Empirical Perspectives on Memory and Motivation

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CONTENTS

Introduction .......................................................................................................................................................................40
Methodological Issues.......................................................................................................................................................40
Learning and Memory......................................................................................................................................................41
  Theories of Human Memory .....................................................................................................................................41
  Cognitive Multimedia Learning and Memory ..............................................................................................................41
  Results of Research on Audio-Video Redundancy ......................................................................................................43
  Alternative Theories and Predictions ..............................................................................................................................43
Learning and Remembering in Cognitive Psychology ..................................................................................................44
  Parallel Distributed Processing, Schemata, and Mental Models ...................................................................................44
  Episodic Memory ............................................................................................................................................................47
Learning with Media and Motivation .................................................................................................................................48
  Schema-Based Approaches to Motivation in Multimedia Learning ...............................................................................49
  Flow, Engagement, and Self-Efficacy ...............................................................................................................................49
  The Uses-and-Gratifications Approach ...........................................................................................................................50
Summary ............................................................................................................................................................................51
References ...........................................................................................................................................................................51

ABSTRACT

This chapter is concerned with empirical research on memory and motivation within the realm of educational communication and technology. A variety of research methods and methodologies are described, with emphasis on the accessibility of theoretical constructs such as memory and motivation and the validity and reliability of assessments. The abundance of issues surrounding the topics of memory and motivation is narrowed to a few which appear repeatedly in the literature and are dominant in the domains under discussion in current instructional psychology. Several theoretical approaches to the architecture of cognition and models of human memory are described and discussed with regard to the question of how experiences with media and human memory interact. Accordingly, cognitive load theory and dual-code processing, as well as the
Theories of schemata and mental models, are reviewed critically and evaluated with regard to their advantages and drawbacks for learning with media. This chapter furthermore introduces relevant motivational research issues concerning technology-enhanced learning. After a description of several theoretical approaches concerning relevant motivational factors (such as flow and self-efficacy), the empirical research dealing with the question of how media and motivation interact are critically reviewed and evaluated.

**KEYWORDS**

*Information processing*: The modeling of sensory input and cognitive transformations as a series of processing stages.

*Memory*: The mental faculty of retaining and recalling past experiences.

*Mental model*: A mental representation that people use to organize their experience about themselves, others, the environment, and the things with which they interact; its functional role is to provide predictive and explanatory power for understanding these phenomena.

*Schemata*: Data structures for representing both generic and specific knowledge.

**INTRODUCTION**

We do not learn only through experience; rather, media and technological artifacts also play a central role in the formation of our knowledge of the world. Accordingly, learning with media has been at the core of instructional research for more than six decades, and there is not any medium or feature of a medium that has not been investigated with regard to its effectiveness on learning. The use of media may change the characteristic features of learning environments, bringing about effects on cognitive operations, representational formats, interactivity, visualization of semantic structures, and feedback. More specifically, the perceptual organization of messages affects how learners encode information because it is responsible for the nature of the mental representations that learners construct as a result of interaction with media of communication (Seel and Winn, 1997).

Media that combines visual and auditory presentation modes is called multimedia, and much research has been done on how people process audio-visual information. This research on audio-video redundancy has led to the development of several theoretical approaches over the past decades. Although Severin’s (1967) cue-summation theory was a promising approach in the 1960s, Paivio’s (1971) dual-code theory emerged in the 1970s and was then combined with Sweller’s (1988) cognitive load theory (CLT) in the 1980s. Both dual-code theory and CLT operate with the stage model of memory, which presupposes sequential information processing. In contrast, cognitive psychologists emphasize parallel information processing and functional capabilities that a memory system requires to support performance in a broad range of cognitive tasks. Important movements are the *levels of processing* approach (Craik and Lockhart, 1972), *parallel distributed processing* (PDP) models, as well as *connectionist models* of information processing (McClelland et al., 1986). Finally, *dual-process memory models* have influenced the understanding of recognition memory over the past 30 years. Dual-process memory models distinguish between a *recall-like process* in which episodic information is retrieved at the time of recognition and a *fluency-based process* in which general *familiarity* is used as a basis for recognition (Kelley and Jacoby, 2000). Dual-process models focus on the relationships between semantic and episodic memory, for which research shows the importance of *subjectivity* in remembering. Indeed, memories are constructions made in accordance with present needs and desires, and they are often accompanied by feelings and emotions (Schacter, 1996). This corresponds with studies that show that multimedia learning can enhance the *motivation* of students (Cheung et al., 2003). Consequently, more researchers are proposing connecting motivational and cognitive features of interaction with multimedia (Hede, 2002).

This chapter describes the major lines of research on *memory and motivation* within the realm of multimedia learning. It follows the current discussion about the need for sound models of multimedia learning in which cognitive and motivational factors of information processing are integrated to achieve a better and instructionally relevant understanding of the effectiveness of learning.

**METHODOLOGICAL ISSUES**

Theoretical constructs such as memory, learning, and motivation are scientific inventions that serve to describe phenomena that cannot be observed and therefore must be inferred from observable data. Cognitive psychology has at its disposal a great variety of methods for assessing cognition, ranging from naturalistic observation to computer simulation, from experimental methods to verbal protocols, from recording electrical impulses of the brain to collecting
reaction times (Simon and Kaplan, 1989). Correspondingly, we can find two major methodologies of memory research based on these methods. The first methodology corresponds to a physical approach and applies psychophysical methods (such as EEG or PET) to assess mental states. The other methodology corresponds with functional aspects of cognition and infers mental operations from observable behavior. The functional methodology is at the core of experimental methods. It contains traditional tests, questionnaires, the time needed for learning, the frequency and type of errors in performing tasks, drawings, eye fixations during task accomplishment, and so on. In natural settings, verbal communication is convenient for mediating ideas, thoughts, and feelings. Taking into account the prime importance of language for communication, it is evident that different methods of verbalization play a central role in the diagnosis of cognition. Psychologists often consider think-aloud protocols as an adequate method for verbalizing thoughts, explanations, inferences, speculations, and justifications. From a methodological perspective, an important effect of the infusion of information technologies into education consists in the potential of the methods of thinking to handle complex tasks that require large quantities of information at a time without overloading working memory.

Several alternative theories of information processing, however, do not correspond with the stage model; for example, the Soar architecture is a theory of cognition that also presupposes the notion of a working memory but in a different sense than the stage model (Newell, 1990). In Soar, the working memory is a more elaborate temporary memory structure that holds information pertaining to the state of the current problem-solving context. The functions of working memory are distributed across multiple components of the architecture, including long-term production memory, which enables the cognitive system to handle complex tasks that require large quantities of information by relying on recognition-based long-term working memory.

The levels-of-processing (LOP) approach, dual-process memory models, and connectionist models do not include the conception of working memory; rather, the LOP approach argues that all stimuli that activate a receptor cell are permanently stored in memory but different levels of processing contribute to the ability to access or retrieve information from memory. Connectionist models, which are currently at the core of cognitive psychology (McLeod et al., 1998), and PDP models suggest that information is stored in multiple locations throughout the brain in the form of networks of connections. At a molar level, however, PDP models operate with the theoretical constructs of schemata and mental models to explain human information processing (Rumelhart et al., 1986).

The fact that memory is studied in a range of disciplines often leads to academic suspicion. Educational psychologists focus on the stage model of memory, whereas cognitive psychologists focus on parallel associative memory. The question comes up as to whether educational psychologists and cognitive scientists are really addressing the same phenomena when they focus on human memory.

Cognitive Multimedia Learning and Memory

An analysis of the literature on multimedia learning shows that mainstream educational psychology agrees on a cognitive architecture that corresponds to
the stage model of information processing (Reed, 2006). In this model, restrictions in the processing of information occur at specific points, especially within the working memory with its limited capacity. In accordance with this assumption, Mayer (2002) has presented a cognitive theory of multimedia learning in which he also refers to Paivio’s (1971) dual-code theory of information processing. Paivio suggests that there are two cognitive channels, one specialized in processing nonverbal objects by means of imagery and the other specialized in dealing with language. Learning is better when information is processed through both channels instead of only one, but the working memory limits the amount of information that can be processed in each channel at one time. The capacity may be increased through the simultaneous use of both channels when the corresponding visual and verbal representations are contiguously present in working memory. In addition, by creating connections between corresponding verbal and visual information along with relevant prior knowledge, the learner organizes this information into a coherent representation both verbally and visually. The complete model is described in Figure 5.1.

Because working memory can only process limited amounts of new information, an overload can result if the learning task is too complex. This is the central assumption of the cognitive load approach (Sweller, 1988). Cognitive load may be affected by the mental effort necessary to process new information (intrinsic cognitive load), the manner in which the material is presented (extraneous cognitive load), or the effort required for activating schemata (germane cognitive load). Earlier, Berlyne (1971) had already introduced the simple idea of information overload and suggested that the more elements a pattern contained, the more complex that pattern would be. The cognitive load approach deals with complexity using a single construct: element interactivity. If many elements interact, element interactivity is high; if few interact, element interactivity is low. To bypass the limitations of working memory, cognitive load theory stresses the activation of schemata that may encapsulate numerous elements of information in a single chunk. The activation of schemata allows automatic processing and thus minimizes the load of working memory. Skilled performance develops through the construction of an increasing number of ever more complex and abstract schemata (Sweller, 1994).

Cognitive load theory is an instructional design theory that aims to reduce the cognitive load caused by poorly designed learning tasks (Sweller et al., 1998), whereas Mayer’s cognitive theory of multimedia learning can be easily integrated into the field of research on audio-video redundancy.
Results of Research on Audio-Video Redundancy

Many attempts employing the concept of audio-video redundancy have been made to understand how people integrate and learn information presented verbally and visually—for example, through a text enriched with static pictures or through dynamic pictures (animation or video) accompanied by narration. This research on how people process audiovisual information has highlighted many complexities and inconsistencies (Lang, 1995); for example, people have better short-term recall of auditory than of visual information (Penney, 1989), and they need narration to receive effective instruction from animation (Mayer and Anderson, 1991). Furthermore, Nugent (1992) found increased achievement for combinations of audio and images but not for audio and text, whereas other studies (Mayer and Gallini, 1990) revealed that visual cues amplify and explain text and facilitate the recall of new knowledge because visual cues create imagery during learning that is critical to memory processes. Obviously, information across two channels can serve as reciprocal reinforcement and enhance both recall and comprehension (Levie and Lentz, 1982).

These observations correspond with the cue-summation theory, which states that learning is increased as the number of available stimuli are increased (Severin, 1967). Multiple-channel communications are superior to single-channel communications when relevant cues are summed across channels, are neither superior nor inferior when the cues provided on the two channels are redundant, and are inferior when irrelevant cues are combined, presumably because irrelevant cues cause interference between the two channels. If the stimuli provided on different channels are not reciprocally relevant, the distraction causes a decrease rather than an increase in learning and retention (Brashears et al., 2005).

Another issue is the perception of complex visualizations, which can be difficult to perceive and interpret. Several studies (Lowe, 2003; Tversky et al., 2002) have shown that perceptual features of visualizations can interfere with successful comprehension. Although Lowe found an advantage for predictions drawn from animation, this advantage was limited to perceptually salient features. However, novice learners often were distracted by perceptually salient features of an animation at the expense of more important content information. Thus, the interpretation and use of visualizations may be affected greatly by perceptual qualities of the visualization. In a comprehensive study on the effects of static and dynamic complexity on children’s attention to and recall of televised instruction, Watt and Welch (1983) showed that increasing static detail on the screen by using complex sets, elaborate graphics, and long shots decreases recall while leaving recognition unaffected, whereas increases in visual dynamic complexity produce decreases in recall coupled with increases in recognition. An analysis of the entire viewing process revealed that visual attention was only of minor importance in the learning process, whereas static and dynamic complexities were found to have different effects on learning involving a verbal recall process than learning requiring only visual recognition. Although the visual attention was not significant in this study on television viewing, Mayer and Moreno (1998) found that presenting instruction in both auditory and visual modes can cause a split-attention effect in which students have to divide their attention across multiple inputs, resulting in reduced processing of information. These findings were explained from the perspective of cognitive load theory (CLT), which is at the core of current educational psychology (Paas and van Gog, 2006). Although the results of CLT research are important for instructional design, there are some limitations from both a methodological and a theoretical perspective. Advocates of the cognitive load approach, such as Mayer and Moreno (1998), have pointed out that the limitations of CLT studies include the fact that the participants were usually college students; however, numerous studies indicate that the capacity of memory and the application of memory search strategies increase with development (Harris, 1978). Evidently, adults can refer to more perceptual experiences and can use more effective strategies for the retrieval of knowledge representations than children (Lindberg, 1980; Seel, 1984). Another limitation of CLT studies is that the instructional episodes have been short and only how-it-works material has been used (Mayer and Moreno, 1998).

Alternative Theories and Predictions

Cognitive load theory and the dual-code theory presuppose a working memory with a limited capacity. The notion of a working memory refers to computational mechanisms that maintain and provide access to information to be retrieved during the performance of a task. Any computational system must support such functionality because computation is inherently a process that requires the temporary storage of information; however, in cognitive science reaction times longer than 6500 msec are treated as outliers of the working memory (e.g., Reijnen et al., 2005).

The question comes up whether theoretical approaches of educational psychology, such as CLT or dual-code theory, are compatible with theories on information processing within the realm of cognitive science.
Actually, Young and Lewis (1999) argue that complex cognitive tasks simply cannot be performed with a storage capacity of $7 \pm 2$ items. A problem-solving task involving inner speech, for example, may occur over tens of seconds or even minutes according to thought-monitoring studies (Franklin et al., 2005). To capture the involvement of memory in dealing with complexity, Ericsson and Kintsch (1995) introduced the notion of a long-term working memory, and Logie (1995) identified several conceptions of working memory, including the idea of working memory as controlled attention. This corresponds with the argumentation of Shiffrin and Schneider (1977) that individual differences on measures of cognitive limitations primarily reflect differences in the ability of controlled processing. It seems that memory theories of cognitive science are, to a large extent, incompatible with the stage model and related theories; however, if alternative theories exist and make differing predictions, we can test a prediction of the theory and a prediction of a competing theory at the same time. When the two predictions are incompatible, a strong inference (Platt, 1964) results. In contrast to CLT, dual-process models, for example, argue that conscious recollection and familiarity contribute to memory performance. Memory judgments are made by setting some level of familiarity as a response criterion and accepting items that exceed this criterion. A comparison of each information unit to long-term memory produces a continuous familiarity value that is used to make recognition judgments. This process can be appropriately explained by signal-detection theory.

Another example is schema construction, which plays an important role in CLT. Bransford (1984) has pointed out that schema activation and schema construction are two different problems. Although it is possible to activate existing schemata with a given topic, it does not necessarily follow that a learner can use this activated knowledge to develop new knowledge and skills. Furthermore, a major criticism of schema theories is that they are basically assimilation models that fail to answer questions on how existing conceptions are modified in the face of inconsistent input and how such theories deal with novelty (Brown, 1979).

**Learning and Remembering in Cognitive Psychology**

Whereas educational psychologists (Clark, 2006) emphasize the importance of automated knowledge for learning and memory, cognitive psychologists focus on the role of consciousness in information processing because much of human cognition functions by means of continuous interactions between contents of information and various memory systems. Franklin and colleagues (2005) call these interactions cognitive cycles. Human computational ability has been estimated at 10 cognitive cycles per second, where each cycle is able to recognize or select information. Although these cycles can overlap, producing parallel actions, they must preserve consciousness. This corresponds with the basic assumption of cognitive psychology that humans store information in memory by relating new information to what is already known. This process is semantic in nature because information is stored in terms of its meaning, as defined by its associations to other information in the memory. The capacity for such storage is essentially unlimited, and the cognitive system can handle complex tasks that require large quantities of information by relying on a recognition-based long-term memory, which works in concert with the external environment.

Humans have some basic abilities that are essential for processing information and acting successfully in different environments. According to Rumelhart and colleagues (1986), one of these abilities is that humans are very good at pattern matching to quickly settle on an interpretation of any input pattern. Times for object recognition, counting, and selection tasks vary from 25 to 170 msec (with 70 msec as the average). Potter and Levy (1969) cited ranges from 50 msec to 300 msec for the processing of single pictures with low to high levels of visual noise, and their studies demonstrate that the accuracy of visual recognition improves as display times increase from 125 msec (16% accuracy) to 1000 msec (80% accuracy). A second basic ability of humans is that they are very good at modeling their worlds; that is, they can anticipate the new state of affairs resulting from actions or from an event they observe. This ability is based on building up expectations and assumptions and is crucial for inferential learning (Seel, 1991). Third, humans are good at manipulating their environments. This can be considered as a version of “man the tool user” and is perhaps the crucial skill in forming a culture. Especially important here is the ability to manipulate the environment so it comes to represent something. Rumelhart and colleagues (1986) argue that these three basic cognitive abilities involve the interplay between two units of memory: an interpretation network, which corresponds to the activation of schemata, and the construction of a model of the world.

**Parallel Distributed Processing, Schemata, and Mental Models**

In cognitive psychology, schemata are defined as large-scale slot-filler structures that play critical roles in the interpretation of input data, the guiding of action, and the storage of knowledge in memory (Anderson,
PDP models, however, do not work with concepts such as schemata but rather conceptualize, consistent with recent brain research, memory by means of constraint networks resulting from the sum of excitatory and inhibitory influences on a unit. Input comes into the cognitive system and activates a set of units that tend to act together as response to certain patterns of the input. These tightly interconnected units correspond to what has been called a schema in cognitive psychology. A schema is the state that maximizes the particular set of constraints acting at a given moment. This conception, of course, contradicts the conventional story that schemata are stored in memory. In PDP models, they are the major content of memory, but nothing stored corresponds to a schema. What is stored is a set of connection strengths which, when activated, contains the ability to generate mental states that correspond to an instantiated schemata.

Similarly, mental models consist of relaxation networks, which take as input some specification of the actions we intend to carry out and produce an interpretation of what would happen if we did that. It is not necessary for world events to have really happened. In the case that they have not, the cognitive system replaces the inputs from the world with inputs from a model of the world. In PDP models, schemata and mental models are defined at a molar level of cognition, at which individuals organize symbols of experience or thought in such a way that they form a systematic representation of this experience or thought as a means of understanding.

Mental models and schemata are basic formats of mental representation that fulfill, in terms of Piaget’s epistemology, the functions of assimilation and accommodation. Schemata regulate the assimilation of new information into cognitive structures. If a schema does not fit with a new task it can be adjusted to meet the task requirements by means of accretion, tuning, or reorganization. If this is not successful, accommodation must take place for the individual to reorganize the available knowledge to construct a mental model (Seel, 1991). This can be illustrated as in Figure 5.2.

Mental models are dynamic representations constructed to serve several functions, such as (1) the simplification of an investigation to particular and relevant phenomena in a domain, (2) the envisioning of complex structures (to make visible the invisible), (3) analogical reasoning, and (4) mental simulation in the sense of thought experiments (Seel, 1991). There are two procedures for coming to a mental model: either by means of constructing an analogy with the known or, if this is not possible, by integrating relevant bits of generic knowledge into a coherent structure to meet the requirements of a phenomenon to be explained. Both procedures require quite a lot of time and mental effort. A central component of modeling consists in the process of fleshing out (Johnson-Laird, 1983), which can be understood as the step-by-step completion of an initial model to a more complete model. While a schema is a slot-filler structure, a mental model contains assumptions that must be justified by observations. The justification of the assumptions is connected with a reduction to absurdity (Seel, 1991).

This is a process of testing continuously whether a model can be replaced with a better model. As long as this is not possible, the model is considered as suitable.

**Research on Schemata and Mental Models**

The schema concept has been an influential construct of cognitive psychology since the early 1970s and has inspired an abundance of studies in the field of text and picture processing as well as television viewing. In
In many studies, the role of human memory has been ignored, but some researchers (e.g., Watt and Welch, 1983) have referred explicitly to the interplay among perception, attention, and memory. In these studies, it became evident that both the context and complexity of, for example, pictorial information can play an important role for learning and remembering. Friedman (1979) found that unexpected (i.e., schema-dissonant) objects embedded in a complex scenario can be recalled better than expected objects because dissonant information evokes a focus of attention that is not necessary in the case of schema-congruent information.

The research on memory for schema-relevant information has produced contradictory results. Some studies demonstrate memory selectivity for schema-consistent information, whereas others demonstrate memory selectivity for schema-inconsistent information. A meta-analysis by Rojahn and Pettigrew (1992) on a sample of 60 independent studies with 165 comparative tests suggested a slight overall memory advantage for schema-inconsistent information. In addition, a study by Seel (1984) demonstrated that learners’ attention to local information within a complex scenario as well as the processing of this information and its retrieval from memory are dependent on age-related development. First-graders could encode the global and local information of complex scenarios by referring to scene schema, but they could not recall the pictorial details with a quantity and quality comparable to older children and adults. Visual attention runs from a small area with high resolution to a broad area with a loss of details, and focusing attention on a specific object can lead to a neglect of other objects (Shaw, 1982).

Obviously, the salience of specific local information plays a central role for comprehension and remembering. Finally, the study by Seel (1984) demonstrated that the content of complex scenarios can evoke emotional reactions with a resulting focal attention on salient features of the scenarios due to a novelty effect.

Text and picture processing has also been a central issue of mental model research since its beginning in the 1980s. The effects of graphical diagrams or even helpful video on the construction of mental models have been investigated (Hegarty and Just, 1993; Sharp et al., 1995). Evidently, diagrams of complex technical systems, for example, proved to be effective not only for the representation of the complex real scenarios but also for the simulation of their processes; however, the success of such media presupposes that the learner is semantically sensitive to their model-relevant characteristics. The concept of semantic sensitivity was introduced by Anzai and Yokoyama (1984), who argued that individuals spontaneously respond to the information from the environment to generate a basic understanding of it. Numerous studies demonstrate the semantic sensitivity of learners acting in learning environments that demand the construction of a mental model (Anzai and Yokoyama, 1984; Seel, 1995).

Despite these promising results, several authors (Snow, 1990) have criticized the early research on mental models because it was regularly done piecemeal in small-scale, specialized contexts. In many of these early studies (Kieras and Bovair, 1984), the following method was applied. After an initial training in which the subjects had to generate an initial mental model and again after an experimentally varied learning phase, the subjects performed specific tasks considered indicative of successful model construction. Since the 1990s, however, alternative approaches have emerged that focus on instructional research on constructing and revising mental models. These approaches of model-oriented learning and instruction follow an understanding of learning as an active, constructive, and cumulative process, which has been described by Norman (1981, p. 284) as follows:

I have estimated that experts at a task may spend 5000 hours acquiring their skills: that is not such a long time; it is 2-1/2 years of full-time study, 40 hours a week, 50 weeks a year. Not much time to become a professional tennis player, or computer programmer, or linguist. What goes on during that time? Whatever it is, it is slow, continuous. No magic dose of knowledge in form of pill or lecture. Just a lot of slow, continual exposure to the topic, probably accompanied by several bouts of restructuring of the underlying mental representations, reconceptualizations of the concepts, plus many hours of accumulation of large quantities of facts.

Accordingly, approaches to model-oriented learning and teaching emphasize long-time learning and the accumulation of knowledge. Model-oriented teaching focuses on the patterns of participation and discourse in the classroom, where learners construct their understanding of some phenomenon (Buckley and Boulter, 1999). This is accomplished mainly with the help of external representations, provided and guided by the teacher or a multimedia program. Model-based learning, on the other hand, focuses on the construction of mental models of the phenomena under study. When the model is used successfully, it is reinforced and may eventually become a precompiled, stable model or even, after many repetitions, a schema. If the model is not satisfactory, it may be revised or rejected in a progression of mental models.

At the moment, several research groups are concerned with model-oriented learning and teaching (Lesh and Doerr, 2003; Penner, 2001). This line of research is characterized by references to the traditional...
use of models in math and science instruction, but it does not refer to theories and research on human memory.

Alternatively, my own studies (Seel et al., 2000) correspond with PDP models of information processing and are concerned with complex problem solving and the learning-dependent progression of mental models. The main results of different replication studies (in total with more than 600 students of various ages and backgrounds) can be summarized as follows:

- Mental models are not fixed structures that can be retrieved from memory but are constructed when needed to master the specific demands of a new learning situation.
- Students dynamically modify and restructure their initial mental models when they evaluate externally provided information as being more plausible and convincing than their prior knowledge. This can be interpreted as an indicator of the learners’ semantic sensitivity with regard to relevant information from the environment. The learning environment serves as an information resource from which the learners extract the information they need to construct an explanatory model.
- With regard to the stability and change of mental models, the various studies agreed on the observation that mental models are highly situation dependent. Although they were not constructed independently from each other at various points of measurement, their structures were obviously different. Naturally, it was cognitively less demanding for the students to construct new models at each point of measurement than to remember previously constructed models.
- Mental models proved to be effective for mentally simulating the relevant properties of complex systems to be cognitively mastered (Seel et al., 2006).

The results of these studies indicate that the time needed for successful model-based learning was not sufficient with regard to the emergence of a schema, defined here as an automated routine that can be used to access and apply stored knowledge structures without mental effort.

The instructional research on mental models has highlighted several complexities and consistencies. One consistency is concerned with the development of a new methodology for assessing the learning-dependent progression of mental models. The principles of this methodology include embedding the diagnosis of mental models in a complex problem situation, collecting data in a longitudinal design, providing valid and reliable quantitative data, and enabling a methodologically straightforward analysis and interpretation of the data collected (Seel et al., 2007). At the core of this methodology are the SMD (Surface, Matching, Deep Structure) Technology and MIToCaR (Model Inspection Trace of Concepts and Relations). These can be combined with alternative methods for assessing mental models, such as think-aloud protocols, structure-formation techniques, concept-mapping tools, and causal diagrams, all of which have been applied successfully in mental model research (Seel, 1999). Another consistency of mental model research consists in new instructional approaches for improving the construction and refinement of effective mental models (Seel, 2003).

Summary and Criticism

Modern psychology regards the human being as playing an active and selective role in approaching each new environment. Cognitive theorists place much greater emphasis on the fact that individuals bring to each environment preestablished schemata based on previous experiences. These schemata have been built up in the course of many previous interactions with the environment as well as further reflections upon these experiences during mental rehearsal. Some of these schemata are more complex, integrated, organized, or differentiated than others; however, although the activation of schemata plays a central role in different psychological approaches, such as the cognitive load theory, we still do not know enough about the construction of schemata. For example, it is not clear under which conditions mental models merge to schemata. Recent research (Seel et al., 2006) has demonstrated that it takes a lot of time and repetitions of successful construction of mental models within a domain until they become precompiled and stable and merge to a schema.

All of the theoretical conceptions and related research that have been considered in the foregoing sections are concerned with structures and functions of the semantic memory; however, in cognitive psychology a distinction has been made between semantic and episodic memory as specializations of the declarative memory.

Episodic Memory

A simple definition of episodic memory is that it encompasses everything we remember as opposed to everything we know. The latter is usually called
semantic memory, upon which episodic memory is believed to be built. A memory of the last family vacation is an episodic memory; however, if someone asks what color a ripe banana is, semantic memory is used to answer. The notion of episodic memory was first proposed some 30 years ago by Tulving and Thomson (1973). At that time episodic memory was defined in terms of materials and tasks. Today, episodic memory is understood as a neurocognitive system, uniquely different from other memory systems that enable human beings to remember past experiences (Tulving, 2002). It includes time, place, and associated emotions that affect the quality of the memorization. Interestingly, an autobiographical memory has been introduced as a specialization of the episodic memory. It is related with the investigation everyday memory, which refers to memory operations that routinely occur in one’s daily environment, and eyewitness testimony, which has inspired a lot of research into its accuracy (Loftus, 1975). Evidently, human memory for events is fragile and susceptible to distortion.

Although the notion of episodic memory plays a central role in research on human memory, it does not play this role in the cognitive architectures for multimedia learning. Indeed, in the most recent overview by Reed (2006), neither episodic memory nor autobiographical memory is mentioned. Nevertheless, we can learn from the theoretical conceptions and research on this topic that memories are constructions made in accordance with present needs, desires, social influences, etc. Accordingly, memories are often accompanied by strong feelings and emotions that increase the recall of the stored events from episodic memory. Finally, memory usually involves awareness of the memory (Schacter, 1996).

Memory is the retention of, and ability to recall, information, personal experiences, and procedures. A memory system is fairly universally agreed to have three high-level activities: encoding, storage, and retrieval. Most lost memories are lost because they were never elaborately encoded. Perception is mostly a filtering and fragmenting process. Our interests and needs affect perception, but most of what is available to us as potential sense data will never be processed, and most of what is processed will be forgotten. We do not forget simply to avoid being reminded of unpleasant things. We forget because we either did not perceive closely in the first place or did not encode the experience (Schacter, 1996); thus, a central feature of human memory is the subjectivity of remembering. This leads to the next section of this chapter, where motivational aspects of multimedia learning are emphasized.

LEARNING WITH MEDIA AND MOTIVATION

Motivation is a fairly difficult area, and a number of theories have been developed to try to explain why people behave in the ways that they do and predict or guess what people actually will do on the basis of these theories. Although motivation is generally considered a key variable in learning, it is surprising that so little attention is apparently paid to studies on motivation in multimedia learning as well as, vice versa, to learning and cognition in the motivation literature. Indeed, an analysis by Elliott and Dweck (2005) shows that, among more than 5000 citations, no reference is made to cognitive load theory and the stage model of information processing. On the other side, Lowe (2003), for instance, divorced the motivational aspects of animation from its instructive power. It seems apparent that there are two large groups of researchers who are not making much use of each other’s insights.

As a consequence, we can find only a few theoretical approaches that aim at integrating motivation into comprehensive models of multimedia learning (Astleitner and Wiesner, 2004; Samaras et al., 2006); however, these models lack substantial empirical evidence, and future research is necessary to analyze the interrelations of the motivational and cognitive variables. The infusion of motivation in multimedia learning is a complex challenge. Motivation might be intrinsic, extrinsic, mixed, or absent altogether. There is some evidence that intrinsic motivation encourages the learner to become cognitively engaged with the multimedia material and improves learning.

Nevertheless, extrinsic motivational factors such as the design features of a multimedia package are thought to provide some initial incentive for learners to access the material, but sustained effort occurs only when they encounter intrinsic motivational factors provided by interesting and challenging content (Najjar, 1998). This may lead to cognitive engagement, which is the process whereby learners become motivated to take full control of their own learning. Generally, it has been argued that multimedia and computers have the capacity to allow for external regulation and autonomy support (Stefanou et al., 2004). Technology may also provide for context and variety in learning tasks that theoretically could be exploited to situate motivation. Hede (2002) sees the various motivational factors as impacting learner control or, more specifically, the time and effort learners devote to engaging with multimedia. Beyond Hede’s model, there are three approaches to integrating motivation into multimedia learning: (1) schema-based approaches, (2) flow-based approaches, and (3) the uses-and-gratifications approach.
Schema-Based Approaches to Motivation in Multimedia Learning

In correspondence with Piaget’s (1952) theory of disequilibrium, a class of theoretical models postulates strong relationships between cognition and emotions. Eckblad (1981), for example, argued that each resistance for assimilating new information into existing schemata evokes affects and emotions of a specific nature. Similarly, Stein and Levine (1991) argued that attempts to assimilate new information into schemata are associated with emotional experiences. When the incoming information is novel, it causes a mismatch with existing schemata and results in arousal of the autonomic nervous system. When this arousal occurs in conjunction with a cognitive appraisal of the situation, a more or less specific emotional reaction occurs. Plans or anticipatory schemata are not only specific to situations; they also involve search and selection strategies related to the kind of information to be processed. When the strategies for processing new materials and specific anticipations match well with the information we actually confront in a new setting, we generally experience positive affects, joy, or a general sense of well-being. If, however, our anticipatory schemata or plans for processing information are inadequate, we may experience negative emotions (Singer and Singer, 1983).

The basic assumption of schema-based research on motivation is that deep comprehension occurs when learners confront contradictions, anomalous events, obstacles to goals, salient contrasts, perturbations, surprises, equivalent alternatives, and other stimuli or experiences that fail to match schema-based expectations (Mandler, 1999). Cognitive disequilibrium has a high likelihood of activating conscious and effortful cognitive deliberation, questions, and inquiry that aim to restore cognitive equilibrium. The affective states of confusion and perhaps frustration are likely to occur during cognitive disequilibrium. Recent research (Rozin and Cohen, 2003) has indeed pointed to confusion as an important affective state for learning. Confusion indicates an uncertainty about what to do next or how to act; thus, confusion often accompanies cognitive disequilibrium. Similarly, states of perturbation and hesitation often indicate the need for clarification or more information.

In four experiments, Schutzwohl (1998) investigated the effects of stimuli discrepant with schemata of varying strength on three components of surprise: (1) the interruption of ongoing activities (indexed by response time increase), (2) the focusing of attention on the schema-discrepant event (indexed by memory performance), and (3) the feeling of surprise (indexed by self-reports). Response times were consistently found to increase with schema strength. This effect was attributed to the increasing difficulty of schema revision. In contrast, memory for the schema-discrepant event was not affected by schema strength, supporting the hypothesis that schema-discrepant stimuli are stored in memory with a distinct tag. Finally, self-reports of surprise intensity varied with schema strength only if they were made immediately after the surprising event without any intervening questions, suggesting that self-reports of surprise are highly susceptible to memory distortions.

Emotional and motivational aspects of learning and remembering are also discussed in connection with cognitive load theory; for example, Early (2006) argued that it may be useful to separate factors that affect learner motivation into distinct groups: the variables or values of variables that increase learner motivation and the variables or values that decrease or fail to influence learner motivation. Custers and Aarts (2005) have identified positive affect as an example of a variable value that increases future goal pursuit via choice. The memory of the pleasurable sensation associated with prior goal pursuit may, over time, become automated and lead to an active choice of novel goals; however, excess burden on working memory may serve as an example of a variable value that decreases goal pursuit by decreasing effort or persistence.

This corresponds with Berlyne’s (1971) precept that another process at the other extreme of information overload is boredom. Overly simple visual fields, for example, may lead to the uncomfortable feeling of boredom. One response to boredom with the external environment is to switch to internal information processing (for example, to daydream). Another interesting experiment is that of Ashcraft and Kirk (2001), who investigated the impact of anxiety on working memory. Individuals with high math anxiety demonstrated a reduced working memory capacity, which led to a pronounced increase in reaction time and errors when mental addition was performed concurrently with a memory load task. The effects of the reduction also generalized to a working-memory-intensive transformation task. Overall, the results demonstrated that anxiety affects performance in tasks and that this effect can be interpreted as a transitory disruption of working memory.

Flow, Engagement, and Self-Efficacy

According to the constructivist theoretical frameworks, a person’s affective states are expected to systematically influence how they process new material. The intrinsic motivation literature has identified affective states such as curiosity as indicators of motivation level and learning. Learners with more intrinsic motivation and interest display greater levels of pleasure,
more active involvement in tasks (Tobias, 1994), more task persistence and lower levels of boredom (Miserandino, 1996), and less anxiety and anger (Patrick et al., 1993). Furthermore, because a person’s affective state is linked to their motivation level, intrinsically motivated learners who are engaged should demonstrate more engagement and persistence in performing tasks. A deeper understanding of the materials should be one important consequence.

In an exploratory study, Craig and colleagues (2004) investigated the role of several affective states (frustration, boredom, flow, confusion, eureka, and neutral) that potentially occur during learning with an intelligent tutoring system for dialogs in natural language. Observational analyses revealed significant relationships between learning and the affective states of boredom, flow, and confusion. Other research suggests that interest increases as anxiety decreases and attitude improves and that such motivation assists the achievement of self-efficacy in virtual learning environments (Dyck and Smither, 1994).

These findings indicating that learning correlates negatively with boredom and positively with engagement are consistent with predictions from Csikszentmihalyi’s (1975) analysis of flow experiences. Flow describes a state of complete absorption or engagement in an activity and refers to the optimal experience. During optimal experiences, individuals are in a psychological state where they are so involved with the goal-driven activity that nothing else seems to matter. Past research has shown that the flow state has a positive impact on learning (Salanova et al., 2006; Webster et al., 1993) and should be taken into account when designing learning materials. The flow theory is used by Kiili (2005) as a framework for facilitating positive user experience and engagement to maximize the impact of digital learning environments. The purpose of the study was to support an active learning process, creative participation, and learner engagement in learning with a multimedia environment. In addition, Kiili integrated assumptions of cognitive load theory into a participatory multimedia learning model in which learners had to produce learning materials by themselves. The proposed model was studied through an educational game with university-level students. Post-tests and course grades demonstrated no significance, whereas results of an item-to-item analysis of a questionnaire showed overall satisfaction with the teaching methodology and varied results for self-efficacy, self-reliance, and motivation.

The Uses-and-Gratifications Approach

This approach has an influential tradition in media research and focuses on why people use particular media rather than on their content. The uses-and-gratification approach goes back to Blumer and Katz (1974), who suggested that media users play an active role in choosing and using the media that best fulfills...
the needs of the user. From the perspective of motivation psychology, the uses-and-gratifications approach can be considered a specific variant of expectation-value models of motivation. These models traditionally assume that both expectancy and value are required for goal commitment.

For a long time, the focus of the uses-and-gratifications approach was clearly on mass media, such as television. Sufficient evidence suggests that television viewing use is often habitual, ritualistic, and unselective (Barwise and Ehrenberg, 1988) but television viewing can sometimes also be an aesthetic experience involving intrinsic motivation. Furthermore, Zillmann (cited by McQuail, 1987, p. 236) has shown the influence of mood on media choice: Boredom encourages the choice of exciting content, whereas stress encourages a choice of relaxing content.

Due to the fact that the World Wide Web has become a major contemporary mass medium, the uses-and-gratifications approach has been applied for studying the Web as a whole and for examining specific types of sites on the Web. Kaye (2002), for example, examined the uses and gratifications of accessing online sources for political information. A factor analysis revealed four primary motivations for connecting to online political information, among which the need for entertainment is of motivational concern. Interestingly, Grace-Faragalia and colleagues (2005) investigated the issue of gender and Internet uses and gratifications with a representative sample recruited from Internet users in different countries. In general, men still maintain higher Internet skills and self-efficacy in computer applications, but the gender gap is narrowing in each country. Indeed, a regression analysis of Internet gratification factors found gender differences in Internet motivations and online community participation. The data suggest that real-world social motivations impact participation in the virtual space.

An analysis of the recent literature shows that motivations relating to the use of the Internet have been well researched (Parker and Plank, 2000; Song et al., 2006); however, these studies remain to a great extent within the realm of the traditional uses-and-gratifications approach, providing a typology of use motivations, and fail to develop new Internet-specific gratifications (Stafford et al., 2004).

SUMMARY

When we take the major fields of research on memory and motivation into consideration with regard to their implications for the design of instruction, we find a tension between strong (those that lead to very precise conclusions) and weak (those that lead to less precise conclusions) assumptions. Strong assumptions are helpful when the assumptions apply, but they often do not apply, which then invalidates the conclusions prescribed by the model. Weak assumptions are less helpful in creating specific instructional systems and learning activities, but they are more generally applicable and less likely to be invalidated. Finding the right balance is the challenge for professional practitioners. Extending the research so weak models become stronger and more useful is the challenge for instructional design research.

REFERENCES


* Indicates a core reference.