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Second-Language Use, Theories of Working Memory, and the Vennian Mind

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The parts of the title of this essay also are the headings of its three sections. In turn, they consider what second-language use may be like, how theories of working memory might be of importance in understanding second-language use, and how the structures of the existing theories may need to be broadened further to accommodate all of the important concepts in second-language use. My expertise is not in second-language use so readers may have to cut me some slack to accept, for the sake of argument, my examples in that domain.

Second-Language Use

Imagine yourself in a rather dire circumstance in the ancient world. In your home territory, a ferocious dispute has taken place and you find yourself a wandering refugee. You and your family arrive at a territory in which you are treated passably well, but with a great deal of suspicion regarding your intentions. You have had very little prior contact with the language spoken in your new refuge, and you are trying to learn the words that you urgently need to get food and shelter and put your new hosts at ease. Suddenly, your spouse and children are no longer just responsibilities to you in your troubled journey; they are assets, in that they might notice language meanings that you have overlooked. You must be careful, though. If you miss a critical meaning, your family might miss the opportunity to have warm shelter that night. If you think you have heard that you are invited to sit down but a certain word is not exactly what you thought, you might seriously offend your hosts. Slight subtleties of meaning may make a big practical difference, as in the difference between *come* and *go*. Slight sounds may matter, as in the difference between *folk* and *foe*. Idiomatic expressions might concern you; the expression *we don’t mind* means *we think that it is all right*, but a foreign visitor might take it to mean *we don’t pay attention* (with reference to the human *mind*). With the wrong turn of a phrase, you might accidentally insult one of their deities. (If one translates *it is raining* into a certain other language literally, might one imply that the deity is an *it* rather than a *he* or *she*, and would that be insulting?) You use everything at your disposal to try to interpret the language or give it an educated guess; tones of voice, facial expressions, gestures, and the situational context.

It is easy to understand that under such a circumstance as the acquisition or use of a second language, certain properties and limitations of the human mind are critically important for success. Key among these properties and limitations are the characteristics of human working memory, the faculty that retains a small number of things at a time and allows us to work with them mentally. What sets language apart from other forms of communication is the arbitrary relations between symbols – in the form of words – and the meanings symbolized. These arbitrary relations allow a great many meanings to be expressed in symbolic form by combining the symbols in new ways. We can eventually learn many of the mappings between language and meaning but the new ones are difficult to keep in mind for long; the mind is overwhelmed with new information to learn. The capacity of working memory will determine how complex can be the learned information. For example, in order to understand the meaning of the word *tiger*, one must grasp that it is a big cat with stripes. Lose any part of that definition and a different animal could fit the bill (e.g., a small cat with stripes, a zebra, or a lion). This sort of mistake often happens in young children, and it may be that their small working memories compared to adults are one reason.

Theories of Working Memory

The term working memory was used by Miller, Galanter, and Pribram (1960) to describe memory for plans one hoped to carry out, and the small goals that had to be met along the way to an ultimate goal. Such plans could easily include those of language. In a running fashion, people plan ahead when formulating sentences, and then fill in the words at a later point and the phonemes within those words still later, just before actually speaking them. That process is clear, for example, in a corpus of speech transposition errors that show longer-distance swaps in the case of higher-level units (Fromkin, 1973). Any of the phases of planning can be affected by the novelties of a new language that are discrepant from one's first language.

Working memory, of course, also must come into play during language comprehension, when the words presented by mid-sentence may not add up to a sensible thought until words coming later clarify them. This is all the more important when one does not understand some of the words and must rely on the total context more heavily to help guide understanding, or an educated guess at understanding. In the sense of Miller et al. (1960), one must plan to construct a meaningful interpretation of the sentence, ruling out other possible meanings, or possibly keeping in mind more than one possible meaning until the situation makes clear which one was actually meant.

Miller et al. (1960) provided only an intuitive sketch of the idea of working memory, though. Does the actual theory of working memory make a difference for an understanding of second-language acquisition and processing? I believe it does, for reasons that I will explain.

The idea of something like working memory as a storage buffer was prevalent throughout the early phase of cognitive psychology, including well-known works, especially a book titled *Communication and Perception* by Broadbent (1958), moving away from behaviorism and toward a cognitive approach; and then a book chapter by Atkinson and Shiffrin (1968), emphasizing the importance of modeling processes that controlled the flow of information into and out of working memory. This view of a unified working memory changed with the seminal chapter by Baddeley and Hitch (1974), which preserved the central store but noted that there also appeared to be two dissociable, auxiliary storage units. These were specific on one hand to phonological information (later called the phonological loop, a reference to the importance of covert verbal rehearsal of the phonological information) and on the other hand to visual, spatial information (the visuospatial sketchpad). All of the components operating together as a system were collectively termed working memory.

Perhaps the most important type of evidence for this multi-component system of Baddeley and Hitch (1974) was that phonological inputs interfered heavily with other phonological information in working memory but interfered much less with nonverbal, visual or spatial information in working memory, and vice versa. That is, interference patterns were pretty domain-specific, which seemed to indicate separate stores for the different kinds of information. For the sake of parsimony, Baddeley (1986) thought he could use only these two peripheral storage buffers, with the additional catch-all, general-purpose central storage component mentioned in passing by Baddeley and Hitch was now omitted for the sake of parsimony. An attention-related, central executive component to carry out processing was now conceived as being devoid of actual storage. Baddeley (2000) however, found the model unable to explain some types of memory (for example, memory for the association or binding between a verbal item and a spatial location; memory for semantic units or syntactic structures). He therefore added the episodic buffer to cover such cases. It has yet to be rigorously described but is the topic of considerable ongoing research. The seeds of the episodic buffer, however, appear to be present in the central storage component mentioned by Baddeley and Hitch, and in the earlier unified approaches to working memory.

We have already seen in my language examples that second-language use must involve the coordination of many kinds of information. The language user may have to interpret orthography and spatial or visual context, as well as semantic and pragmatic context, in addition to phonological information. Consequently, from a multi-storage viewpoint, all of the storage buffers are likely to get a workout during the acquisition and processing of a second language.

One can do quite well in discussing language processing with this model but a lot may rest on getting beyond a naïve interpretation of the model. In the naïve interpretation, each stimulus goes to a certain buffer. If the stimulus has phonological value it goes to phonological storage, if it has visual-spatial value it goes to the sketchpad, and if it somehow does not fit these categories it goes to the episodic buffer. That kind of interpretation has been the subject of jokes; it is like a lampoon parody I once read about how one's body is nourished when one eats a cheeseburger (the slice of cheese goes to the right arm, the top of the bun to the right leg, the meat to the head, and so on). The problem with the simplistic interpretation of the multi-modal working memory model is that the stimulus does not know where it should go, and it is unclear what mechanism would direct it to the right store. Instead, it seems more likely that a stimulus activates multiple features at the same time. A printed word can activate orthographic, phonological, and semantic features and, in fact, focusing attention on the latter, deeper features is better for long-term remembering than focusing on features close to the surface of the stimulus (Craik & Tulving, 1975). The different features allow different types of language processing to take place.

The phonological representation is presumably of special use for rote rehearsal, which may be a good way to remember or repeat new sequences of phonological material, such as ordered lists of words (as in a phrase that one doesn't completely understand), or ordered sequences of syllables (as in a new word that one is just learning). The key importance of a phonological representation for word learning is well-established (Baddeley, Gathercole, & Papagno, 1998). However, if one can hold in mind semantic and visual information concurrently, that should be quite advantageous for the interpretation of language in real time.

One might remember the sound of a word in a foreign language, a few recent visual events that may be candidates for the meaning of this new word, and the context in terms of the meaning of the interaction taking place (e.g., commerce, romance, education, conflict, etc.). All of this information along with long-term knowledge that has been built up could lead to a new fusion; the fusion may be a new hypothesis about the meaning of this word, which is then stored in long-term memory.

The theoretical framework of Cowan (1988, 1999) is often viewed as a unitary framework that is devoid of the modules of Baddeley and Hitch (1974) or Baddeley (2000). That was not exactly the intent. Cowan just considered that the Baddeley and Hitch model was tailored to the types of stimuli that they used in their experiments, and taken by the rest of the world as a general model of how the human mind operates with respect to working memory. It seems unlikely that it can be taken as so general. There was an emphasis in the model on the classic finding (Conrad, 1964) that confusions between printed letters in working memory are primarily acoustic rather than visual in nature; the most common confusions between English letters are between consonants with names that rhyme (e.g., between *B, C, D, G, P, T, V, Z* except when *Z* is pronounced “zed”). Although this is a profound finding that shows the importance of an internal phonological code, there were later findings of visual confusions between letters in working memory, as well (Logie, Della Sala, Wynn, & Baddeley, 2000). Moreover, there are sensory features that are activated in addition to phonological ones; memory for the end of a verbal list is typically superior with acoustic as compared to written presentation (for a review see Penney, 1989). There are modalities that have not been included in the Baddeley model, such as tactile, olfactory, and gustatory stimuli, and muscle senses. It is difficult for all of these stimuli and feature types to be stuffed into the several stores in the multistore model.

What Cowan (1988, 1999) assumed instead is that a stimulus activates many kinds of features in long-term memory. Subsequent stimuli with some similar features may interfere with memory for those features in the previous stimuli. (That assumption can account for dissociations between types of memoranda and different types of interference effects.) For example, if the word *horse* is followed by the picture of a cat, there will be some interference with the semantic features of the horse but very little interference with the phonological or orthographic features. If the word *laugh* is followed by *ghost*, there may be orthographic interference because of the *gh* appearing in two different contexts (with completely different pronunciations). If *root* is followed by *route*, the interference is with phonological features, making rote verbal rehearsal risky as the meaning might not be preserved, unless there is a separate effort to remember the meaning specifically.

Instead of concluding that the many different types of features each have their own modules, Cowan (1988, 1999) assumed that the features all reflect temporary activation of long-term memory information. There is clearly a structure to the brain that implies that different kinds of stimuli activate different brain patterns. Nevertheless, the taxonomy of this activation was taken to be complex and not yet fully known, so any subdivisions into specific modules were not marked in the model by Cowan, at least for the time being.

Cowan (1988, 1999) also reserved a special role for attention in the model. A subset of the information in the activated part of long-term memory is in the focus of attention, and even the part of activation outside of the focus of attention is considered part of working memory. Historically, the activated portion of long-term memory and the focus of attention are reminiscent of the concepts of Hebb (1949) and James (1890), respectively, and something like this whole ensemble can be found, I am told, in the previous German writings of Wilhelm Wundt.

A considerable variety of studies limits the information in the focus of attention to about 3 to 5 meaningful items in normal adults (Cowan, 2001). People are assumed to be able to think about these items consciously and combine them to form new concepts. That is not necessarily true of the information that is in working memory but outside of the focus of attention. It can be fragmentary, consisting of bundles of features that can be brought into focus for further consideration, maybe a few at a time, but these activated features do not necessarily form a meaningful pattern all together.

In language learning, a key issue I see is whether the focus of attention plays a special role in combining diverse sources of information to arrive at new composites (e.g., a new word connected to its meaning in the focus of attention). This might correspond to the function of the episodic buffer in the model of Baddeley (2000) though the jury may still be out, in his view, as to how the episodic buffer relates to attention (for recent work see Allen, Hitch, Mate, & Baddeley, 2012).

A key difference between the two different theories of working memory is in the prediction about how much of a tradeoff there will be between verbal information and nonverbal visual information when both have to be retained at the same time. The tradeoff presumably comes from the use of the focus of attention to hold information about either type of stimulus, with the capacity limit applying across both types. The limit should be especially notable when there is a mask to prevent sensory information from being used as an auxiliary store and when there are precautions to prevent covert verbal rehearsal from being used. Saults and Cowan (2007) presented verbal stimuli as concurrent spatial arrays in different voices, making the voices difficult to rehearse. They found a considerable tradeoff between memory for voice-digit pairing, on one hand, and color-location pairing, on the other hand (see also Morey, Cowan, Morey, & Rouder, 2011).

For language learning, one implication of this tradeoff in working memory is that keeping in mind several verbal items at once and several visual items concurrently might create conflict. To learn and use language effectively, that conflict has to be managed by limiting the focus of attention. Either a teacher has to help the learner by limiting the amount of multimodal information to be integrated, or the student or learner has to learn to manage the information ideally on his or her own (e.g., when learning word referents, perhaps by adopting a strategy that involves concentrating on one spoken word at a time and trying to match it to several potential referents sequentially). For further discussion see Cowan (2013, 2014).

There is now neuroimaging evidence supporting the existence of brain regions that support a focus of attention that includes several items at once. Cowan, Li et al. (2011) found activity in the left intraparietal sulcus that increased as a function of the number of items to be held in working memory, no matter whether those items were spoken letters, colored squares, or some combination of the two. This area had previously been shown to be activated in attention tasks even when working memory was not involved, and to respond to increasing visual working memory loads in a manner mirroring capacity according to behavioral results.

Lewis-Peacock, Drysdale, Oberauer, and Postle (2012) showed that there is also brain activity specific to the item or items being used in the focus of attention. In one experiment they used multivoxel pattern analysis to identify patterns corresponding to three different categories: words for which a synonym judgment was required, pseudowords for which a rhyme judgment was required, and line segments for which a spatial orientation judgment was required. Then these items were used in a same-different task with two cues in succession, to yield some interesting information about what is active in working memory. For example, at the beginning of a trial, a word might be presented along with line segments. The first cue might indicate that the first test would be on a word. Then a word would be presented and the required response would be to indicate whether it is the same as the originally-presented word. The second cue could indicate that what was coming next was another word, or a line segment. When the latter was the case, the results were especially interesting. The multivoxel pattern activity for the first-tested category was high after the first cue, and then was reduced after a second cue when it involved a switch to the other category. More interestingly, the pattern activity for the second-tested category suddenly rose after the second cue. That is to say, when the item to be tested second (the line segment in the example) was in the activated part of long-term memory and therefore was still retrievable, there was no multivoxel pattern activity for it; but when the cue indicated that it would now be tested, the multivoxel pattern activity rose. This activity thus indicates that an item is in the focus of attention. Perhaps what Cowan (1988) called activated long-term memory outside of the focus of attention is preserved through an ionic balance in the brain that is not reflected by available MRI techniques; observable activation seems to reflect the information in the focus of attention. When two items are being used at the same time, the multivoxel pattern activity for both of them can be seen concurrently, indicating that the focus of attention can hold more than one item at a time.

The multivoxel pattern activity for the items appears not in the intraparietal sulcus, but in posterior visual regions. The warranted conclusion appears to be that the sensory processing regions represent the actual information, whereas the focus of attention holds pointers to a limited number of items represented in the activated portion of long-term memory. The frontal-parietal regions do show multivoxel pattern activity reflecting not the stimulus types, but the task instructions (Riggall & Postle, 2012).

What is the special significance of the focus of attention, as compared to the information represented in working memory outside of that focus? I believe that the focus of attention may be the workshop whereby new concepts are formed, by linking together information that is currently in focus to form new information. An example is the co-existence of *big+striped +cat* in the focus of attention, to form the folk concept of a tiger. Halford, Cowan, and Andrews (2007) suggested that the childhood development of cognition involves the increasing amount of complexity that can be understood as the number of items that can be cross-tabulated in a limited-capacity working memory increases.

There is little direct evidence that this cross-tabulation must occur in the focus of attention, but Cowan, Donnell, and Saults (2013) made a start toward that end. Participants received lists of 3, 6, or 9 items at once and were to indicate which item in the list was "most interesting." Later, there was a surprise test on whether pairs of words came from nearby serial positions in the same list, or from nearby serial positions in different lists. Presumably, nearby items from the same list would have co-existed in the focus of attention much more often for lists of 3 items (within the presumed capacity of the focus of attention) and less often for longer lists of 6 or 9 items. Performance on the surprise associative memory task was much better for lists of 3 items than for lists of 6 or 9 items, which were both not much better than chance. So it may be, as Cowan (1999) suggested, that the linking together of elements to form new concepts must take place in the focus of attention.

In short, the model of Cowan (1988, 1999, 2001) has borrowed much from the previous model of Baddeley and Hitch (1974) but has placed more emphasis on the diversity of inputs that must be handled (a point with which seems in agreement with Baddeley, 2000), and more emphasis on the role of the focus of attention in storing and recombining information.

How can humans conquer complex languages using such a minimal system, one that can only hold several items at once in the focus of attention while rehearsing a few more items outside of the focus and adding in just a little more potentially relevant visual and semantic information, in case it's needed? The key to that question was addressed by Miller (1956) in his classic article, and has been brought up again in more recent work (e.g., Cowan, Rouder, Blume, & Saults, 2012). The answer is in the use of long-term memory to form new chunks. The capacity limit is in chunks, not items. Thus, if one is presented with the series of letters FBICIAIRS to be remembered, one may recognize the 3-letter acronyms for three U.S. agencies, FBI, CIA, and IRS, simplifying the task from 9 letter chunks down to 3 acronym chunks. This simplification presumably occurs in many ways during language acquisition and comprehension.

One builds a unified semantic structure as one listens to language and is forced to throw away much of the verbatim information because working memory cannot hold it (Jarvella, 1970; Fedorenko, Gibson, and Rohde, 2007), or one interprets a sentence in a manner that includes shorter separate parts until the whole thing can be integrated (Swets, Desmet, Hambrick, & Ferreira, 2007). In some cases, people even tend to ignore the confining details of syntax and often just retain semantic gist elements that arise (Ferreira, Bailey, & Ferraro, 2002). For example, one may encounter the sentence, *While Stuart dressed the baby played* and retain from that sentence the propositions that (1) Stuart dressed the baby and (2) the baby played, even though there is no grammatically correct reading of the sentence that allows both of those two propositions. (Stuart had to have dressed himself, not the baby.) So in the real world, there does not seem to be a syntactic module that is used in a way that isolates it from concerns of a general working memory, as Caplan, Waters, and DeDe (2007) suggested. In second-language use, there presumably is an especially prevalent use of non-linguistic information to complement and support the limited linguistic information available.

The Vennian Mind

It is worth considering the structures that we have drawn upon in describing the working memory system and its relation to language. The model of Baddeley and Hitch (1974) is one in which boxes are used separately, as modules. This representation provides a nice, simple starting point for the field, but it is not easy to understand in neural terms if some of the same assemblies of cells participate in more than one type of working memory activity (cf. Hebb, 1949). Cowan (1988) introduced a different representation in which major faculties occurred in an embedded fashion, with the focus of attention embedded within the activated portion of long-term memory, which is in turn embedded in the memory system at large. This conception can be more brain-friendly in allowing embedded relations; thus, the same neurons can participate in representing information both in and out of the focus of attention, but with additional processes kicking in for the attended information.

Even this embedded structure, however, is too confining to describe the mechanisms we have discussed. We need the representation commonly attributed to Venn (1880), whose diagrams showed overlapping circles to represent sets of elements that were partly convergent and partly different. In linguistics, a given verbal stimulus can activate visual, orthographic, phonological, morphological (word-form), syntactic, semantic, and pragmatic features all at once; two stimuli often overlap in some features and differ in others. The overlapping features can cause one idea or stimulus to prime or activate a related idea, but concurrently-activated items with overlapping features also can cause mutual interference.

An open question is what happens to these overlapping items in the focus of attention. Cowan (2001) suggested that the focus of attention was simply limited by an absolute number of chunks but, even if that is so, our recent unpublished work suggests that the focus of attention does not stay on the job in the same way throughout a trial. Items in a set may be taken into the focus of attention only momentarily, so that a meaningful configuration of the items can be set up in activated long-term memory. This could be an important mechanism for the chunking of separate words and phrases into a coherent message that is comprehended.

In preparing an interesting sentence to express an idea, the basic idea may be held in the speaker’s working memory while a configuration of colorful words might be brought to mind that, together, express that idea well. These components might be retained while a syntactic structure is mentally designed. The focus of attention may prove small enough that these components of speech (phonological, semantic, syntactic, etc.) cannot all be kept in the focus of attention at once as separate configurations; attention probably must be shuttled between them to keep the components sufficiently active (cf. Barrouillet, Portrat, & Camos, 2011; Vergauwe, Camos, & Barrouillet, in press). Extraneous distractions (notably emotion-laden events) also compete with the linguistic elements and lead to errors. The need to aim and continually shift the focus of attention may contribute to the struggle, hesitations, and slips of the tongue that can become so painfully apparent in the expression of thought, especially in a language other than one’s native tongue.

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