CHAPTER 12

Information Processing Theory

INTRODUCTION

Information Processing Theory is concerned with how people view their environment, how they put that information into memory, and how they retrieve that information later on. The Information Processing Theory approach is based on the idea that humans process information they receive instead of simply responding to external stimuli. According to the Information Processing Theory model, the mind is often compared to a computer. The computer, like mind, analyzes information and determines how the information will be stored. There are three components of the Information Processing Theory: sensory memory, short-term memory, and long-term memory. Sensory memory is all of the things that you experience through your five senses-hearing, vision, taste, smell, and touch. The capacity of sensory memory is about four items and the duration is limited to .5 to 3 seconds. Short-term memory, also called working memory, is the temporary storage, lasts about 15-30 seconds, holds about 7 items of information, and includes the thinking part of applying what come out of the sensory memory. Long-term memory is memory that can be accessed at a later time, is long lasting, and can hold infinite information. The Information Processing Theory addresses how people respond to the information they receive through their senses and how they further process those information with steps of attention, forgetting, and retention. Unlike other cognitive developmental theories, the information processing theory includes a continuous pattern of development instead of development in stages.

REQUIRED READING

The information processing (IP) theory is a cognitive approach to understanding how the human mind transforms sensory information. The model (Figure 12.1) assumes that information that comes from the environment is subject to mental processes beyond a simple stimulus-response pattern. "Input" from the environment goes through the cognitive systems which is then measured by the "output." Information that is received can take several paths depending on attention, encoding, recognition, and storage. The central executive feature controls how much information is being processed, though more primitive sensory areas of the brain first accept environmental input. The theory looks at real time responses to presented stimuli and how the mind transforms that information.

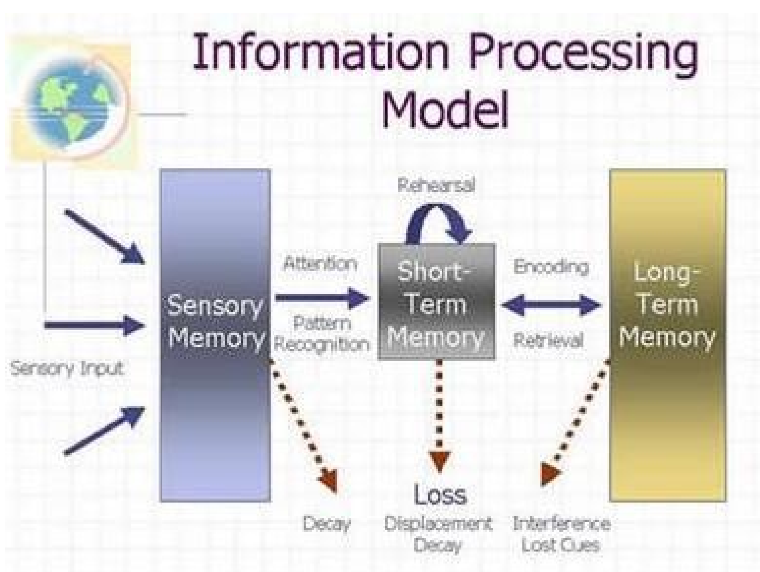


Figure 12.1 Information Processing Model. The model is constructed to represent mental processes much like that of a computer. No one theorist claims to have invented the model. The model creates a basic structure for experimental research of these internal cognitive processes.

The model assumes that through the process of maturation, one develops greater abilities to attend to stimulus, recognize patterns, encode, and retrieve information. Over long spans of time, individuals process information with greater efficiency.

Over the life span, individuals experience more information, associations, and ways to categorize the input. The process may seem passive, but the model assumes that input from the environment is actively transformed and rehearsed to become a part of long-term memory. For environmental information to become a part of long-term memory, one must attend to, rehearse, and make sense of the stimuli. The interaction between nature and nurture coincide for changes in development. The model does not attempt nor can it distinguish between the two.

How Does the Information Processing Model Work?

Sensory Memory (Figure 12.5)

Sensory memory is where information gathered from the environment is stored. Sensory memory is very limited, passive, and lasts about .5-3 seconds. It has the capacity of holding 4 items. It is affected by attention. Information is gathered from the environment through the sensory register (sensory motor). In order for information to enter the short-term memory from the sensory register, it must be attended to by the senses. Information that is not attended to is lost from the sensory memory and never enters the short-term memory. The best understood sensory registers (SRs) are for seeing (iconic) and hearing (echoic). Very little is known about tactile (touch), olfactory (smell), and gustatory (taste) SRs. For example, light reflecting off the cup hits my eye; the image is transferred through my optic nerve to the sensory register. If I do not attend to it, it fades from this memory store and is lost. In fact, my cup is on my desk most of the day, and I see it without really "seeing" it many times during the day. Each memory stage has four attributes: 1. Representation; 2. Capacity; 3. Duration; and 4. Cause of forgetting. For the visual sensory register, for example, representation is iconic-limited to the field of vision, and lasts for about 250 milliseconds. The main cause of forgetting is decay. Representation in the auditory register is echoic (based on sound); its duration is 2-3 seconds; it is only limited to the sounds we can actually hear and decay is the primary cause for forgetting. Much less is known about the other three register types.

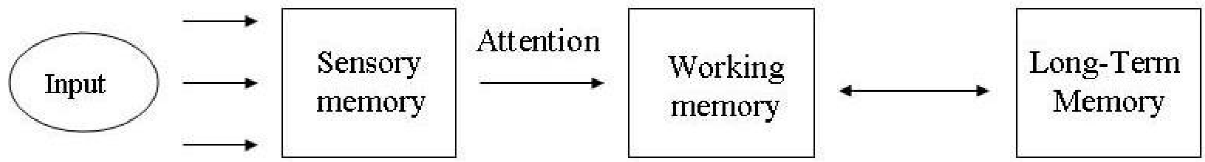
Short-Term Memory (Working Memory) (Figure 12.5)

Short-Term Memory (STM) is also known as working memory. It is where consciousness exists. In the cup example, if I attend to the cup, it will be moved into STM. At this point, it is difficult to talk about the cup in STM memory without referring to long-term memory (LTM). For example, I might attend to the cup and think, "That's my cup. It has coffee in it. I poured that coffee 3 hours ago." Each of those statements draws on LTM. I know it is my cup because it is the one that a potter friend of mine made for me. I know it has coffee in it, because I remember getting it this morning. I know that I poured that cup at 9:00 am. The statement that the coffee is 3 hours old required me to look at the current time, and retrieve from LTM that subtracting the current time from pouring time tells me how old the coffee is. Performing the subtraction used no STM processing space, because experience in doing arithmetic allows me to do this automatically.

STM is where the world meets what is already known, and where thinking is done. You perceive and attend to stimuli; that information is then actively processed based on information stored in LTM. The use strategies such as rehearsal (repeating information verbally (acoustic encoding) and chunking (categorizing information together in one memory slot) can expand the capacity of short-term memory (McLeod, 2009). In terms of the characteristics of this memory stage, the representation is echoic. It is limited to 5-9 items, and it lasts between 15-30 seconds (Atkinson & Shiffrin, 1971). At the STM stage, interference is the principal cause of forgetting. STM can hold about 7 (the magic number) items (Miller, 1956). A common example of this is calling information for a phone number. After the operator gives you the number, you begin repeating it to keep it in STM. This repetition is termed rehearsal. Rehearsal can also be used to get information into LTM, but it is very inefficient. Rehearsal primarily serves a maintenance function; it can be used to keep information in STM. In the phone number example, if someone interrupts you to ask you a question while you are rehearsing the number, responding interferes with rehearsal, and the phone number is lost. You must call the information again.

Baddeley and Hitch (1974) further researched short-term memory and developed an alternative model as working memory model (Figure 12.2; Figure 12.3).

Figure 12.2 Working Memory



In the working memory model (Figure 12.3), Central Executive is the part of working memory where information is controlled. Visuospatial Sketchpad stores and processes visual and spatial information. Phonological Loop stores and processes speech-form based sound information. Episodic Buffer is where information is brought to the forefront, used, constructed from and to the Long-Term Memory, where information is retained indefinitely.

Figure 12.3 Working Memory Model Components

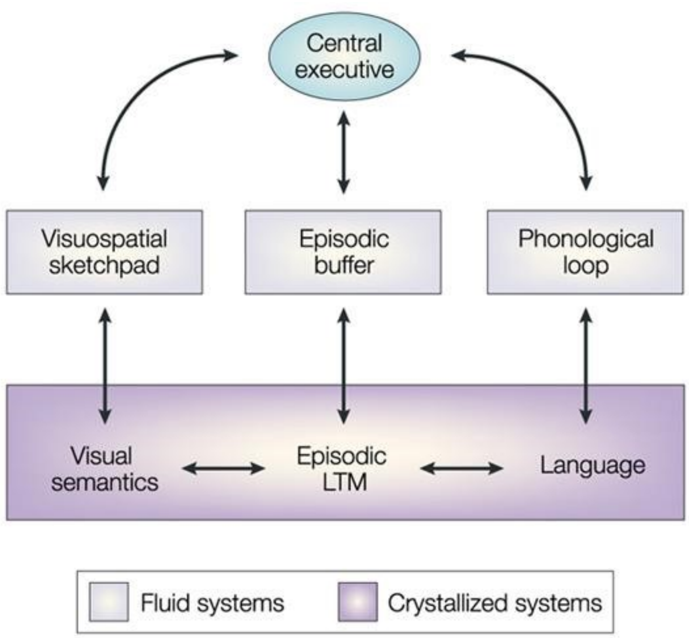


Figure 12.3 The above diagram shows the components of working memory, which is an alternative model for short term memory, developed by Baddeley and Hitch (1974). It can also be found in Miller (2011, pp. 272-272).

Long-Term Memory (Figure 12.5)

The final stage in the IP model is long-term memory (LTM), which involves the storage and recall of information over extended periods of time, such as hours, days, weeks, or years (Merriam-Webster, 2017). LTM is everything we know and know how to do. For most cognitive psychologists, the world of LTM can be categorized as one of three types of memory (Figure 12.4): declarative, procedural or episodic. Declarative knowledge can be defined as knowledge needed to complete this sentence "Knowing that…" By contrast, procedural knowledge is "Knowing how…" These two types of knowledge account for most of what is learned in school and at work. The remaining type of knowledge is episodic which might also be called anecdotal. This is memory for specific events in one's life: a memory of your first kiss or of your graduation. The personal stories in our lives comprise episodic memory. While this makes for a neat tautology, some have suggested that it is incomplete.

Figure 12.4 Declarative Knowledge, Procedural Knowledge, and Episodic Knowledge in Long-Term Memory

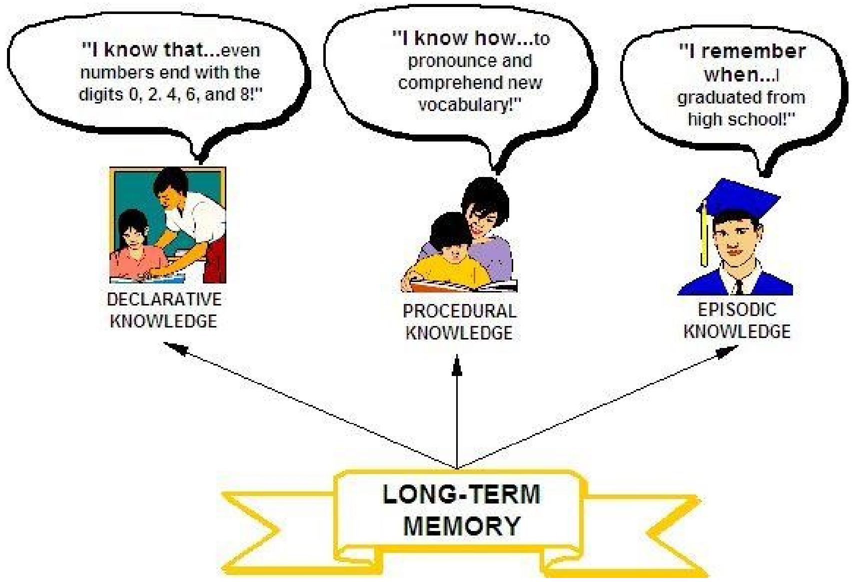


Figure 12.4. The Inspiration web illustrates that most cognitive psychologists categorized that Long-Term Memory consists of declarative knowledge ("I know that… even numbers end with the digits 0, 2, 4, 6, and 8!"), procedural knowledge ("I know how… to pronounce and comprehend new vocabulary!"), and episodic knowledge ("I remember when… I graduated from high school!"). By Tiffany Davis, Meghann Hummel, and Kay Sauers (2006).

Pavio (1986) has asserted that memory for images differs from memory for words. He offers a dual coding hypothesis asserting that when we see an image, both the image and a label for that image are stored in memory. He has extended the hypothesis, suggesting that dual codes may exist for the other senses as well. For example, the smell of an orange is stored along with its label "orange." Others have suggested that there are mechanisms that control thinking and learning. These control processes are called metacognition. Metacognition often takes the form of strategies. For example, learners attempting to master a complex topic might choose to use a strategy such as drawing pictures to help them understand the complex inter-relationships of the various components of the topic. Strategic readers might stop and mentally summarize what they have just read in order to ensure comprehension.

The 1970s saw great expansion of understanding of human learning. It became clear that there was no one method of teaching that ensured successful learning. Many researchers, especially in the field of second language (L2) acquisition, recognizing this fact, turned their attention to learners, attempting to answer the question "Why is it that some learners succeed in learning regardless of the methods used to teach them?" Rubin (1975) and Stern (1975) formulated lists of the characteristics and strategies that "good" language learners use in their study. Rubin and Thompson (1982) offered guidance to foreign language students on how to make themselves better learners. Extensive study of this notion of learning strategies in the 1980s led O'Malley et al. (1985) to formulate a list of 24 strategies used by English as a Second Language (ESL) students in their study. Most importantly, the strategies were classified into three categories: Metacognitive Strategies**:** is a term borrowed from IP theory. These strategies, according to O'Malley et al. (cited in Brown,1987), "indicate an 'executive ' function…that involve planning for learning, thinking about the learning process as it is taking place, monitoring…and evaluating learning…" (Brown, 1987, p. 94). Metacognitive strategies might include using advance organizers, self-planning, self-monitoring, and self-evaluation; Cognitive Strategies: are more task-specific, and often refer to "direct manipulation of the learning material itself" (Brown, 2000, p. 124). Examples of cognitive strategies are note-taking, repetition, guessing meaning from context, or using mnemonic devices; Socio-affective Strategies: refer to strategies that use association with or input from teachers or peers. O'Malley, Chamot, Stewer-Manzanares, Russo, and Kupper (1985) have gone on to suggest that these strategies can be overtly taught to learners, facilitating one of the most important goals of learning, learner autonomy.

Finally, there is another viewpoint that offers the notion of concepts. For example, there exists a concept called "bird," which can be reduced to declarative statements such as: "It has feathers," "It has wings and flies," "It lays eggs," and the like. The concept of "bird" can also include our episodic experiences with birds-the parakeet I had when I was a child, the sparrow I found dead by the fence one morning, etc. It can also include the hundreds of images that we have seen of birds, as well as all instances of real birds we have seen. All of this collectively is what we know of as "bird." It is the concept of bird, the tightly woven collection of knowledge that we have for birds.

In the end, there are five types of knowledge in LTM-declarative, procedural, episodic, imagery, and strategic knowledge; there also exists one collective type called conceptual knowledge. For the LTM stage, the representation is semantic (based on meaning). Capacity and duration are considered unlimited in LTM, and the cause of forgetting is failure to retrieve.

How information gets into the LTM? In order to keep information in the working, it needs to be rehearsed (rote memorization). Rote memorization is not an effective way to move information to the long-term memory. However, by using the correct methods, information can be moved from the short-term memory into the long-term memory where it can be kept for long periods of time. Information that is stored in the long-term memory does not need to be rehearsed. To retrieve information from the long-term memory, short-term memory must be used. Usually if someone "forgets" something that is stored in the long-term memory, they have simply forgotten how to retrieve it or where it is stored.

In order for information to move from short-term (working) memory to long term memory, it must be attended within 5 to 20 seconds of entering. Information must be linked to prior knowledge and encoded in order to be permanently stored in long term memory. It is generally believed that encoding for short-term memory storage in the brain relies primarily on acoustic encoding, while encoding for long-term storage is more reliant on semantic encoding (The Human Memory, n.d). Some encoding methods include chunking, imagery, and elaboration. For examples, when I think about teaching learners, I need to know what they already know so that they can relate the new information to their existing knowledge. This is elaboration. While teachers can do some of that for learners, elaboration is an active process. The learner must be actively engaged with the material that is to be learned. This does not necessarily mean that the learner must be physically active; rather, it implies that they should be actively relating this new piece of information to other ideas that they already know. LTM is often regarded as a network of ideas. In order to remember something, ideas are linked, one to another until the sought-after information is found. Failure to remember information does not mean that it has been forgotten; it is merely the procedure for retrieval has been forgotten. With more elaboration, more pathways to that piece of information are created. More pathways make retrieval of the information more likely. If it is found, it is not forgotten.

Figure 12.5 Sensory, Short-Term (Working), and Long-Term Memory

Type	Characteristics	Representation	Capacity	Duration	Cause of Forgetting
Sensory Memory	limited and passive; store information gathered from the external environment	senses (seeing, hearing, taste, feel, touch)	4 items	.5-3 seconds	decay
Short-Term Memory	active information processing: rehearsing and chunking	visual imaging and acoustic (sound) encoding	5-9 items	16-30 seconds (5-15 seconds without rehearsal)	interference
Long-Term Memory	unlimited; store information over extended periods of time (hours, days, weeks, months, years, etc.)	semantic encoding: chunking, imagery, and elaboration (knowledge: declarative, procedural, episodic, imagery, strategic, collective/ conceptual)	infinite	permanent	forgetting the retrieval pathway

Human as Computer

Within the IP model, humans are routinely compared to computers (Figure 12.6). This comparison is used as a means of better understanding the way information is processed and stored in the human mind. Therefore, when analyzing what actually develops within this model, the more specific comparison is between the human brain and computers. Computers were introduced to the study of development and provided a new way of studying intelligence (Lachman & Lachman, 1979) and “added further legitimacy to the scientific study of the mind” (Goodwin, 2005, p. 411). In the model below, you can see the direct comparison between human processing and computer processing. Within this model, information is taken in (or input). Information is encoded to give meaning and compared with stored information. If a person is working on a task, this is where the short-term memory (working) memory is enacted. An example of that for a computer is the Central Processing Unit (CPU). In both cases, information is encoded, given meaning, and combined with previously stored information to enact the task. The latter step is where the information is stored where it can later be retrieved when needed. For computers, this would be akin to saving information on a hard drive, where you would then upload the saved data when working on a future task (using the short-term (working) memory).

Figure 12.6 Human Memory and Computer Comparison

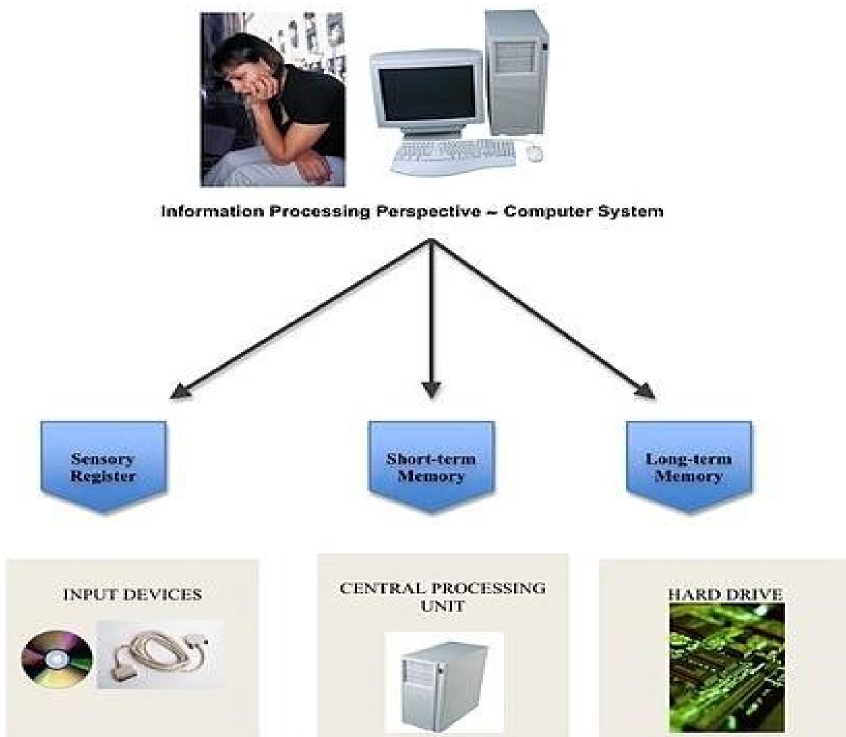


Figure 12.6. The Inspiration web above shows how Information Processing can be likened to the model of a computer. The Sensory Register would include input devices like CDs. Short-Term Memory includes the Central Processing Unit. Long-Term Memory would be viewed as the hard drive or storage. By Tiffany Davis, Meghann Hummel, and Kay Sauers (2006).

Information Processing Theory views humans as information processing systems with memory systems sometimes referred to as cognitive architecture (Miller, 2011). A computer metaphor is often applied to human cognitive systems, wherein information (a stimulus) is inputted (sensed) and the brain then performs processes such as comparing the information to previously stored information (schemas), transforming information (encoding), or storing information in long-term memory.

This theory views humans as machines, actively inputting, retrieving, processing and storing information. Context, social content, and social influences on processing are generally ignored in favor of a focus on internal systemic processes (Miller 2011). Nature provides the hardware, or the neurological processing system likely predisposed to economical and efficient processing, as well as being pre-tuned to attend to specific stimuli. The “Nurture” component presents as the environment which provides the stimuli to be inputted and processed by the system.

Current Areas of Research

Information Processing Theory is currently being utilized in the study of computer or artificial intelligence. This theory has also been applied to systems beyond the individual, including families and business organizations. For example, Ariel (1987) applied Information Processing Theory to family systems, with sensing, attending, and encoding stimuli occurring either within individuals within the system or as the family system itself. Unlike traditional systems theory, where the family system tends to maintain stasis and resists incoming stimuli which would violate the system's rules, the Information Processing family develops individual and mutual schemas which influence what and how information is attended to and processed. Dysfunctions can occur both on the individual level as well as within the family system itself, creating more targets for therapeutic change. Rogers, Miller, and Judge (1999) utilized Information Processing Theory to describe business organizational behavior, as well as to present a model describing how effective and ineffective business strategies are developed. In their study, components of organizations that "sense" market information are identified as well as how organizations attend to this information, which gatekeepers determine what information is relevant/important for the organization, how this is organized into the existing culture (organizational schemas), and whether or not the organization has effective or ineffective processes for their long-term strategy.

Memory, Human Development, Social Influences, and Learning

When children are faced with information that is unfamiliar to them, they are left with the task of developing strategies to encode the information so as to store it and accurately and easily access it at a later time (Miller, 2011). Depending on the age of the child, the method of storing information into memory differs. As children develop, increased cognitive abilities, increased memory capacity, and other social/cultural factors serve as major contributors to their development. Older children are more likely to develop memory strategies on their own, are better at discerning what memory strategies are appropriate for particular situations and tasks, and are better able to selectively attend to important information and filter out extraneous information.

Memory and Strategies

The strategies children use to encode and remember information are of interest to Information Processing researchers (e.g., task analysis research). For example, “young children are capable of using rehearsal to aid memory if they are told to rehearse, but they are deficient at spontaneously producing a strategy” (production deficiency) (Miller, 2011, p. 283). Therefore, young children are unable to ascertain the appropriate time to use particular strategies. On children’s encoding strategy development characteristics, Miller (2011) pointed out the following:

- As children develop they become more capable of developing appropriate strategies to acquire and remember units of knowledge when necessary;
- A child’s ability to selectively choose which information they attend to is another developmental milestone;
    - A child may choose a strategy that does not produce a desired outcome (utilization deficiency);
    - Children may use several strategies on the same task;
    - They may frequently change their strategies used or strategies develop as a result of increased knowledge, development, etc.;
- Children develop strategies over the course of their development;
- Children may employ strategies at an early age that prove ineffective later in development; and
- Children may develop new strategies that they find effective and useful later in life.

Information processing theory combines elements of both quantitative and qualitative development. Qualitative development occurs through the emergence of new strategies for information storage and retrieval, developing representational abilities (such as the utilization of language to represent concepts), or obtaining problem-solving rules (Miller, 2011). Increases in the knowledge base or the ability to remember more items in short-term (working) memory are examples of quantitative changes, as well as increases in the strength of connected cognitive associations (Miller, 2011). The qualitative and quantitative components often interact together to develop new and more efficient strategies within the processing system.

Memory and Knowledge

Information Processing Theory views memory and knowledge formation as working together, and not as separate and mutually exclusive concepts. Humans are better able to remember things they have knowledge of, which increases the recall of stored information. Increased knowledge allows the person to more readily access information because it has been categorized and the bits of information relate to one another.

As children develop, they also gain an understanding of their own memory and how it works, which is called metamemory. Also, children also gain information about how human cognitive functioning, which is called metacognition. These are other important developmental milestones, which indicate the child is able to process much more complex and less concrete information. This is important in our overall functioning, because it shows an understanding of our own functioning related to specific tasks and how to best adapt our learning and memory strategies.

Younger children have less memory capacity. A child's level of comprehension is integrally connected with their memory (Miller, 2011). As the child develops, they are able to process information at a faster speed, and they have an increased capacity of how much information they can take in at a time. Increased memory capacity allows the child to process and store more bits of information (Miller, 2011). Thus, older children are able to take in more information at a faster rate, therefore allowing better efficiency of information processing.

Increased knowledge enables the child to more readily access information from their long-term storage and utilize it in appropriate situations (Miller, 2011). The more associations one is able to make and the more complex their network of associations, the better their information recall. A developmental milestone examined in children is their ability to take information and expound upon it. Younger children are more likely to purely recall the information they process. However, as children develop and gain knowledge, they are better able to gather information, make inferences, judgments, and go beyond pure recall (Miller, 2011).

Memory and Social Influences

One's culture greatly influences how one remembers bits of information by how the culture emphasizes various elements, emotions, or even events (Shaki & Gravers, 2011). As the text discusses, children can manage and handle more information at once due to increased capacity, and "because new information can be packaged into preexisting categories and structures" (Miller, 2011, p. 290). The knowledge gained, however, is not obtained without interaction with the child's external environment. Attitudes and beliefs about gender, race, sex roles, etc. greatly influence how a child processes and recalls information (Miller, 2011). Beck (1975) suggests that as we develop we learn how to process external stimuli, and these messages are processed, interpreted and incorporated into one's internal schemas. For example, children in a school setting who are taught that men and women occupy certain gender-stereotypic jobs are thus more likely to process information through such a "filter" (Best, 1983). The text points out that children may even reconstruct images later to fit with their schema of a particular occupation (Miller, 2011). This relates to the construction of scripts, which are assumptions or expectations about what is supposed to happen in a particular situation. They can greatly influence how a child remembers events and may potentially lead to assumptions about people, events, etc. (Miller, 2011). While scripts are helpful in making the information processing system more efficient, they can hinder the recall of specific information and enhance the generalizations made about people, events, etc. Language is an integral part of one's culture that can greatly influence the information processing system. Language, the nature of a task's instruction, and the type of task can all greatly impact the processing of information (Shaki & Gravers, 2011). Furthermore, individualistic versus collectivistic cultures can have different outlooks on human development as well as the proper formation and development of an individual, which therefore influences motivations and actions toward goals (Hamamura, Meijer, Heine, Kamaya, & Hori, 2009).

Criticisms of Information Processing Theory

Models based upon Information Processing Theory take a somewhat simplistic view of cognitive processing, with information processing being viewed largely as a linear process. This IP model does not take into account simultaneous or parallel processing. For example, with the linear model, which suggests rehearsal is required to encode information in long-term memory, is likely faulty in cases of trauma, where information can be encoded automatically and without rehearsal due to a single exposure to traumatic stimuli. The metaphor of the computer is off-putting to many, who dislike comparing human beings to machines. Moreover, no current computer program can truly simulate the full range of human cognition. Computer constructed models that are based upon this theory are highly complex and again cannot take into account all the nuances of human thought despite their complexity. Information Processing Theory does not account for fundamental developmental changes, or changes to the "hardware" of the brain. For example, how do humans gain the ability to utilize representational thought utilizing language? How do people develop "formal operations" thinking, such as abstract logical or social thinking when previously their thoughts were in "concrete" terms? There is an excessive focus on internal cognitive processes, with little attention being paid to environmental influences or the nature of the external stimuli the individual is exposed to. Lastly, the impact of emotions or behaviors on cognitive processing or interpretation is not sufficiently included in this model. For example, the Information Processing model does not consider how an individual can process a stimulus differently if they are angry versus if they are in a calm state. The Information Processing model is described as being universal, with little attention being paid to individual differences or cultural differences.

Educational Implications

In K-12 classrooms, most teachers hand out worksheets to help students practice (or rehearse) their new information. To improve students' encoding, teachers should look for ways to incorporate more senses. For example, when learning new vocabulary (such as in a foreign language) teachers could have the students act out the words. In higher education classrooms, the more modes of information an instructor can provide to students the better. If the classroom or course doesn't condone itself to a lab-like lesson or environment to allow students to actually experience the concept on their own, instructors could point the students in the direction of a good video tutorial on that day's lesson. The instructor could even make their own videos.

Making learning multi-modal. The more modes the teacher or the instructor have working at one time, the more likely learners are going to remember (e.g. the more senses used, the better). Humans, like computers, need to do something with new information so to store it in our brains so that we can recall it again later when needed. We need to create a similar pathway so we make sure our brain knows not to discard the newly learned information. This process is called encoding. A good example of encoding we are all familiar with is ROY G BIV. This acronym was created as a way to remember the colors on the color spectrum: Red, Orange, Yellow, Green, Blue, Indigo, and Violet. Additionally, the more times we practice pulling the information out, the easier and easier it becomes when needed. During encoding, a learner may watch, listen, repeat, recall, etc., it is very important to keep cognitive load in mind when trying to learn, recall, and remember new information. Cognitive load is a term concerning the manner in which cognitive resources are focused and used during learning and problem solving (Chandler & Sweller, 1991; Sweller, 1988, 1989). It is argued that cognitive load can be reduced for learners via instructional design. When designing and presenting information, teachers and the instructors are encouraged to consider learner activities that optimize intellectual performance. Overloading a learner with information and stimuli can have negative effects on task completion and comprehension. To help students effectively process information, the teacher or the instructor could use the following guidelines:

- Gain students' attention. Example: Gain attention before providing information, move around the room, voice fluctuations, etc.
- Ask students to recall prior relevant learning. Example: review of previous day's material.
- Point out important information. Example: information on the board, handouts, study guides, etc.
- Organizing information. Example: present information starting at simple and moving to more complex.
- Categorize related information. Example: Present information in a logical sequence and teach students to look for similarities and differences.
- Have students relate new information. Example: Connect new information with something that is already known.
- Teaching encoding for memorizing lists. Example: mnemonics and imagery.
- Repetition of learning. Example: Present information in many different ways and provide many ways for students to manipulate information.
- Overlearning. Example: Daily practice drills.
- Pay attention not to create cognitive overloading activities.

REFERENCES

Ariel, S. (1987). An information processing theory of family dysfunction. *Psychotherapy, 24,* 477-495.

Atkinson, R. C., & Shiffrin, R. M. (1971). *The control processes of short-term memory*. Institute for Mathematical Studies in the Social Sciences. Standford, CA: Stanford University.

Baddeley, A. D., & Hitch, G. (1974). Working memory. In G. H. Bower (Ed.), *The psychology of learning and motivation: Advances in research and theory* (Vol. 8, pp. 47-89). New York, NY: Academic Press.

Beck, A. T. (1975). *Cognitive therapy and the emotional disorders*. Madison, CT: International Universities Press, Inc.

Best, R. (1983). *We've all got scars: What boys and girls learn in elementary school*. Bloomington, IN: Indiana University Press.

Brown, H. D. (1987). *Principles of language teaching and learning* (2nd ed.). Englewood Cliffs, NY: Prentice-Hall.

Brown, H. D. (2000). *Principles of language learning and teaching*. White Plains, NY: Pearson Education.

Chandler, P., & Sweller, J. (1991). Cognitive load theory and the format of instruction. *Cognition & Instruction*, *8*, 293-240.

Goodwin, C. J. (2005). *A history of modern psychology*. Danvers, MA: John Wiley & Sons, Inc.

Hamamura, T., Meijer, Z., Heine, S. J., Kamaya, K., & Hori, I. (2009). Approach avoidance motivation and information processing: A cross-cultural analysis. *Personality and Social Psychology Bulletin*, *35*, 454-462.

Lachman, J. L., & Lachman, R. (1979). Theories of memory organization and human evolution. In C. R. Puff (Ed.), *Memory organization and structure.* New York, NY: Academic Press.

McLeod, S. A. (2009). Short term memory. Retrieved from www.simplypsychology.org/short-term-memory.html

Merriam-Webster. (2017). Long term memory. Retrieved from https://www.merriam-webster.com/dictionary/long-term%20memory

Miller, G. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. *The psychological review*, *63*, 81-97.

Miller, P. H. (2011). *Theories of developmental psychology*. New York, NY: Worth.

O'Malley, M., & Chamot, A. (1994). *The CALLA handbook: Reading*. Boston, MA: Addison-Wesley.

O'Malley, M., Chamot, A. U., Stewer-Manzanares, G., Russo, R. P., & Kupper, L. (1985). Learning strategy applications with students of English as a second language. *TESOL Quarterly*, *19*, 557-584.

Pavio, A. (1986). *Mental representations: A dual coding approach*. New York, NY: Oxford Press.

Rogers, P. R., Miller, A., & Judge, W. Q. (1999). Using information-processing theory to understand planning/performance relationships in the context of strategy. *Strategic Management Journal, 20,* 567-577.

Rubin, J. (1975). What the "good language learner" can teach us. *TESOL Quarterly*, *9*, 41-51.

Rubin, J., & Thompson, I. (1982). How to become a more successful language learner. Boston, MA: Heinle & Heinle.

Shaki, S., & Gevers, W. (2011). Cultural characteristics dissociate magnitude and ordinal information processing. *Journal of Cross-Cultural Psychology*, *42*, 639-650.

Stern, H. H. (1975). What can we learn from the good language learner? *The Canadian Modern Language Review*, *31*, 304-318.

Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive Science*, *12*, 257-285.

Sweller, J. (1989). Cognitive technology: Some procedures for facilitating learning and problem solving in mathematics and science. *Journal of Educational Psychology*, *81*, 457-466.

The human memory. (n.d.). Retrieved from http://www.human-memory.net/processes_encoding.html

ADDITIONAL READING

Credible Internet Sites

Can understanding information processing theory help student learning? (n.d.). Retrieved from http://www.etsu.edu/fsi/learning/infoprocessing.aspx

Hall, R. H. (n.d.). Information processing theory. Retrieved from http://web.mst.edu/~rhall/ed_psych/info.html

Huitt, W. (2003). The information processing approach to cognition. *Educational Psychology Interactive*. Valdosta, GA: Valdosta State University. Retrieved from http://www.edpsycinteractive.org/topics/cognition/infoproc.html

Information processing theory. (n.d.). Retrieved from http://psysc613.wikispaces.com/Information+Processing+Theory

Information processing theory. (n.d.). Retrieved from http://www.shsu.edu/aao004/documents/8_003.pdf

Lutz, S., & Huitt, W. (2003). Information processing and memory: Theory and applications. *Educational Psychology Interactive*, Valdosta, GA: Valdosta State University. Retrieved from http://www.edpsycinteractive.org/papers/infoproc.pdf

McLeod, S. A. (2008). Information processing. Retrieved from http://www.simplypsychology.org/information-processing.html

Orey, M. (2001). Information processing. In M. Orey (Ed.), *Emerging perspectives on learning, teaching, and technology*. Retrieved from http://epltt.coe.uga.edu/index.php?title=Information_processing

Slate, J. R., & Charlesworth, J. R. (n.d.). Information processing theory: Classroom applications. Retrieved from http://files.eric.ed.gov/fulltext/ED293792.pdf

Peer-Reviewed Articles

Ruiji, L. (2012). The development on multimedia teaching resources based on information processing theory. *International Journal of Advancements in Computing Technology*, *4*(2), 58-64.

Books in Dalton State College Library

Coolen, A. C. C., Kühn, R., & Sollich, P. (2005). Theory of neural information processing systems. Oxford, UK: Oxford University Press.

Lindsay, P. H., & Norman, D. A. (1972). Human information processing: An introduction to psychology. New York, NY: Academic Press.

Videos and Tutorials

Kahn Academy. (2013). Information processing model: Sensory, working, and long-term memory. Retrieved from https://www.youtube.com/watch?v=pMMRE4Q2FGk