Semantisk information i arbetsminne

Adam Johansson

Örebro universitet

**Sammanfattning**

Mycket av vår kognitiva förmåga beror på lagringen och bearbetande av meningen olika objekt, ord eller handlingar innefattar. Denna mening kallas för semantik där semantik inom arbetsminne har till största del ignorerats och istället tillskrivits långtids semantiskt minne. Med användning Baddley och Hitch model av arbetsminne är målet av denna studie att tillskriva semantisk bearbetning till en komponent inom modellen, undersöka skillnader mellan typer av semantiskt material till episodiskt material och hur dessa är påverkade av seriella positionseffekter. Relaterad semantik, orelaterad semantik och episodiskt material var inkludera i studien och var representerade av ord-par. 42 deltagare, med användningen av en bekvämlighetsurvals metod, blev slumpmässigt tilldelade ett av tre experimentella förhållanden designade för att förändra mängden material som de kan memorera. Det första experimentella förhållanden fastställde att med direkt återkallelse hade semantiskt material högre grad av återkallelse än episodiskt material. Det andra experimentella förhållandet visade att effekten av artikulatoriskt undertryckande (articulatory suppression) inte signifikant sänker mängden som memorerat. Det tredje förhållandet demonsterrade att fördröjd återkallelse signifikant förminskade mängden orelaterad semantik. Dessa resultat visade att semantiskt material återkallas till högre grad men relaterad semantik och orelaterad semantik lagras av olika system då orelaterad semantik är påverkad av förfall (decay) eller störning (interference). Resultaten visade betydelsen av att använda simpelt och precist språk för att ge ett mer effektivt sätt att memorera och lära sig.

Nykkelord: semantik, arbetsminne, chunking, articulatory suppression, seriella positionseffekter.

Handledare: Reza Kormi-Nouri

Psykologi 3

VT2018
Semantic Information in Working Memory

Adam Johansson

Örebro University

Abstract

Much of our cognitive abilities rely on maintaining and processing the meaning of different objects, words or actions. This meaning is known as semantics however, the use of semantics in working memory have been mostly ignored and instead attributed to long-term semantic memory. Using Baddeley and Hitch’s model of working memory this study aims to attribute semantic maintenance to a component within the model, examine differences between types of semantic material to episodic material and how these were affected by serial position effects. Related semantics, unrelated semantics and episodic material were included in the study which were all represented by word-pairs. 42 participants, using a convenience sampling method, were randomly assigned to one of three experimental conditions designed to alter the amount of material memorized. The first experimental condition, by using immediate recall, demonstrated that semantic materials had a significantly superior recall rate than episodic materials. The second experimental condition showed that the effect articulatory suppression didn’t significantly reduce the amount memorized. The third condition demonstrated that delayed recall significantly reduced the amount of unrelated semantics. These findings showed that semantic materials had superior recall but related and unrelated semantic material were found to be maintained by different systems as unrelated material was subject to decay or interference. The results showed the importance using simple and precise language to provide a more effective way to memorize and learn.

Keywords: semantics, working memory, chunking, articulatory suppression, serial position effects.

Supervisor: Reza Kormi-Nouri

Psychology 3

ST2018
Semantic Information in Working Memory

The ability to perform complex cognitive tasks such as reasoning, understanding and learning is based on our capacity to temporarily maintain information in an active state within our working memory (Shivde & Anderson, 2011). A large portion of our mental activity is spent processing the meaning or so-called semantic concepts of different objects such as the fact that knives are sharp or abstract concepts like the meaning of a handshake (Shivde & Anderson, 2011). That semantic information is used within our working memory can be demonstrated by the findings of a study that examined how words with meaningful semantic concepts referred to as content words which include words like anxiety, healthy and place are remembered better than words with few semantic concepts referred to as function words which are words such as else, rather and could (Bourasa & Besner, 1994). Additionally, a study showed that words are better remembered compared to non-words where the underlying logic is that normal words that we use have a specific meaning tied to them while non-words are simply a string of letters void of any meaning that we apply to them (Hulme, Maughan, & Brown, 1991). Thus, semantic concepts are a vital component for our working memory and involved in many cognitive tasks where the semantic information within working memory will be the focal point of the present study.

Working memory or those memories we temporary store have been studied for a long time under the guise of different names for example, primary memory, short-term memory, short-term store and working memory but all these models represent the same memory system, specifically our temporary storage of information (Ashcraft & Radvansky, 2014; Baddeley, 2012). There is a conceptual difference between an older iteration of our temporary storage like short-term memory which is only used to store information temporarily while newer models such as working memory is a multi-component model used for both maintenance and manipulation of information (Baddeley, 2012; Eaben, Estapert & Eblokland,
The term working memory originates from Miller, Galanter and Pribram in 1960 which was later used by Baddeley and Hitch for their multi-component model of short-term memory (Baddeley, 2010). Working memory is the system where we consciously expend effort to remember things such as an entry code and not a simply a passive storage of the information we encounter (Ashcraft & Radvansky, 2014; Baddeley, 2012). Working memory consists of four components which are called the central executive, the phonological loop, the visuospatial sketchpad, and the episodic buffer (Baddeley, 2000). The four components are used for both storing and manipulating information and together form our working memory where each component is responsible for unique tasks.

The central executive is the core of working memory which is responsible for decision making, planning, initiating recall of memories and integrates information that we receive (Baddeley, 2012). When information is being processed the central executive may send information to the phonological loop to rehearse to maintain it in an active state if it’s going to be used at a later point of a process in this sense it acts as a director of the task and not a storage of information (Baddeley, 2012). The central executive can also allocate attentional resources to its subsystems where each system has its own pool of resources that can be depleted by performing demanding tasks, once depleted they can draw resources from the central executive which in turn can be depleted as well (Baddeley, 2012). In this sense the central executive is the boss of working memory, allocating resources, planning and makes the decisions.

There are two slave systems of the central executive that only maintain and process a specific type of information which is the phonological loop and the visuospatial sketchpad (Baddeley, 2000). The phonological loop is a slave system of the central executive that’s in charge of rehearsing verbal information and storing phonological information (Baddeley, 2012). The information stored within the phonological loop is held within a system called the
phonological store, the information within this system is only retained if it’s actively
rehearsed by another system called the articulatory loop which refreshes or rehearses the
information held within the phonological store (Baddeley, 2000). The visuospatial sketchpad
is another slave system of the central executive and it retains visual and spatial information
(Baddeley, 2012). Information held within the visuospatial sketchpad can be manipulated and
is subject to long-term memory through an effect called boundary extension where we add
information that we expect (Ashcraft & Radvansky, 2014). For example, if you saw a picture
of a staircase but the all the steps aren’t shown in the picture you would add the expected
number of steps outside the frame if you were asked how many steps the staircase had. An
important factor of both the phonological loop and visuospatial sketchpad is that they aren’t
limited to processing information from their respective sensory input i.e. visually read words
will be phonologically rehearsed, and visual imagery which refers to visual representations of
verbal information for example you can mentally picture a forest by simply reading the word
(Baddeley, 2012). While these two systems serve the same function of maintaining
information they have different ways of maintaining and processing the specific type of
information they are responsible for.

The last component is the episodic buffer which integrates information from different
modalities or sources to create new episodic long-term memories which are memories of
experiences or events that are temporally bound to a specific point in time, the episodic buffer
also binds the information drawn from working memory to information stored within long-
term memory (Baddeley, Allen, & Hitch, 2011). The episodic buffer wasn’t originally part of
the working memory model and was included by discarding the notion that the central
executive had its own storage capacity however, there was still a need for a temporary storage
capable of integrating phonological, visual and potentially other types of information leading
to the conceptualization of the episodic buffer (Baddeley & Logie, 1999; Baddeley, 2000;
Baddeley, et al., 2011). Within the episodic buffer we integrate information, for example shapes are integrated with colors and the memory process called chunking occurs within this system (Baddeley, et al., 2011). Chunking is the process where we relate several points of information to a concept held within our long-term memory which allows us to store more information at once, you can think of it as semantically compressing information. For example, if you were provided a list of 20 unrelated alphabetical characters to remember you would remember 7±2 of these as they are uncompressed in working memory, however if these characters that are formed into meaningful words you would remember 16 or more of these characters (Baddeley, 2000; Miller, 1956; Holt, et al., 2015). This is achieved by breaking down parts of a sentence into different parts where the information held are these chunks of information rather than single pieces and the capacity of chunks is thought to be around 4±1 chunks or episodes (Baddeley, 2000; Baddeley, 2010; Mathy & Feldman, 2011). One method of chunking-prevention is to use the effect of articulatory suppression which is when you repeat meaningless phrases or digits that prevents rehearsal of the articulatory loop (American Psychological Association [APA], 2005). The capacity of uncompressed items and compressed items is generally attributed to decay and interference where decay refers to that the passage of time deteriorates memories and interference refers to previous material or new material interfering with items in working memory (Mathy & Feldman, 2011). The episodic buffer is distinctly different from the other maintenance systems as it acts as an intermediary between the central executive, its two slave systems called the phonological loop and visuospatial sketchpad, and long-term memory and holds a capacity of 4±1 compressed chunks of information.

Thus, it is questionable if semantic concepts are tied to the information held within the slave systems in working memory, to clarify this a few studies examined if semantics are associated with the information held within the phonological loop. One study examined if the
information stored within the phonological loop is equally affected by articulatory suppression as semantics, where the effect of articulatory suppression prevents us from rehearsing information and limits the amount of information maintained (Nishiyama, 2014). This study found that articulatory suppression has a larger effect on the phonological loop than semantic representations, it also showed that a task that disrupts attention has a larger effect on the phonological loop compared to semantic information (Nishiyama, 2014).

Conclusively, two experiments showed that disruptions of the phonological loop don’t affect semantics to the same extent. This can also be shown with physical evidence where a study performed experiments using two brain-damaged patients where one of them had difficulties maintaining phonological information and the other had difficulties retaining semantics (Martin, Shelton, & Yafee, 1994). The study found that these two patients had larger difficulties in tasks where their brain-damage influenced their performance, however they both performed worse than a control group where in tasks where their brain-damage doesn’t influence their performance (Martin, et al., 1994). This shows that storing information in the phonological loop is separate from maintaining semantic information but that these systems interact when we recall things. These results show that phonological and semantic information are stored in different modules, however they are part of the same system since they interact to form a more complete piece of information.

Another component which has been researched in relation to semantics is the central executive. A study found that contrary to previous predictions both simple and complex executive functions found no correlation to semantic short-term memory, however this study did find that semantic processing was correlated to complex executive functions (Allen, Martin, & Martin, 2012). Further, the same study also concluded that phonological short-term memory was correlated with aspects of executive control where phonological maintenance supports executive functioning (Allen, et al., 2012). A study examined if chunking depends
the central executive using sentence recall, the study concluded that chunking occurs automatically without depending on the central executive contrary to the initial conceptualization (Baddeley, Hitch, & Allen, 2009). The results found from these studies makes the relation between the episodic buffer and semantic maintenance questionable since the component is thought to be an intermediary between the components of working memory and is conceptualized to be under the influence of the executive control.

Given a list of characters, words or digits, some items are recalled more frequently than others, this is known as the serial position curve and can be studied using free recall and serial recall where the former is simply recalling the presented items in any order while the latter refers to recall of items in the originally presented order. There are two specific effects found on serial position curve without manipulation which are known as the primacy and recency effects (Murdock, 1962). The primacy effect refers how many items of the starting portion of a list we can recall, a study found that we tend to remember these more frequently compared to items found in the middle of the list, this is attributed to rehearsal of the first items presented allowing them to enter our long-term memory (Glanzer & Cunitz, 1966; Murdock, 1962). The recency effect is how many items of the ending portion of a list we can recall, research found that we recall these items at a higher rate than the middle portion, this is attributed to our short-term memory (Glanzer & Cunitz, 1966; Murdock, 1962). The middle portion of a list will be recalled less frequently due to not being rehearsed enough to be encoded into long-term memory and presented too long ago to be active in short-term memory (Glanzer & Cunitz, 1966). The serial position curve can be manipulated by introducing a delay of recall or by having participants perform an additional unrelated task, this degrades or eliminates the recency effect (Glanzer & Cunitz, 1966). The serial position curve is different depending on what kind of information we are maintaining, a study found that semantic information has a stronger recency effect than episodic information where
recency normally encompasses the 3 to 5 last items on a list where this extends up to 12 items with the use of semantic information (Healy, Havas, & Parker, 2000). These effects are important when dealing with information acquired in a serial manner, it also shows that the first items and the last are expected to be recalled more frequently but that they also differ depending on the type of information.

Since very few studies examine semantic maintenance in working memory directly it’s implied from research that draw this conclusion, these implications are drawn by results such as that we remember content words better than function word or that we remember words better than non-words (Bourasa & Besner, 1994; Hulme, et al., 1991). The results of these studies may be attributed to both semantic maintenance in working memory and semantic binding from long-term memory where the latter has mostly received the credit for this (Shivde & Anderson, 2011). To answer this ambiguity a study created a new method of examining semantic maintenance in working memory which they called the concurrent probe task that was performed together with a delayed judgment procedure (Shivde & Anderson, 2011). The method entails participants remembering the meaning behind a presented word where they must later answer a question regarding its relation to a later presented word (Shivde & Anderson, 2011). The underlying logic of the procedure is that you can only answer questions regarding the relation to the target if you actively maintain the meaning of the first word in working memory instead of attributing this to long-term memory (Shivde & Anderson, 2011). Using this method, the study found that semantic information is actively maintained in working memory rather than the contribution of semantic or episodic long-term memory (Shivde & Anderson, 2011). Used together these implied results and the finding of active semantic maintenance provides us with a way of examining working memory with the assumption of semantic maintenance in working memory. However, the method used doesn’t
fully ensure that semantic information was the maintained stimulus where the semantic concept could have been drawn from an episodically remembered word.

Which system within working memory is then responsible for semantic maintenance in working memory and how this information stored, the only system within Baddeley and Hitch’s model of working memory which has any mention of processing semantic information is the episodic buffer that binds information from the other systems to our long-term memory (Baddeley, 2000; Baddeley, et al., 2011). Since this system is responsible for chunking, it creates even more ambiguity when the episodic buffer is thought to be responsible for chunking which involves semantic information that has been shown to be less affected by articulatory suppression than phonological information which is a common chunking-prevention method (APA, 2005; Baddeley, 2000). Further it remains unclear if single semantic concepts are stored in the same way that semantic relations which in the episodic buffer are in the form of chunks, for example is the string of characters that form the word elephant chunked in the same way as the relation between trees and roots. Additionally, it’s unclear if single semantic concepts are affected in the same way as semantic relations by serial position effects. Thus, the previous results and interpretations make it ambiguous which system is responsible maintaining semantics in working memory, further it’s unclear if semantic relations and semantic concepts are chunked in the same way and how these are affected by serial position effects.

The main goal of the present study is to clarify these inconsistencies from previous literature, specifically if the episodic buffer can be attributed all types of semantic maintenance, if single semantic chunks are stored in the same way as semantic relations and how these are affected by serial position effects. In addition, to control for the assumption that people actively maintain semantics in working memory as indicated by previous studies, semantic material and non-semantic material were used (Martin, et al., 1994; Nishiyama,
2014; Shivde & Anderson, 2011). Furthermore, by using a disruption of the maintenance process, it will be tested whether semantic information has a stronger recency effect than episodic information (Healy, et al., 2000; Martin, et al., 1994; Nishiyama, 2014). The research questions will be explored without hypotheses due to ambivalent conclusions that can be drawn from the inconsistencies in previous literature.

Method

Participants

The sample was obtained using convenience sampling which refers to selecting people based on their availability, a total of 42 participants were included in the sample. The 42 participants were within the age range 15 to 72 (M = 27.14, SD = 9.39) and 31 (73.8%) were men and 11 (26.2%) women where all the participants were Swedish speakers. A total of 16 (38.1%) participants included in the sample were students at Örebro University where they were studying. A single participant was tested but wasn’t included in the sample due to not properly following instructions.

Measures

I created an adaptation of the free recall paradigm that consists of word pairs as opposed to the typically presented single words (Glanzer & Kunitz, 1966; Murdock 1962). The idea behind using word pairs was that it allows for relation between the words to be memorized, these pairs consisted of non-word pairs, word pairs that were semantically unrelated and word pairs with a semantic relation. An example of a non-word pair could be Fnuq-Pznokba, a pair semantically unrelated could be Mountain-Keyboard, a pair semantically related could be Water-Ice. I included 4 pairs of these three types of word pairs which results in a total of 8 non-words, 8 unrelated words, and 8 related words being presented for the participants.
Semantic maintenance. Our ability to maintain semantics was measured using two types of word pairs, the two types used was related and unrelated semantics where previous research showed that people remember meaningful words better than non-words (Hulme, et al., 1991). One of the semantic types of was related words which have a pre-existing semantic relation within long-term memory and thus exist within long-term memory before reading the words, the second semantic type was unrelated words which don’t have a pre-existing semantic relation within long-term memory (Haarmann & Cameron, 2005).

Semantically related. Related words that represent semantically related objects were used to measure memory of semantic relations which have a pre-existing relation in long-term semantic memory. The words were individual objects that have a relation rather than properties of an object for example there’s a relation between fork and a knife while a knife can possess the property of being sharp. Related semantic concepts were measured by the following related word pairs in Swedish; Skepp-Segel (3), Hammare-Spike (10), Papper-Träd (6). Salt-Peppar (8) where the number in parenthesis reflects presentation order including other types. The English version of these pairs would be the following; Ship-Sail, Hammer-Nail, Paper-Tree, Salt-Pepper.

Semantically unrelated. Unrelated words that represent individual semantic objects were used to measure maintenance of semantic concepts in working memory which doesn’t have a pre-existing relation in long-term semantic memory. A single concept could for example be the word refrigerator which can be memorized as a chunk that semantically represents a thermally insulated space which is generally used to keep food at a lower temperature. Semantic concepts were measured by the following unrelated word pairs in Swedish; Kabel-Nyckel (11), Bräda-Paket (9), Krabba-Penna (1), Tårta-Karta (5) where the number in parenthesis is the order they were presented including other types. The English
version of these pairs would be the following; Cable-Key, Board-Packet, Crab-Pen, Cake-Map.

**Episodic maintenance.** Maintenance of episodic material were measured by non-words, these words were all in the length of five alphabetical characters without sharing structure or phonological similarity to any words. The reason for using non-words rather than pseudo-words or words from a language the participants don’t have knowledge of is that I wanted to limit the extent that participants can apply any semantic meaning to the non-words due to phonological or structural similarity to words or abbreviations they might know. The non-word pairs that was presented were the following; Klfro-Qptrs (12), Mcyjm-Zrvdg (2), Jhgf-Splko (7), Acxnw-Ghcsf (4) where the number in parenthesis represent the presentation order including other types.

**Serial position effects.** The recency effect was be measured as the last three pairs presented in the list could be recalled better compared to other items, the primacy effect was measured as improved recall on the first three pairs compared to the other items presented (Healy, et al., 2000).

**Materials**

The word pairs were presented using a laptop running the Windows operative system, using the software PowerPoint. The presentation was set with an automatic slide transition every 5 seconds after an introductory slide that required a mouse click to proceed. The word-pairs were presented using the font Times New Roman, centered of the screen and was set to a font size of 60.

**Procedure**

With the use of an experimental design, I randomly assigned participants to one of the three conditions which consist of a dual task condition (articulatory suppression), a delayed
recall condition (elimination of recency) and a control group which served as a baseline condition. The items presented were placed in a fixed order based on two conditions, the first condition was that the same pair type wasn’t presented consecutively, the second condition was that one of each pair type must be presented before a pair type can be reused.

**Control condition.** The control group data was collected from 15 participants in a quiet setting without distractions or interruptions. I started the procedure with asking the participants for age and gender. Then, I instructed participants about the goal which was to remember as many pairs as possible, that only full pairs were valid, and that they would be asked to write the pairs that they remember on a blank sheet of paper after they have been presented 12 pairs for a total of 24 words. After informing participants of the procedure, the participants were presented series of word pairs and recalled these in any order afterwards. When the test was completed I informed the participants about the purpose of the study.

**Articulatory suppression.** In this condition I collected the data in the same setting as the control condition from 13 participants with one exception in the procedure where this condition used a dual task. This condition began exactly like the control condition where participants were instructed regarding the procedure and asked for demographical characteristics. Articulatory suppression was performed as a dual task procedure, to prevent subvocal rehearsal and as a chunking-prevention method. I instructed the participants to vocally repeat a series of four digits which was 4, 7, 3, and 1 as they were presented word pairs. This procedure was followed by an immediate free recall. The cost of articulatory suppression has been found to be roughly two items removed from recall and would be the expected reduction of this condition (Baddeley; 2012). After performing the dual task procedure and immediate recall, I informed the participants of the purpose of the study.

**Elimination of recency.** In the elimination of recency condition I collected data in the same setting as the control condition from 14 participants with an exception in procedure
where this task used a delayed recall. This condition began like the control condition where participants were instructed regarding the procedure of the experiment and asked about demographical characteristics. Then the participants were presented the 12 target pairs with a distractor task added after the presentation of target items. The additional task was used to remove the recency effect where the participants were instructed to solve three picture puzzles otherwise known as a rebus for 20 seconds each representing the Swedish words; Bats, meatballs, and a made-up word duckdog. This is known as a delayed free recall where they do not have access to any stimuli for a short period of time and must then freely recall the target items. Similar to the other two conditions, following the test, I informed the participants regarding the purpose of the study.

**Ethics**

The present study used human subjects and ethical considerations had to be made in terms of how participants would be recruited and informed, what personal data would be collected and how this data would be handled. Participation in the experiment was done willingly without the use of any coercive methods or compensation where the participants gave a form of passive consent to participation because they were performing the experiment entirely of their own volition. Prior to initiating the experimental procedure, the participants were fully informed of the stimuli that they would be exposed to and due to this the participants had the opportunity to make an informed decision to decline participation if they thought anything included in the experiment could negatively affect them. There was no sensitive personal data collected and the personal information collected couldn’t be used to determine whom those details apply which ensured anonymity of the participants. The collected data was only used for answering the research questions of the present study and following the analysis the data was destroyed. Finally, the stimulus presented and the procedure of the experiments were deemed harmless to participants.
Analysis

The resulting data comprised of three distinct pair-types as variables; Non-words, unrelated words, related words that were all measured continuously and a categorical variable for the experimental condition. To examine if there were significant differences between the pair-types a within-subject analysis was used in a repeated measures ANOVA where each pair-type was set up as a repeated measure. A one-way ANOVA was used to answer if there were significant differences between the three pair-types in each experimental condition. The serial position effects were measured as improved recall of the primacy and recency portions of the presented items within the pair-type without any statistical testing.

Results

Descriptive statistics

Table 1

Memorization of word-types within experimental conditions.

<table>
<thead>
<tr>
<th></th>
<th>Related pairs</th>
<th>Unrelated pairs</th>
<th>Non-word pairs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>Control condition</td>
<td>2,33</td>
<td>1,05</td>
<td>1,80</td>
</tr>
<tr>
<td>Articulatory suppression</td>
<td>2,00</td>
<td>.82</td>
<td>1,62</td>
</tr>
<tr>
<td>Elimination of recency</td>
<td>1,93</td>
<td>.83</td>
<td>.64</td>
</tr>
</tbody>
</table>

Note. N = 42. Several analyses of variance were conducted separately for each condition, refer to the specific condition for within-subject and between-subject significance levels.

Inferential statistics
The statistical assumptions of the one-way ANOVA and repeated measures ANOVA were partially met, they were specifically lacking a test of non-normality however the robust nature of the ANOVA means that the power of the F statistic is relatively unaffected by the possibility non-normality when group sizes are equal (Field, 2013). Additionally, the sphericity assumption of the repeated measures ANOVA was violated in the elimination of recency condition which was corrected by Greenhouse-Geisser.

**Control condition.** I used a repeated measures ANOVA to examine the difference in memory of three pair-types; Non-words, unrelated words and related words. The results showed that there were significant differences in memory between the types of pairs, $F(2, 28) = 37.18, p < .001, \eta^2 = .73$. Posthoc analysis showed that participants remembered related pairs ($M = 2.33, SD = 1.05$) and unrelated pairs ($M = 1.80, SD = .78$) significantly more than non-word pairs ($M = .07, SD = .26$). However, there was no significant difference in memory of related pairs and unrelated pairs.

In the control condition a primacy effect was found for the first position which was an unrelated pair and the third position that was a related pair (see Figure 1). There was a single instance of recency of non-word pairs in the twelfth position however this couldn’t be accounted as a measure of recency effect due to the floor effect found of non-word pairs. There wasn’t a recency effect for related pairs or unrelated pairs (see Figure 1).
Articulatory suppression. I conducted a one-way ANOVA to examine if there was a significant difference in memory of the three pair-types to compare between the articulatory suppression condition and the control condition. The results showed that there were no significant differences between any pair-type items in the two conditions. Thus, participants were able to memorize the same number of pairs of each pair-type in the control condition and articulatory suppression condition (see Table 1).

Further, I used a repeated measures ANOVA to examine if there was a significant difference in memory between the three pair-types in the articulatory suppression condition. The results showed that there was a significant difference in memory between the types of pairs, $F(2, 24) = 52.82, p < .001, \eta^2 = .64$. Posthoc analysis showed that participants remembered related pairs ($M = 2.00, SD = .82$) and unrelated pairs ($M = 1.62, SD = .87$) significantly more than non-word pairs ($M = .08, SD = .28$). There was no significant difference in memory of related pairs and unrelated pairs.

In the articulatory suppression condition, the primacy effect was found for related and unrelated pairs (see Figure 2). Additionally, a single instance of primacy for non-word pairs

![Figure 1. Control condition](image-url)
was found in the second position which wasn’t regarded as a primacy effect due to the floor effect of non-word pairs (see Figure 2). There was no recency effect measured of any pair-type due to none of the last three items presented having improved recall compared to the rest of the list (see Figure 2).

**Fig. 2.** Serial position curve of the articulatory suppression condition. Positions 3, 6, 8, 10 are related pairs, positions 1, 5, 9, 11 are unrelated pairs, positions 2, 4, 7, 12 are non-word pairs.

**Elimination of recency.** I used one-way ANOVA to examine if memory of the three pair-types significantly differed in the elimination of recency condition compared to the control condition. The results showed that there was significant difference in memory of unrelated pairs between the two conditions, $F(1, 27) = 16.77, p < .001$. However, there were no significant differences between the conditions of related pairs and non-word pairs. In summary, participants in the control condition could memorize more unrelated pairs than in the elimination of recency condition, however memory of related pairs and non-word pairs didn’t change between the two conditions (see Table 1).

Additionally, I performed a repeated measures ANOVA to examine if there was a significant difference in memory between the three pair-types in the elimination of recency condition. The results showed that there was significant difference in memory between the
three pair-types, $F(1,35, 17,52) = 28.46, p < .001, \eta^2 = .69$. Posthoc analysis showed that related pairs ($M = 1.93, SD = .83$) were recalled significantly more than unrelated pairs ($M = .64, SD = .75$), and non-word pairs ($M = 0, SD = 0$), unrelated pairs were also remembered significantly more than non-word pairs.

In the elimination of recency condition there was a primacy effect for related and unrelated pairs however non-word pairs received no change (see Figure 3). There was a recency effect for related pairs but reduced recall for the unrelated pair and unchanged for the non-word pair (see Figure 3).

![Figure 3. Elimination of recency](image)

**Fig. 3.** Serial position curve of the elimination of recency condition. Positions 3, 6, 8, 10 are related pairs, positions 1, 5, 9, 11 are unrelated pairs, positions 2, 4, 7, 12 are non-word pairs.

**Discussion**

This study provides evidence of how people maintain semantic within working memory when both semantic and episodic material are presented. The main findings of the study were that semantic materials were more effectively maintained and recalled at a higher rate than episodic materials, that articulatory suppression doesn’t significantly degrade semantic maintenance, and that the delayed recall procedure significantly reduced the amount of unrelated semantics memorized. Previous studies found evidence of direct semantic
maintenance where this study found the same results with words having semantic meaning;
Both related and unrelated semantics were maintained better than episodic material (Shivde &
Anderson, 2011). However, the results of articulatory suppression task demonstrated that
neither the episodic buffer which chunks information nor the phonological loop are the
systems responsible for maintaining the integrated information in the episodic buffer since the
amount of semantic information maintained didn’t get reduced with the use of articulatory
suppression (APA, 2005). Additionally, the serial position effects within the experimental
conditions did not reflect those typically found in research using serially presented material
indicating a difference depending on the type of material used (Healy, et al., 2000). However
due to the fixed positions used in the present study no conclusions could be drawn from the
data. In summary, the results provided evidence that people could maintain semantics
separately from the information held within the chunks in the episodic buffer and the
phonological loop because the effect of articulatory suppression which influences both these
systems had no effect.

These findings bolster the small amount of research regarding semantic maintenance
in working memory where this study was able to find evidence of direct semantic
maintenance and show a difference between types of semantic material. Notably this study
examined if semantic maintenance can be attributed to the episodic buffer where the results of
this study presented evidence that articulatory suppression which is supposed to prevent
chunking didn’t significantly reduce the amount of memorized unrelated or related semantics.
Further, this study contributes evidence that in order to properly measure the serial position
effects of semantic and episodic materials they need to be tested separately due to the trend
finding a floor effect of the non-word pairs found in every condition when both semantic and
episodic materials were presented. For example, if a researcher used random positions of both
semantic and episodic materials the positions randomly assigned episodic material would
always result in a nearly non-existent recall rate due to the floor effect found of episodic materials.

There are two different theoretical explanations why the effect of articulatory suppression didn’t affect semantics using the multicomponent model of working memory made by Baddeley and Hitch (Baddeley, 2000). The first explanation is that there are two subsystems within the episodic buffer that do perform tasks independently. One system compresses information in form of chunking and the second system integrates received material, binds it to long-term memory and stores it for active use in working memory with a minimum of a single dissociation where disruption of the chunking system doesn’t affect the binding system. The second explanation is using the viewpoint argued by Cowan (1988) where short-term memory is the activated part of long-term memory where the episodic buffer can access the activated portion of long-term memory and thus doesn’t retain the information itself. It’s important to note that the second explanation is only for the semantics in the episodic buffer and not for the working memory model as a whole. Considering the capacity of 4±1 chunks of information both explanations are possible due to the paired nature of the stimuli, in the first explanation each pair would have to be chunked as a single unit regardless of being related or unrelated where the second explanation chunks each word of unrelated pairs resulting in roughly four chunks and the related words are remembered through long-term memory.

The difference between immediate recall and delayed recall formed an unexpected result between related and unrelated pairs where the introduction of a delay significantly reduced the amount of memorized unrelated pairs. The delayed recall adds a grace period where information in working memory can be forgotten either from decay which refers to time decaying the memory trace or from interference where new material interferes with the memorized causing one to forget. A possible explanation for the difference between related
and unrelated semantics is the nature of the paired words where related semantics have a pre-existing relation within long-term memory and are activated for usage within working memory and unrelated semantics do not have a pre-existing relation within long-term memory where they are only maintained in working memory and subject to decay or interference (Haarmann & Cameron, 2005).

A limitation of the present study was that the results can’t be generalized to another known population. First, with the wide range of ages of the sample used (15-72) the results cannot be applied to a specific age group. Secondly, the majority of participants included in the sample were aged close to the mean age of the sample (27.14) which doesn’t account for performance degradation in working memory or semantic long-term memory due to aging. Finally, very few demographical characteristics were collected from participants resulting in difficulty inferring the results to another population since you can’t relate it to another population with known characteristics. The major limitation of the study was the time constraint of data collection which caused me to take shortcuts in terms of designing the experimental conditions while trying to achieve a comprehensive view of semantics in working memory, two of these shortcuts influenced the results. The first shortcut was that all three word-types (non-word, unrelated, related) were included in each experimental condition to save time however this resulted in a floor effect of non-word pairs, the floor effect was possibly due to conscious prioritization of semantic pairs and disregard for episodic material where many participants stated post-test that they focused on the semantic pairs and ignored the episodic ones. The second shortcut was the fixed positions of the pairs which limits interpretation of serial position effects.

One of the strengths of the study was the use of an experimental design where it allows for causal conclusions regarding the effects of articulatory suppression in the dual task procedure and delayed recall. With the use of randomization and experimental conditions it
can be concluded that articulatory suppression didn’t significantly reduce the amount memorized regardless of unmeasured characteristics. Another strength of the study was that many of the confounding variables that affect any type of memorization such as related, unrelated and non-word pairs to gain a comprehensive view of how these are maintained in working memory.

While you cannot fully disentangle semantics in long-term memory from those in working memory you would be unable to imagine a crab holding a pen without the capacity to process and use semantics within working memory, these two memory systems must then either work together through the binding process in the episodic buffer or an activated portion of long-term memory is accessible through the episodic buffer. With semantic maintenance in working memory and a difference between types of semantic material compared to episodic material makes a case for focusing on semantic aspects when trying to learn or memorize any form of material, for example memorizing a string words without semantic understanding of the words will yield poor results in recall compared to association through meaning of the memorized words. Within the same line of reasoning, it shows the importance of easy to understand language and a clear structure of how different parts relate when writing where you can facilitate both memorization and learning by keeping things simple.
References


Miller, G. (1956). The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information. *Psychological Review, 63*, 81. DOI: 10.1037/h0043158
