyuga, Chandler, & Sweller, 1999). Redundancy explores the effect of redundant or overly repetitive information on the learning process (Chandler & Sweller, 1991; Kalyuga et al., 1999). Further discussion follows in the Reducing Cognitive Load through Message Design section.

Sweller, van Merrienboer, and Paas (1998) formed a more concrete definition of the component parts of cognitive load present during instructional processes. Cognitive load was divided into three component parts each with special considerations for instructional design – intrinsic, extraneous, and germane.

Intrinsic cognitive load is contingent upon the number and complexity of required elements to be considered, and the level of interaction that exists between these elements (Kirschner, 2002; Sweller, 2008; Sweller et al., 1998). Things that can be learned in isolation of one another, for example definitions of new vocabulary or individual events on a timeline produce low intrinsic load. However, once the elements begin to require interaction, the cognitive load increases (Kirschner, 2002; Sweller, 2008; Sweller et al., 1998). The same vocabulary becomes more challenging, when one must also use them in appropriate context, or events need to be expressed in relation to one another. Similar to the work of Miller, the level of intrinsic load is heavily influenced by schema creation (Miller, 1956; Sweller et al., 1998). Although intrinsic cognitive load can be minimized through instructional design (by chunking and sequencing complex content into simpler components and elements), its effect on required overall processing cannot be ignored.

Extraneous cognitive load is commonly defined as load which detracts from the process of learning (Chandler & Sweller, 1991; Sweller, 2008). Extraneous cognitive load was indicated as the one area of cognitive load which can also be directly affected by instructional design, including instructional message design (Beckmann, 2010; Sweller, 2008; Sweller et al., 1998). Consider a simple arithmetic lesson, using an example to illustrate. Should an instructor choose to show examples involving complex calculus functions, that happen to include arithmetic calculations to demonstrate, they would be introducing extraneous load. For someone who has not yet mastered arithmetic, solving calculus equations would most likely serve to confuse rather than explain. Diverting attention from the learning process can be detrimental, especially when the sum of the component cognitive load surpasses the processing ability of the learner (Sweller, 2008; Sweller et al., 1998).

Germane cognitive load encourages effective cognitive processing. Even in cases where intrinsic load is low, and extraneous load is minimized, instruction can be improved through the inclusion of germane cognitive load produced through appropriate instructional design. For example, goal free problem sets, worked examples and completion problems are examples of instructional interventions which have been shown to increase germane load (Baars, Visser, Gog, Bruin, & Paas, 2013; Fernandez-Duque, Baird, & Posner, 2000; van Merrienboer & Sweller, 2010). For message design, reduction in redundant information (to eliminate unnecessary processing) has also been shown to increase germane load (Kalyuga et al., 1999; van Merrienboer & Sweller, 2010).

The intersection and combination of these three component parts result in the overall load on cognitive processes within short-term memory. The levels of each component can be adjusted, provided that the overall requirement of the short-term memory fits within the capacity of the learner.

Figure 2 below represents varying stages of cognitive capacity. In line A of the chart, capacity exists in the brain to add germane cognitive load through instructional design techniques, but it may not be necessary to facilitate learning. In line B, no additional learning strategies could be added without leading to cognitive overload, unless extraneous or intrinsic load was lessened, however learning can still occur. In line C, learning may not prove effective, regardless of the addition of instructional strategies without a decrease in extraneous or intrinsic load.

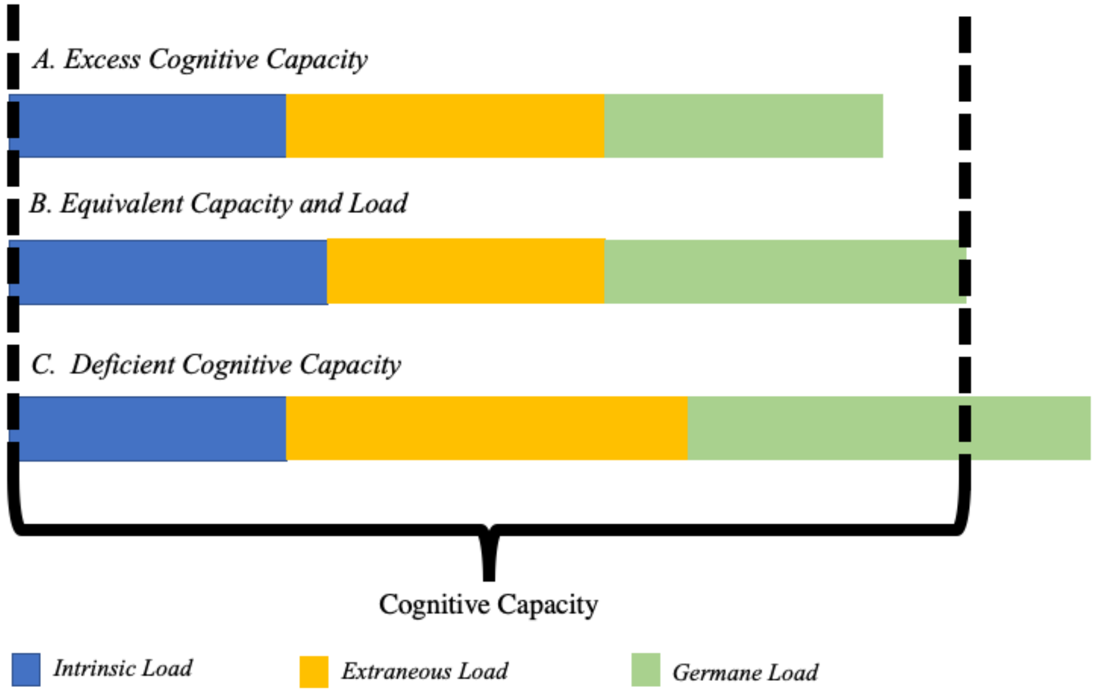

Figure 2. Cognitive capacity by facets of cognitive load Adapted from “Cognitive load theory in health professional education: design principles and strategies” by Jeroen J G van Merrienboer and John Sweller (2010, p. 88).

The goal in both instructional design, and instructional message design, is to ensure that the learner is not taxed beyond their cognitive capacity. In the next section, we will explore methods to reduce this load to an appropriate level through applying heuristic methods of instructional message design.

Reducing Cognitive Load through Message Design

The goal of instructional design is to decrease extraneous and intrinsic load to allow for effective germane load to be added to assist learners. As Morrison et al. (2011) remind us, the goal of effective message design is to "…create an appropriate interface between the instructional materials and the learner" (p. 165). By considering the effects of cognitive load on the presentation of information, extraneous and intrinsic load can be minimized.

Still, no design lives in a vacuum. The ability to decrease extraneous cognitive load through message design, like many other instructional interventions, is contingent upon the expertise level of the learner (Kalyuga, Ayres, Chandler, & Sweller, 2003; Sweller, 2008). Many strategies which reduce extraneous cognitive load, have been shown to be more effective on novice learners. In fact, positive results have been minimized or reversed in some learners with developed expertise (Kalyuga et al., 2003). Researchers in the field of cognitive load theory refer to this effect as the expertise reversal effect (Kalyuga et al., 2003; Sweller et al., 1998). Most findings suggest that this effect is caused by a lack of schema development in novices (Amadieu, Tricot, & Mariné, 2009; Ayres & Gog, 2009; Kalyuga, 2007; Kalyuga et al., 2003; Sentz, Stefaniak, Baaki, & Eckhoff, 2019). This is especially true when encoding has moved from an active process within the working memory, to a rote or automatic process as is common in experts (Mellanby & Theobald, 2014; Sweller et al., 1998). In their study, Kalyuga, Ayres, Chandler, & Sweller (2003) found the expertise reversal effect influenced each method of limiting extraneous load mentioned in this chapter.

Split-Attention Effect

Split attention effect can occur when a learner must acquire information from two different sources to master a concept. Split attention effect occurs when these pieces of information are unnecessarily placed at a distance from each other (Mayer & Moreno, 1998; Sweller, 2008). Due to the need to integrate this information, unnecessary cognitive load is exerted (Kalyuga et al., 1999; Sweller, 2008).

Split attention in static visuals. The quintessential example of split attention effect can be seen in geometry problems. As is often the case, a diagram most clearly represents the problem to be solved. However, additional text information is especially necessary to support novice learners. Consider the two examples provided in Figure 3.

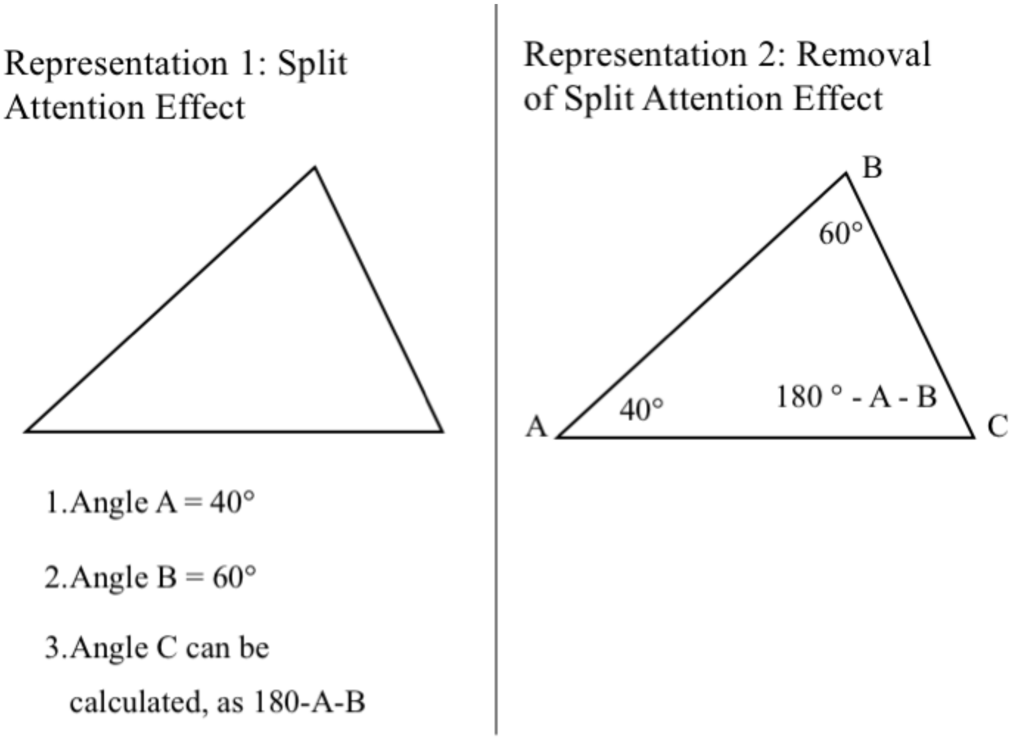

Figure 3. Split attention effect within a geometry problem

For novice learners approaching the problem as displayed in Representation 1, the working memory would be required to split its ability to process between integrating the two disparate presentations of information and solving the problem. Even in this simple example, some cognitive capacity is wasted. By integrating the information, as is done in Representation 2, the designer reduces the amount of extraneous cognitive load through message design.

Split attention in animated media. For animated media, although the concepts remain the same, some applications differ. In relation to simulations which require text information (explanations for example), the included information should again be essential for understanding, and should be incorporated as closely as possible to the animation or visual representation (Mayer & Moreno, 1998; Sweller, 2008).

When simulation is used to illustrate processes, attention must be paid to the level of detail and scope included. For example, consider the example of a simulation of the parts of a jet engine. Split attention effects could be created if the functions of separate parts of the engine, which relied on one another for comprehension, were presented separately (Sweller, 2008). Animations that focus too specifically on isolated component parts may cause the learner to seek further explanations rather than connecting the information to their long-term memory.

Modality Effect

Similar to the split attention effect, the modality effect is present when the combination of two disparate sources of information are required to comprehend. Where split attention effect is removed by making the integration of information simpler, modality effect seeks to improve the processing ability of working memory (Sweller, 2008; Sweller et al., 1998). You will remember the three processing supports in the working memory, the phonological loop, visuospatial sketchpad, and episodic buffer. Research has strongly suggested that when information includes content that can be processed through both channels, the episodic buffer will assist in its processing (Baddeley, 2000; Sweller, 2008; Sweller et al., 1998). This results in a reduction of extraneous cognitive load.

Modality effect in static visuals. In recent years, the combination of text and imagery, as is suggested through the modality effect, has given birth to a rise in usage of infographics, See Figure 4 (Dunlap & Lowenthal, 2016; Lee & Kim, 2016; Martin et al., 2018). Infographics are defined by Krum as "a larger graphic design that combines data visualizations, illustrations, text, and images together into a format that tells a complete story" (Krum in Dunlap & Lowenthal, 2016, p. 46). Effective infographics include design elements that focus on engaging the learner quickly, flexibility in application to support different learning objectives, and the coherency of the message (Dunlap & Lowenthal, 2016). Given their ability to increase the modality effect in complex subjects, researchers are beginning to support the use of infographic heuristically in instructional design (Barnes, 2016; Martin et al., 2018; van Merrienboer & Sweller, 2010).

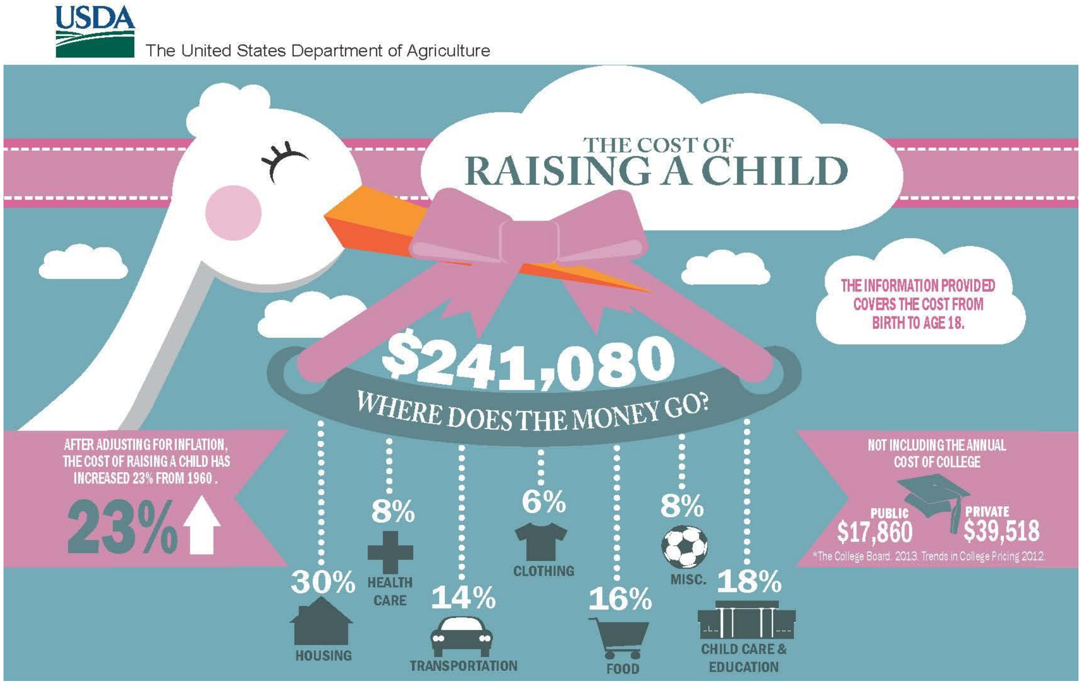

Figure 4. Example of an infographic including Creative Commons Citation Information - "The Cost of Raising a Child" by US Department of Agriculture CC BY 2.0

Modality effect in animated media. Although static images have proven to be useful in limiting extraneous cognitive load, indications also support its effect in animated media as well (Guttormsen Schär & Zimmermann, 2007; Mayer & Moreno, 2003; Moreno, 2006). Heuristic suggestions for reducing cognitive load in animated media include using narration in lieu of text and ensuring that audio tracks appear simultaneously with animation (Mayer & Moreno, 2003).

Redundancy Effect

Where the split attention and modality effects are only felt when multiple sources of information are required for comprehension, the redundancy effect occurs when multiple sources of information can be processed in isolation of one another yet are presented together (Kalyuga et al., 1999; Sweller, 2008; Sweller et al., 1998). Where the split attention effect asks working memory to integrate information increasing cognitive load, the redundancy effect asks working memory to determine the usefulness of multiple presentations of the same information (Sweller, 1988). For example, when presented the same information in both textual and auditory or narrated form, working memory may occupy itself in first determining if the information differs prior to encoding (Sweller, 1988). As a result, extraneous and overall cognitive load is increased.

Redundancy effect in static visuals. To minimize extraneous load through redundancy, designers of instruction must first ensure that functionally identical information is presented only once, and second must ensure that it is presented through the most cognitively effective manner as possible. A process of curating or weeding instructional materials to remove incidental repetition of information is suggested (Mayer & Moreno, 2003). For instance, presenters should not read their presentation slides verbatim or provide narration of the exact text in dynamic visuals. Alternatively, design methodologies such as universal design for learning suggest providing alternative representations of information to serve the broadest set of learners (Kumar & Wideman, 2014; Navarro, Zervas, Gesa, & Demetrios, 2016; The Center for Applied Special Technology, 2016). In this case a process of signaling learners to the appropriate use of materials may prove more effective.

Redundancy effect in animated visuals. Techniques to minimize cognitive load in animated visuals are similar to those in static media. For example, when presenting a spoken narration, one should not include the same text on screen to avoid redundancy (Kalyuga et al., 1999; Mayer & Moreno, 2003; Sweller, 2008; Sweller et al., 1998). Universal design principles can be accommodated by using tools available in the animated world which are not as easily implemented in the world of static media (The Center for Applied Special Technology, 2016). For example, should a learner need a textual representation of narration due to an auditory impairment, need access to the narration in a foreign language, or for a number of other needs, closed captions should be available. However, to eliminate redundancy these captions should be available but not imposed (Kalyuga et al., 1999; Keeler & Horney, 2007; Navarro et al., 2016). This can be accomplished by using a video player which allows them to be hidden, see Figure 5. Further discussion of accommodating the needs of diverse learners can be found in the Cultural Aspects and Implications of Instructional Message Design and Instructional Message Design for Learners with Special Needs chapters in this book.

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Figure 5. Example of customizable captioning in animated media including Creative Commons Citation Information "Screenshot Closed Captioning using TimedMediaHandler" by Eben Moglen CC BY SA-3.0

Isolated Interacting Elements Effect

High intrinsic load, which can be characterized by a high level of interaction between elements, may require that designers take advantage of the isolated interacting elements effect (Sweller, 2008).

This effect decreases the cognitive load necessary to process complex elements by allowing learners to build schema prior to integrating knowledge. This is done by ensuring that learners have an opportunity to master the component elements prior to integrating them (Sweller, 2008).

Isolated interacting elements in static and animated media. To minimize intrinsic load while presenting complex materials, message design and instructional design processes both must be considered. Initially the complex content needs to be specifically divided into manageable chunks of information, that can be isolated and explained independently. In addition, learner analysis is key, as the size of chunks will vary dramatically based on the expertise of the learners.

Once the appropriate learning objectives and procedures have been chosen, message design will become essential. Morrison et al. refer to the size of the instructional steps when considering how to best interact with the complex variables involved in this process (Morrison et al., 2011). Steps are described as the jumps that learners must make to become familiar with the content, and connect it to prior knowledge (Morrison et al., 2011). Message design of both static and animated media can assist in this process through the selection of consistent terminology, and inclusion of explicit connections back to the prior knowledge of the learners.

Secondly, any media should focus on presenting the isolated elements first, to allow schema to be established. This may result in less realistic representations of processes, and limited understanding initially, however gains have been shown in longer term transfer of process understanding (Blayney, Kalyuga, & Sweller, 2015; Pollock, Chandler, & Sweller, 2002). In addition, when animated media was tailored to release content based on learner expertise and performance, learning gain increased even more pronouncedly (Blayney et al., 2015). However, the variables to craft such customized instruction were seen as an area of further research (Blayney et al., 2015).

Worked Example, Guidance Fading and Imagination Effect

The remaining effects of cognitive load, which should be considered when designing effective instruction, have a lesser effect on message design than those discussed previously. Worked example and guidance fading effects are achieved through the use of the worked example generative learning strategy (Baars et al., 2013; Sweller, 2008). This multi-phase process begins by allowing students to progress through a problem using an expert's solution as a guide (Ayres & Gog, 2009; Sentz et al., 2019; Sweller, 2008). This process provides prompts to assist the learner in determining a solution path, which has proven to be more successful than repeated practice using problems without guidance (Ayres & Gog, 2009; Blayney et al., 2015; Sentz et al., 2019). Guidance fading is implemented as learner expertise increases through worked examples. The design begins to withdraw the expert guidance selectively throughout the process, until a learner is able to solve complex problems based solely upon their own abilities (Sweller, 2008). The imagination effect serves to assist learners in expanding schema prior to integrating new information and decreases cognitive load (Sweller, 2008). It is effective for experienced rather than novice learners (Kalyuga et al., 2003; Sweller, 2008). Experienced learners follow prompts to help to recall prior knowledge and integrate new information. In novice learners however, this technique more often than not causes learners to become overwhelmed (Kalyuga et al., 2003).

Worked examples, guidance fading, and imagination effects work well for both static and animated media. To maximize germane load through these instructional processes, message design should incorporate prompts effectively and be designed to support the generative processes. As always, care should be taken to ensure that the learners' level of expertise is evaluated and taken into account. For example, in an animated presentation of a complex problem, options should be available to allow selective release of content (Sweller, 2008). Novice learners should be able to review demonstrations of processes through completion where expert learners may choose to skip this step (Kalyuga et al., 2003; Sweller, 2008). In addition, for media that is designed solely for the use of seasoned learners, animations may include prompts to pause the content and to imagine results prior to being able to access a solution (Sweller, 2008).

Conclusion & Future Directions - Cognitive Load

In a nutshell, all learning will require memory to process information which leads to cognitive load. As designers we can work to ensure only load that is necessary to assimilate information is placed on learners, as a result, learning becomes more effective and efficient. Considering the impact of cognitive load in instructional message design is a critical aspect of the overall instructional design process.

However, determining the appropriate levels of load is not a simple process. As a result, cognitive load theory continues to be researched with the goal of improving instruction, both through improved message and learning strategy design. Current research includes calls for the study of the intersections between cognitive load and self-regulation of learning and the instruction of complex tasks (Ayres & Gog, 2009; Boekaerts, 2017; Delen, Liew, & Willson, 2014; Efklides, 2011; Sentz et al., 2019). In addition, the design of interactive elements which assist in facilitating these integrations are being explored (Amadieu, Mariné, & Laimay, 2011; Blayney et al., 2015; Delen et al., 2014; Roll, Aleven, McLaren, & Koedinger, 2011). Additional areas for future cognitive load and instructional message design research include direct measurement tools for extraneous, intrinsic, and germane load as well as learning with simulations, asynchronous and synchronous online video, multimedia, and augmented and virtual reality.

Key Terms

Channel capacity
Chunking
Episodic buffer
Extraneous cognitive load
Germane cognitive load
Intrinsic cognitive load
Long-term memory
Phonological loop
Schema
Visuospatial sketchpad
Working memory

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