Memory and Language

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Languages are crucial for acquiring and conveying information. In this report, how incoming linguistic information is recognized and maintained is investigated through a review of the research in the field of psychology. Research into language acquisition and comprehension often involves a common factor: memory. The retention of information and the mental representations structured in the process of text comprehension are the two major issues that have been discussed in past research. Two multi-store models of short-term working memory are first discussed to explain the commonality in the processing of verbal and written text. Then, the roles of short-term memory and long-term memory for retention of input are discussed. Finally, the kinds of mental representations used in the process of comprehension of text are described

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Memory and Language

Languages are crucial for acquiring new information and for conveying information. Investigating how we acquire and convey information through language is one of the main streams of research in psychology. Research in cognitive science has greatly contributed to elucidation of this matter. In the field of psychology, memory—that is, how and for how long human beings preserve the information—is the common perspective to be investigated. In other words, what kind of mental processes are involved in acquiring the information and how long one can retain the information are the two major issues. Languages are expressed in two forms: verbal and written. Recent research has pointed out that there is commonality in the processes of verbal and visual linguistic information (Baddeley, 1986, 2000; Baddeley, Lewis & Vallar, 1984; Baddeley, Thomson & Buchanan, 1975; Logie, 1995). Research also has pointed out that the way in which we process the information affects the duration of its retention (Atkinson & Shiffrin, 1971; Craik & Lockhart, 1972; Hyde & Jenkins, 1969; Miller, 1956; Murdock, 1967; Parkin, 1984; Santrock, 1988). Furthermore, understanding of both written and spoken text can be expressed in three different mental representations (Kintsch, 1994; Kintsch, Welsch, Schmalhofer, & Zimny, 1990).

However, few reviews of research that cover the fields mentioned above and follow the flow of information from the time of input and on through the process of structuring mental representations exist. Here, I sketch out the process of acquisition of both verbal and written linguistic information according to past research outcomes.

The Modal Model (Multi-store Model)

Cognitive psychological perspectives point out that there are three levels of processing involved in human memory: encoding, retention, and retrieval. Encoding is the process by which the input stored in sensory registers is changed into forms that can be processed internally for retention and retrieval. Retention refers to preservation of the information encoded in short-term memory (STM) or long-term memory (LTM). Retrieval refers to withdrawal of the information retained in STM or LTM.

Three types of memory are considered related to the processes of encoding, retention, and retrieval (Atkinson & Shiffrin, 1971; Craik & Lockhart, 1972; Murdock, 1967). Atkinson and Shiffrin (1971) developed the modal model, which assumed sensory registers, short-term store (STS), and long-term store (LTS) to explain how memory processes the incoming information. They distinguished the term *store* from *memory*, with the term *store* referring to storage of the information and the term *memory* referring to the information or stimuli to be stored. First of all, all kinds of stimuli are stored in sensory registers for a very short time. Visually presented stimuli are stored in iconic memory, which is one of the sensory registers. Auditory stimuli are stored in echoic memory, which is another type of sensory register. Unless attention is given to the information stored in sensory registers, all the information will be lost in a very short time. The iconic memory can keep the visual information for less than 1 s, and the echoic memory can keep auditory input for about 5s. Thus, only the information given attention in the sensory registers will be encoded and sent to STS for rehearsal to keep it in LTS or allow retrieval of information from LTS. This incoming information flow is shown in Figure 1.

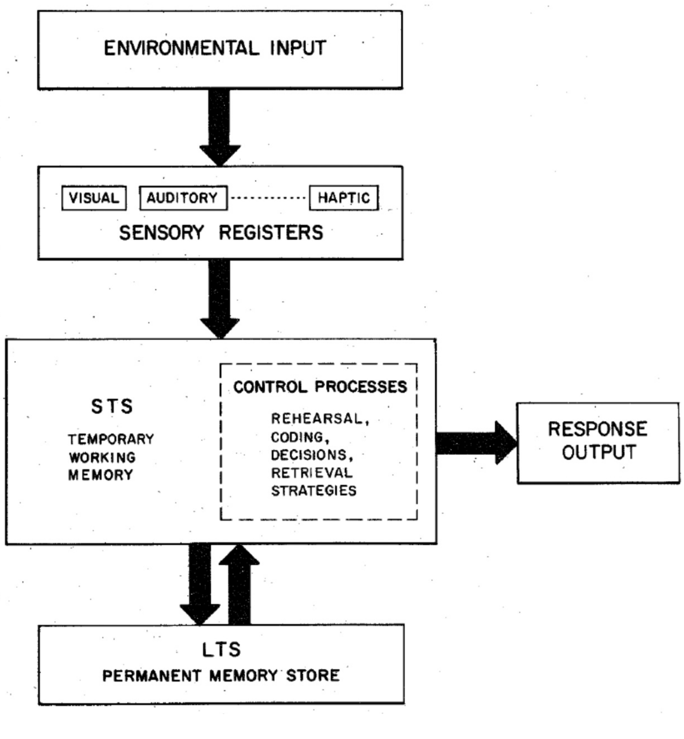

Figure 1. Information flow in the memory system (Adapted from Atkinson & Shiffrin, 1971)

Although STS has limited capacity for holding information at any one point in time, we can remember the information if we internally rehearse or repeat it. For example, we often repeat a telephone number to remember it until we write it down. Miller (1956) points out that humans can hold seven plus or minus two items in STS by rehearsal. He also argues that humans can store much information by chunking, in which we organize items into meaningful or manageable units consisting of seven plus or minus two. For example, consider the following words: hot, cold, car, stop, nut, meat, and dog. If we can store the words listed in STS, 24 letters could be involved. However, by chunking the 24 letters into seven words, we can easily store the information in STS.

As mentioned, Atkinson and Shiffrin (1971) tried to describe how STS processes the information in terms of the flow of information into and out of STS. One of the most important roles in STS is rehearsal, by which humans can preserve the information temporarily and send it to LTS. Atkinson and Shiffrin (1971)used free recall tasks to investigate the effects of rehearsals. The subjects were given a list of words to memorize and were asked to recall the list of words either immediately after the memorization sessions or following a delay. The first few words were usually recalled well in both immediate and delayed recalls. This is called the primacy effect. The last few words were also recalled well only if recalled immediately after the memorization sessions. This is called the recency effect.

The primacy effect is considered to be caused by the subjects' repetitions of the first few words much more frequently than the latter ones; this repetition imprints the information in LTS (Atkinson & Shiffrin, 1971). The recency effect is only detected if the subjects are asked to recall the list of words immediately after the recall sessions. However, the recency effect will disappear if the subjects are asked to recall the list after a period of time. This phenomenon indicates that the reason for the recency effect is that the subjects can hold the information for a short period of time in STS, but the information decays with time (Baddeley & Logie, 1999).

The three key concepts of the modal model by Atkinson and Shiffrin (1971) can be noted here. The first concept is that STS allows for temporal storage of information; the second is that the duration of preservation of information depends on frequency of rehearsals in STS. The more frequent the rehearsals in STS, the more chances that the information can be saved in LTM. The third point is that the modal model showed evidence that STM heavily relies on speech processing for storage of information (Baddeley, 1986, p.18). These three basic concepts of STS continue to impact human memory research.

The more advanced and modified modal model of Atkinson and Shiffrin (1971) is the model of working memory. The term *working memory* was coined in the field of information processing in computer science. Working memory in cognitive psychology refers to a limited capacity of temporal buffer that plays a role in the temporal storage of information, carrying out demanding cognitive tasks such as comprehension, learning, and reasoning (Baddeley, 2000; Baddeley & Hitch, 1974; Miller, 1956). Baddeley and Hitch (1974) tried to reconceptualize the modal model, especially focusing on STM. They assumed that STM plays a more active role in human cognitive activities.

The Multicomponent Model

The model of Baddeley (1986, 2000) is often called a multicomponent model. This model assumes that there is one controlling device called a central executive and three slave systems. One of the slave systems is called a visuospatial sketch pad. It processes visual and spatial images that cannot be textualized coming from the iconic memory for attention. The visuospatial sketch pad is supported by two slave systems: visual cache and inner scribe. Visual cache is considered to be a passive temporal store of visual and spatial images. Inner scribe is an active rehearsal component of visual and spatial images (Logie, 1995). The other slave system of the central executive is called a phonological loop, in which auditory input from echoic memory is processed. The phonological loop has a phonological STS, which preserves auditory input coming from the echoic memory by attention for a very short time. Baddeley (2000) recently added the third slave system called an episodic buffer. This component is assumed to be a limited-capacity temporary buffer from a variety of sources. This buffer is episodic because it plays an essential role in sending visual and spatial information into and retrieving information from episodic LTM according to commands from the central executive. Episodic LTM refers to the knowledge that consists of incidents that happened in a certain place at a certain time (Tulving, 1972). It is considered to be part of the LTM . The role of the central executive is to allot limited cognitive resources in working memory to the slave systems and control the flow of information in working memory (Figure 2).

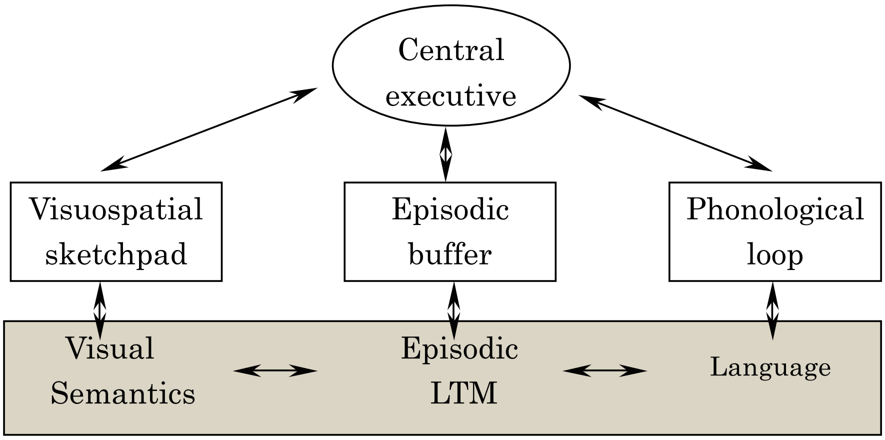

Figure 2. The multicomponent working memory model (Adapted from Baddeley, 2000)

Commonality in Processing Visual and Auditory Linguistic Information

Commonality in processing visual and auditory linguistic information can be noted in the process of encoding both visual and auditory input in the phonological loop. Both visual input and verbal input are considered to be subvocalized in the phonological loop to be encoded or retained. The dual-task method is usually used to investigate the commonality in the processing of both visual and auditory input of linguistic information (e.g., Baddeley et al., 1975; Baddeley et al., 1984). In the dual-task method, subjects are asked to perform two tasks: the primary and the secondary task. Cognitive resources are limited in working memory, so when two tasks are carried out simultaneously, the primary and the secondary tasks have to share the same cognitive resources. When cognitive resources necessary for the primary and the secondary tasks are available, performance in the primary and the secondary task is affected (Baddeley, 1986, p.36). By comparing the outcome of the dual tasks and the outcome of the single task of either the primary or the secondary task, we can evaluate how resources are shared between the primary and the secondary task. Articulatory suppression is usually used as the secondary task when investigating the roles of articulatory loop. Articulatory suppression is a task in which the participants repeat nonwords or count numbers (e.g., one, two, three, four, five) verbally while engaging in the primary task. This task is considered to prevent the participants from rehearsing the words to remember in the phonological loop.

The Phonological Similarity Effect

When given a recall task of phonologically similar words (e.g., bat, pat, mat), subjects find it harder to recall them accurately than those that are dissimilar (e.g., pen, hug, dip) no matter how the words are presented verbally or visually (Baddeley, 1986; Conrad & Hull, 1964). This phenomenon is called a phonological similarity effect. This effect has also been investigated by means of the dual-task method. While the participants engage in remembering a list of words that consists of phonologically similar words as the primary task, the participants are asked to repeat verbally sequential numbers from 1 to 10 as the secondary task. By repeating the sequential numbers, the participants' encoding of the visually presented words in phonological loop is affected, which leads to the disappearance of the phonological similarity effect. However, if the dual task is given by using auditory input, the effect does not disappear. This finding provides evidence that not only verbal information but also visual linguistic information is phonologically encoded in the phonological loop.

The Word-length Effect

People usually recall a sequence of short words (e.g., stop, sun, drug) more easily than a sequence of long words (e.g. unfriendly, university, alternatively). This finding is because it takes more time for long words to encode in a phonological loop than it does for short words. The capacity of the articulatory loop is limited, and the more time we require for rehearsals, the less information we can hold in the articulatory loop. This effect will disappear if articulatory suppression is conducted while materials are presented both visually and verbally (Baddeley et al., 1975; Baddeley et al., 1984).

As clearly shown, there is a possibility that visual and verbal language information is encoded as internally vocalized in the articulatory loop. Logie (1995) describes both visual and verbal linguistic information encoded in the articulatory loop in a diagram shown in

Figure 3. A diagram of phonological loop (Adapted from Logie, 1995)

Figure 3. Therefore, both visual information and verbal linguistic information are internally vocalized in the phonological loop to retain or retrieve information from LTM. Clearly, this process is the commonality in visual and verbal linguistic information. Now I will discuss how the encoded or subvocalized information in the phonological loop is further processed.

Expansion of Span in Phonological Loop

Although Miller (1956) pointed out that the capacity of phonological STS is 7 to 12 items, research has shown that the capacity expands under certain conditions. For example, in immediate serial-recall tasks, twice as many words can be recalled if words are put in an order that forms a meaningful sentence (Brenner, 1940). Also, Jefferies, Ralph, & Baddeley (2004) pointed out that LTM plays a crucial role in expansion of span in the phonological loop.

Their research has pointed out that different levels of lexical knowledge in LTM may contribute to expansion of the span in phonological loop (Jefferies et al., 2004). They assumed three different levels in lexical knowledge; sublexical, lexical, and superlexical. At the sublexical level, the nonwords that consist of sequences of phonemes that often occur in real words are recalled more accurately than the nonwords that are less likely (Gathercole, Frankish, Pickering, & Peaker, 1999, cited in Jefferies et al., 2004). At the lexical level, the lists of real words are recalled better than the list of nonwords (Hulme, Maughan, & Brown, 1991, cited in Jefferies et al., 2004). Also, span is expanded if the lists consist of words that can be easily imaged versus words that cannot be easily imaged (Bourassa & Besner, 1994, cited in Jefferies et al., 2004). Concrete words are better than abstract words (Walker & Hulme, 1999, cited in Jefferies et al., 2004). The similarity in semantic relationships between words is also influential in recall (Baddeley & Levy, 1971). Moreover, if the overall theme in prose or in a passage is given before recall tasks, recall improves (Ausubel, 1977; Bransford & Johnson, 1972). Accordingly, various lexical knowledge in LTM may be concerned in the expansion of the span in phonological loop; this phenomenon may explain the relation between phonological loop and LTM.

Relations Between LTM and STM in Immediate Serial Recall Tasks

In regard to how LTM supports expansion of span in the phonological loop, the common assumption is that the span is expanded with sentence recall because the syntactic and semantic information from LTM increases the predictability of words in a sentence (Jefferies et al., 2004). The process of information retrieval from LTM to support the phonological loop has been investigated by Jefferies et al. (2004), and their findings suggest the sentence recall process requires both attentional and automatic processes of retrieval of information when the information is beyond the capacity of the phonological loop.

The Role of the Episodic Buffer

The initial working memory model developed by Baddeley and Hitch (1974) assumed the articulatory loop works independently from LTM. However, recent studies have pointed out that STM plays crucial roles in learning long-term phonological representations of new words (Baddeley, Gathercole, & Papagno, 1998; Baddeley, Papagno, & Vallar, 1988; Gathercole & Baddeley, 1989, 1990). Immediate recall is better for a sentence than for word lists that don't have any connections in between. This effect is called the sentence superiority effect and appears in both visually or verbally presented materials, although in the case of visual input, the effect is inferior to the case of auditory input because the visual input has to be encoded before chunking (Baddeley, Hitch, & Allen, 2009). Immediate serial recall is better if the task is given as sentences than as word lists because the STM span expands when the information coming into the STM can be recoded into higher chunks according to the prior knowledge in LTM (Miller, 1956; Miller, Bruner & Postman, 1954; Tulving & Patkau, 1962).

Then the following question arises: Where can the information that exceeds the limited capacity of the phonological loop be held in working memory? Baddeley (2000) assumed that the episodic buffer stores chunks that can be retrieved by attention. The episodic buffer, which is newly added to the multicomponent model as the fourth slave system under the central executive, may possibly play a role in binding information in the phonological loop and previously acquired knowledge in LTM to expand the span in STM. They assumed that the episodic buffer is a limited capacity of store attentionally controlled by the central executive and that it plays two roles: storage and manipulation of information.

Baddeley et al. (2009) assumed that the sentence superiority effect would disappear or be reduced by the combination of the primary recall task and the secondary tasks that disrupt working memory if the episodic buffer controlled by the central executive plays roles for holding and binding information from LTM, which exceeds the capacity of the phonological loop. However, to perform these investigations, it was necessary to develop an instrument that could measure the effect. Thus, they created a new paradigm called constrained sentence pattern. They point out that the variable contribution from semantic memory should be controlled to reduce the involvement of memory for gist and to increase the demand on working memory. To make this concrete, they created primary recall tasks based on the same vocabularies for both sentences and word lists in different orders but the same length and emphasized the order of the words during immediate recalls. They used this paradigm as the primary recall task, combining articulatory suppression, the visuospatial continuous reaction time task developed by Craik, Govoni, Naveh-Benjamin, and Anderson (1996), and both as the secondary task to disrupt working memory. Baddeley et al. (2009) conducted a series of four experiments. However, the sentence superiority effect was intact under all three secondary tasks to disrupt working memory. Therefore, how we chunk the information and how we bind the information from LTM is still unknown, although we know that STM plays a role in chunking, holding, and binding information from LTM.

So far, I have discussed how auditory and visual linguistic input can be processed in terms of retention of information. Both verbally and visually presented inputs are held in sensory registers and then sent to the phonological loop to be rehearsed for encoding, which will commit the information to LTM and bind the information from LTM. The phonological loop is of limited capacity for holding information, but by chunking the span of the phonological loop, the capacity can be extended. For the information to be retained longer, it must be sent to LTM. However, how we chunk the information and bind the information from LTM are still unknown.

How LTM Contributes to Comprehension of Text

Although STM has a limited capacity for holding information, LTM is considered to have unlimited capacity (Craik & Lockhart, 1972). LTM consists of two kinds of knowledge: procedural knowledge and declarative knowledge. Declarative knowledge is the knowledge that we can easily express by words, such as "an apple is red." However, procedural knowledge is often difficult to express by words. For example, we can ride a bike, but it is very difficult to explain in words how we ride a bike. Also, declarative knowledge can often be acquired by means of words, but procedural knowledge cannot be acquired by using words and often requires repeated practice to acquire (Mori & Chujo, 2005).

Moreover, declarative knowledge consists of semantic memory and episodic memory (Tulving, 1972). Semantic memory refers to our general knowledge about the world. It includes the knowledge we acquire at school through experiences. Knowing that a red signal means to stop or that an airplane flies in the air is semantic memory. On the other hand, episodic memory refers to knowledge associated with an episode. For example, "We had beef steak for dinner last night" or "I was given a teddy bear for a Christmas present ten years ago." Episodic memory consists of incidents that happened in a certain place at a certain time.

So far, I have discussed the fact that LTM consists of two kinds of knowledge: procedural knowledge and declarative knowledge. Declarative knowledge can be distinguished into semantic memory and episodic memory. Semantic memory refers to knowledge about the world and episodic memory refers to knowledge based on each person's experiences. The information stored in LTM is referred to as one's prior knowledge or background knowledge. Now we know what kind of knowledge is stored in LTM, but a question arises: How can the knowledge be added to LTM, and are there any levels of processing? From our experiences, we can see that some incidents or facts can be recalled more easily than others.

The Role of Background Knowledge in Improving Memory

Craik and Lockhart (1972) developed levels of processing views, suggesting that memory is on a continuum: some information needs to be processed deeply and other information requires shallow processing. According to this view, there are three levels of processing—shallow processing, intermediate processing, and deep processing. Shallow processing detects physical and perceptual features such as lines, angles, or the sounds of a word. At the intermediate level, we can recognize what the stimulus is and can label the object. At the deepest processing level, information is processed semantically. A number of researchers argue that this semantic association, in which the information given is associated with the prior knowledge, can improve memory (Hyde & Jenkins, 1969; Parkin, 1984; Santrock, 1988).

Bransford and Johnson (1972) conducted a series of experiments to investigate whether association of background knowledge with new incoming information improves memory. They came up with a passage that described the process of doing laundry in which no key words for it were used. They set up three different groups: one group was given no topic throughout the task; another group was given the topic right after acquisition of the passage; and the third group was given the topic of the passage to recall prior to the acquisition of the task. The passage was given as an auditory task to all three groups, and they were asked to recall the story as accurately as possible. Then the researchers compared the recall rates of the three groups and found that the group given the topic prior to the task had the highest recall rates. They concluded that the background information helped improve the memory of the incoming information. As discussed, to process incoming information deeper and retain it longer, it is necessary to associate the incoming information with the knowledge that exists in individuals; as Craik and Lockhart (1972) suggest, semantic association is necessary to retain the information longer.

I have discussed what kind of mental process is necessary to retain the visual or verbal information longer. However, retention and comprehension of text are different process Comprehension involves analysis and interpretation of the text while associating it with existing background knowledge. In other words, comprehension of text is completed when individuals can use the information of the text in a different context (Bartlett, 1932; Kintsch, 1994).

Text Comprehension

Bartlett (1932) studied how people remembered stories and found that they left out parts, added information not mentioned in the original stories, and even reconstructed the plots to match their contexts. This idea was formalized as schema theory, which insists on the importance of the role of individual background knowledge in the complete understanding of the text (Bartlett, 1932; Rumelhart, 1980; Rumelhart & Ortony, 1977). According to this theory, a visual or verbal text can only guide the readers or the listeners to which information should be retrieved or matched with background knowledge to comprehend a text. According to Rumelhart (1980), the comprehension of visually or verbally presented input requires both the linguistic knowledge of input and access to one's background knowledge at the same time.

The following question arises: What is comprehension of text? When can we say that we have achieved comprehension of text? Comprehension of text always involves construction of coherent representation integrated with one's prior knowledge according to the information described in the text (Bever, Lackner, & Kirk, 1969; Blumenthal & Boakes, 1967; Kintsch, 1994; Perfetti, 1969; Rohrman, 1968; Sachs, 1967; Zwaan & Radvansky, 1998). Success in memory means such a representation can be retrieved from memory (Zwaan & Radvansky, 1998). In other words, reconstruction of a representation that already exists in the individual is necessary to create a coherent representation along with the text. That is, readers or listeners are considered as active information processors. Kintsch (1993) also points out that the goal of comprehension of text is to create such a coherent mental representation that the individual can use the information acquired from the text in a different context. Kintsch (1986, 1994) defines this as learning from text.

However, comprehending a text involves different levels of understanding, ranging from mostly superficial to deep understanding (Kintsch, 1994). Van Dijk and Kintsch (1983) point out that comprehension of text can be distinguished into three levels. Comprehension always involves encoding incoming information, during which the individual will be required to hold the text as it is. This level is called surface form. However, because working memory has limited capacity for preserving information, the information should be chunked and preserved according to the semantic and lexical information stored in LTM. This level is called textbase, in which the individual does not hold the accurate lexical structure or the text itself but preserves only propositions of a text. Propositions include situation, facts, and actions, which have truth values. A proposition consists of one predicate and at least one argument. Arguments include adjectives, adverbs, and conjunctions, which represent concepts. A predicate represents its central meaning of a sentence. Some parts of surface structure such as tense, voice, or function words will not be preserved (Kawasaki, 2005). Textbase structure has network structures and has two levels. One is called microstructure. Because a text consists of not one but several propositions, readers or listeners have to integrate or relate each proposition described in a text. Microstructure is a network of propositions and arguments that are formed according to the text. The other level is macrostructure, which is considered a network of microstructures. The highest level of macrostructure represents the gist of the text. Textbase provides information based only on the text and not integrated with one's prior knowledge. For complete comprehension of a text, textbase has to be elaborated and integrated with one's prior knowledge; this occurrence results in a situation model. At this level, the individual has a clear image of what is described in a text. The situation model is considered a mental representation independent from modality so that the information can be transferred among modalities. Zwaan and Radvansky (1998) and van Dijk and Kintsch (1983) point out several reasons for the necessity of the situation model. Textbase only represents linguistic aspects of representations; the similarity in comprehension across modality cannot be explained. However, we are often required to integrate visual or verbal linguistic information with the information in different modalities such as visual aids. Moreover, translation cannot be explained if we do not assume higher mental representation. Translation of a text not only involves translating each word but also often requires cultural background knowledge that falls beyond the lexical information used to make sense of the translation. Furthermore, the individual can reconstruct the story even if the sentences are presented in a different order.

Kintsch et al. (1990) pointed out that these three levels of mental representations could be distinguished by means of duration of retention of memory. Surface structure forms decayed quickly and totally disappeared in 4 days. Situation models did not disappear at all in 4 days. Textbase decayed but stayed in the middle between surface structure and situation model.

To sum up, I have described the way comprehension of a text can be described in three levels: surface structure, textbase, and situation model. To complete and preserve the information described in a text for a longer time, a situation model, which is the integration of incoming information with the individual's background knowledge, is necessary.

Conclusion

The present paper sketches out the flow of information in the processing of both verbal and written text according to past research outcomes. Information coming in from different modes is stored in different sensory registers. Only the information that receives attention goes to short-term working memory and is encoded in the phonological loop for retention and retrieval. The length of retention of encoded information depends on frequency of rehearsals and the way it is encoded. The information embedded by one's background knowledge, which already exists in LTM, is retained longer. Three different mental representations are structured according to the depth of process for comprehension of text. Surface structure is the shallow level of representation, in which the information is accurately remembered as it is presented. Because this level comes before the semantic process, the duration of retention is not long. The next step is textbase, in which the syntactic and semantic process is completed and has only propositions and arguments; however, it is not embedded by one's background knowledge. The deepest level is the situation model, in which the information is embedded by one's background knowledge and is multimodal.

The research reviewed for this paper is based on research of English as the first language. Different languages might follow different processes. It has been reported that in regard to the commonality of verbal and written text in the process of encoding, there are no differences between the languages (Kadota, 1987; Suzuki & Okuno, 2006). However, structured mental representations, such as the situation model in the process of comprehension of text, might require extra efforts for a person speaking a second language (van Dijk & Kintsch, 1983; Zwaan & Radvansky, 1998).

Here, only processing of the flow of incoming information is described. We know that the phonological loop in working memory plays a crucial role in encoding both verbal and written texts. Also, one's background knowledge plays an important role in maintaining the information. However, these facts are not directly related to the way one improves learning. In other words, how we learn the new information and apply it in different contexts is not mentioned in this paper. The next step should be to determine how we acquire the new information and apply it in different contexts and what that brings to the level of comprehension of texts.

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