# THE EFFECTS OF INFORMATION LOAD OF WORDS ON WORKING MEMORY CAPACITY

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# THE EFFECTS OF INFORMATION LOAD OF WORDS

# ON WORKING MEMORY CAPACITY

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ABSTRACT

THE EFFECTS OF INFORMATION LOAD OF WORDS

ON WORKING MEMORY CAPACITY

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MS in Experimental Psychology, Department of Psychology

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This thesis analyzes the effects of information load of words on working memory. Generally, studies investigating the word length effect or chunking mechanisms use simple nouns as stimuli. In the Turkish language, verb can convey more than one unit of meaning at a time. We took advantage of this characteristic to investigate whether the retention of agglutinated verbs involves a different kind of chunking mechanism, controlling for the word length effects. In experiment 1A, we compared recall performance with agglutinated verbs and root verbs between groups. Also, we compared performance in each verb condition with nouns. In Experiment 1B, we included some distracter verbs that had the same root but a different agglutination than the target word. The results show that, agglutinated verbs generally decreases serial recall performance and require more cognitive effort for perfectly recalled sets. However, the mean number of words recalled in the correct position across all word sets did not yield a significant difference across conditions.

Keywords: Chunking, working memory, word length effect, agglutinated verbs, operation span

ÖZET

KELİME İÇİNDEKİ BİLGİ YÜKÜNÜN ÇALIŞMA BELLEĞİ KAPASİTESİNE ETKİSİ

Duyan, Yalçın Akın

Deneysel Psikoloji Yüksek Lisans, Sosyal Bilimler Enstitüsü

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Bu tezde, kelimelerdeki bilgi yükünün çalışma belleği kapasitesine etkisi incelenmektedir. Türkçe'de, bazı kelimeler birden fazla bilgi biriminin iletilmesini sağlayabilir. Bu tezde, dilin bu özelliğinden yararlanılarak, çekimli fiillerin akılda tutulmalarının farklı bir kümeleme mekanizmasını içerip içermediğini, kelime uzunluğu etkileri kontrol edilerek incelenmiştir. Deney 1A'da, çekimli fiillerin ve fiil köklerinin hatırlanma performanslarını gruplar arası bir desenle karşılaştırılmıştır. Ayrıca, her bir fiil koşulundaki performans ile yalın isimlerin hatırlanma performansları da karşılaştırılmıştır. Deney 1B'de, çekimli fiil hatırlama görevine, hedef kelimelerle aynı köke sahip fakat farklı ekler almış fiiller de eklenmiştir. Sonuçlar, çekimli fiillerin kelime setlerinin mükemmel bir şekilde hatırlanma performansını düşürdüğünü ve daha fazla bilişsel çaba gerektirdiğini göstermiştir. Ancak, bütün kelime setlerinde doğru konumda hatırlanan ortalama kelime sayısı, koşullar arasında değişmemiştir.

Anahtar Kelimeler: Kümeleme, çalışma belleği, kelime uzunluğu etkisi, çekimli fiiller, hesap uzamı

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It is always a good story when you get through with it.

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# CHAPTER 1

# INTRODUCTION

Working memory, which is the ability to maintain and process information recently encountered, is generally thought to have a limited capacity (Cowan, 2001). There are various theoretical accounts of this capacity, and many factors besides individual differences have been found to affect the number of items that can be held in working memory. These include the length (Baddeley, Thomson & Buchanan, 1975) and the phonological similarity of words to be recalled (Baddeley, 1966a; Conrad & Hull, 1964); and whether irrelevant speech (Salamé and Baddeley (1982), Colle and Welsh (1976)) and articulatory suppression (Murray, 1966) is included in the memory task. The word length effect refers to the fact that shorter words are generally better remembered than longer words, which will be discussed more in detail. The phonological similarity effect refers to the fact that similar sounding stimuli, which are thought to be harder to discriminate at recall (Baddeley, 1990, p. 72) results in a poorer short-term memory. Inclusion of irrelevant speech (e.g. speech in a different language) and articulatory suppression, which requires subjects to repeat a single syllable (eg. "the, the, the...") aloud in order to prevent the articulation of the target words, also impairs working memory performance. In this thesis, a new variable that can influence working memory capacity is suggested: the information load (or the units of information) of words to be recalled.

**Working Memory Capacity**

Exploring the boundaries of human capacity to store and process information is a long-held and ongoing conquest in cognitive psychology. In his seminal article, Miller (1956) suggested that short-term memory capacity was limited to a "magical number seven, plus or minus two", which could be the number of individual items or chunks. However, more recent accounts of this capacity (Cowan, 2001) suggest that it is limited to three or four chunks in the focus of attention. Another issue that arisen was whether working memory consisted of one system or several separate systems.

The term short-term memory, used to denote a simple mechanism, in which items to be remembered were stored in a single store for later retrieval.(e.g., Atkinson & Shiffrin, 1968; Broadbent, 1958; Miller, 1956). These


Figure 1 1 Atkinson-Shiffrin Model of memory early models (see Figure 1.1) failed to account for the versatile nature of temporary retention processes (Cowan, 2005). Working memory models that came after Atkinson and Shiffrin, generally propose more than one storage system.

Baddeley's model (2000), which is an updated version of his earlier model (Baddeley, 1986), Baddeley and Hitch, verbal distraction impaired verbal memory more than did visual distraction (and vice versa), implicating that there are seperate stores for each modality. They theorized a central storage resource that holds the information to be processed, which is called the central executive. Also, they hypothesized that there were separate stores (verbal-phonological and visuospatial) that processed relevant information separately, and did not interfere with reasoning of comprehension processes. The phonological loop, involves the rehearsal of phonological information in a covert fashion, and similarly, the visuospatial sketchpad involves the rehearsal of visual information. The later-added episodic buffer, which is the third slave system, binds information across verbal, visual and spatial domains (see Figure 1.2).

Cowan (1988) opposed this view of separated function in the Baddeley model (see Figure 1.3). While it was true that more interference occurred among similar stimuli, the verbal-visual distinction did not seem that crucial to working memory as it did not account for other kinds of information (say, tactile). Cowan viewed this information storage as instances from long-term memory, that are temporarily activated. He also proposed that an amount of readily accessible

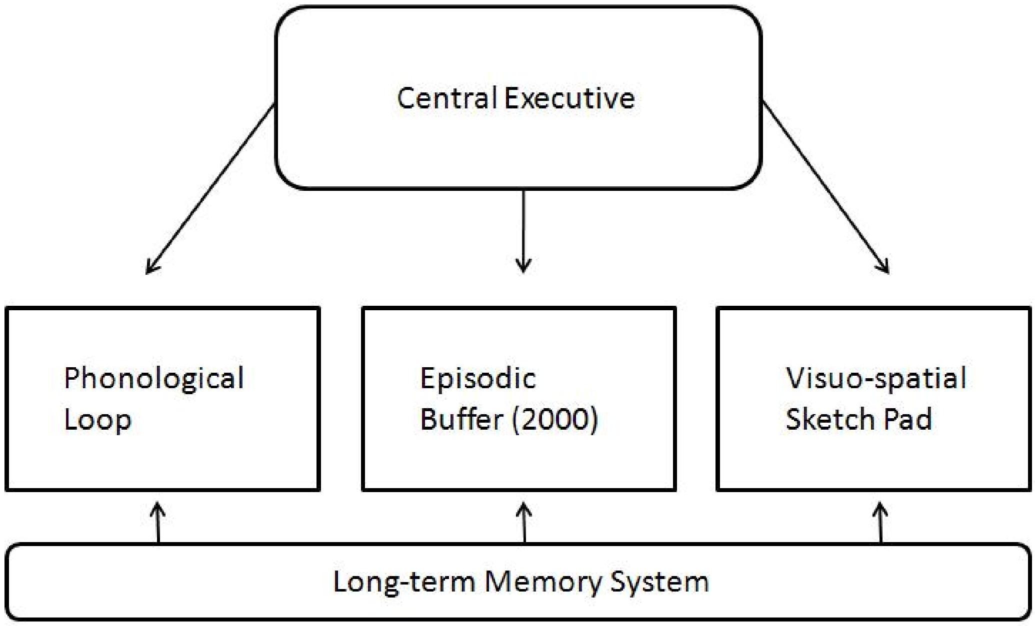


Figure 1.2 Baddeley's (1986, 2000) model of working memory.

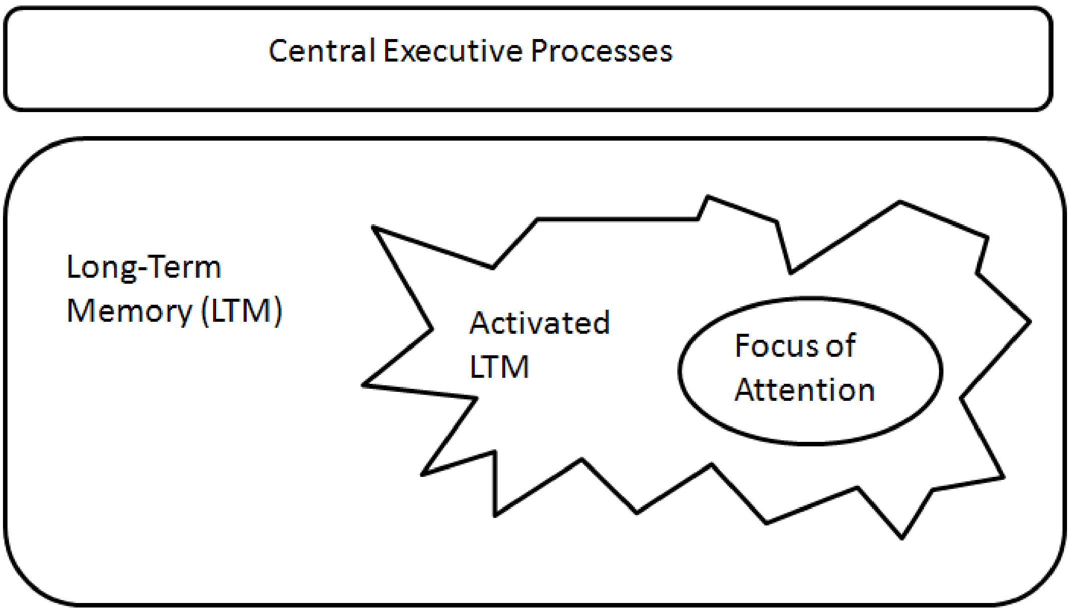


Figure 1.3 Cowan's (1988) model of working memory.

information (which is generally thought to be 3-5 separate items was held in the focus of attention. Activated portion of long-term memory could be virtually unlimited, depending on time that has passed and the interferences that have occurred.

While it seems that there's a clear consensus that working memory capacity is limited, the nature of this capacity is highly disputed. The first argument is on whether this capacity is an item-based one or a time-based one. The other is on the issue of chunking, which refers to the grouping of similar items for better retrieval. Cowan (2005) listed many complications in understanding how chunking works. These issues will be discussed in the following sections. In working memory literature, there seems to be separation between studies that use verbal materials and those that use visual materials. Although there's a wide range of materials that can be used to assess working memory, here, we will only focus on verbal materials.

**Is working memory capacity item-based or time based?**

As mentioned before, after Miller (1956), many researchers tried to discover the number of items that can be held in working memory. However, Baddeley et al. (1975) compared working memory performance on short and long words that were matched in the number of syllables and phonemes among the words sets. The word sets only differed in the amount of time it takes the utter the words. They found that the number or proportion of items that are recalled in the correct serial position from a given list (serial recall) and decreased as the word length increased. This result, along with others, indicated that working memory has a time limit, rather than an item limit. Recall how Baddeley (1986) includes a phonological loop component to his model. It was hypothesized that, on the basis of other research, phonological information that can be covertly rehearsed and refreshed every two seconds. This also could mean that the rate of rehearsal (i.e. how quickly the words are repeated) determines the number of items can be kept active and retrieved.

The word length effect is a well-established phenomenon, which has been confirmed and replicated on many studies using a variety of word sets (eg. Hitch, Halliday & Littler, 1989; Hulme, Thomson, Muir & Lawrence, 1984; Lovatt, Avons & Masterson, 2000). Although, there are a number of reports to the contrary (e.g. Cowan, Wood, Nugent & Treisman, 1997). However, the crucial point here is the characteristics of words that generate this effect and the underlying processes in serial recall that is affected by these characteristics. Lovatt and Avons (2001), explains three ways that could the word-length effect could arise: (1) "long and short words may impose different storage demands on a strict phonological memory", (2) "since long words are pronounced more slowly, any memory system that depends on processing of real-time speech will be sensitive to the duration of these words" and (3) "short and long words may differ in their lexical properties, and these may become crucial if serial recall requires the identification of lexical items.

It had been proposed before that serial recall could be related to duration of the list items (Mackworth, 1963). Mackworth discovered that serial recall performance was better for digits and letters than colors and shapes. People also named the materials that were better recalled faster. Mackworth thought that materials that are named slower required more attention and that memory span was limited in terms of attentional capacity.

Baddeley et al. (1975) were the first investigators to relate serial recall to speech rates. They prepared two sets of ten disyllabic words that had different spoken durations and found that recall was poorer for the long duration items.

Baddeley, Thompson and Buchanan (1975) investigated the word length effect in a series of five experiments. In their first experiment they compared lists of short and long words, controlling for their frequency. The lists were presented at the same rate (1.5 seconds). They found that short words resulted in better memory span that long words (see Figure 1.4). However, their one-syllable and five-syllable word lists tended to differ linguistically in terms of their origin. Short words were generally of Anglo-Saxon origin but long words were generally of Latin origin.

To avoid this problem, they only used country names for their second experiment. This experiment also showed a clear word length effect. However, there were still two factors that can be confounded with the word length: spoken duration of words and number of syllables they contain.

In their third experiment, Baddeley, Thompson and Buchanan (1975) prepared two lists of disyllabic words that differed in their mean spoken duration. They measured the mean spoken length for each list and found it to be 0.77 and .46 seconds for long and short-duration words, respectively. They then divided these lists into four blocks, each containing five words. Two of them contained short duration words and two of them contained long duration words. They presented words at a 2 second/word rate and had their subjects recall the words at the same rate (by the aid of a metronome). (Figure 1.4) shows the results from this experiment. They found a word length effect for serial positions 1,2, and 3 but not for positions 4 and 5. The results were inconsistent with the prediction than a constant number of syllables can be held in short-term memory. Still, the words were not matched in the number of phonemes contained.In their fourth experiment, they matched the words in terms of frequency, spoken duration and number of phonemes. Subjects could recall 61.6% of the long duration words and 72.2% of the short duration words. Even then, an effect of word duration and serial position was found.

Similar results were also obtained in studies that assess digit span. For example, it has been found that Welsh digit names that take longer to read that English digit names and that English-Welsh bilinguals had higher digit spans in English than in Welsh. Chen and Stevenson (1988) found that Chinese digits took

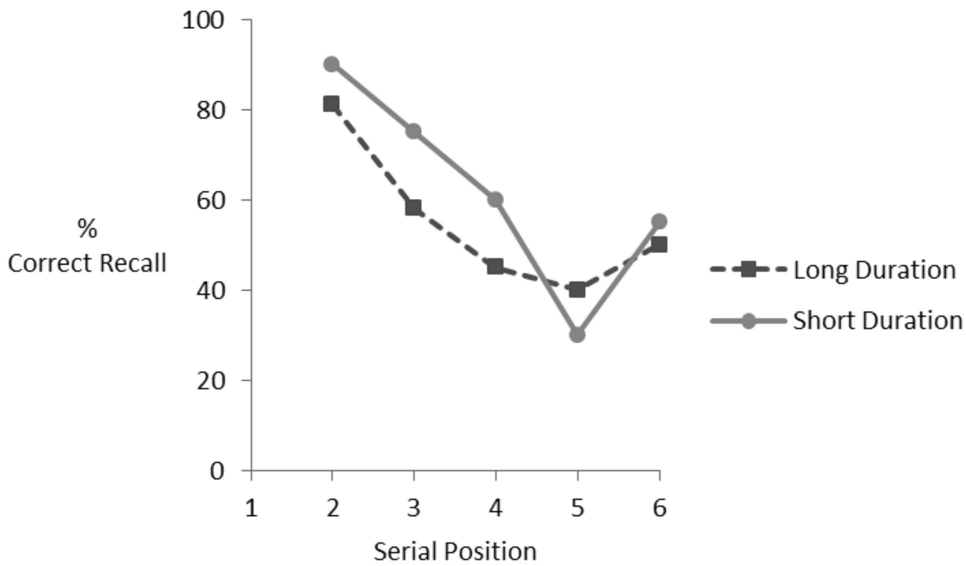


Figure 1 4 Mean recall of short and long duration disyllabic words as a function of serial position (Baddeley, Thompson and Buchanan, 1975) longer to read and that Chinese children living in America had higher digit spans. The general finding is that spoken duration of digits are inversely related to working memory span. Interestingly, individual speech rates have also been linked to serial recall performance. Baddeley et al. (1975), found a strong correlation between reading speed and serial recall. Also, articulatory suppression, which requires subjects to repeat a single syllable (e.g. "the, the, the...") aloud in order to prevent the articulation of the target words impairs memory performance, but eliminates the word length effect.

The relationship between serial recall and word length is linear. This has led Baddeley (1986) to suggest that the duration of the words accounted for word length effect. As mentioned before, Baddeley’s (1986) working memory model consists of a phonological loop, which has two components: articulatory loop, which holds phonological information that is linked to an articulatory process. Information in the articulatory loop decay at a fixed rate but held by rehearsal. Thus, serial recall for short duration words better, because more of them can be rehearsed before they decay from the phonological store. Many have replicated this result using Baddeley's original subset of long/short duration items (e.g. Longoni et al., 1993; Nairne, Neath & Serra, 1997). However, other lexical characteristics such as word frequency and imaginability are known to influence serial recall (e.g. Hulme, Maughan & Brown, 1991; Neath, 1997). So it is crucial to make sure this effect does not result from some other characteristic of the words, rather than their spoken duration.

A number of studies examining the word length effect found results to the contrary. Caplan, Rochon and Waters (1992), prepared word lists that were matched in terms of number of syllables and phonemes, but differed in spoken duration. They used both visual and auditory stimuli and the subjects had to point to pictures corresponding to the words presented. They had two sets of two-syllable long and short words. They used tense vowels for long words (eg., spider) and lax vowels for short words (e.g., devil). The mean output duration was 546 ms and 720 ms for short and long words, respectively. Surprisingly, the results showed that there was an advantage for longer words (Figure 1.5).

However, Caplan et al.'s(1992) study received criticisms regarding the materials used. Baddeley and Andrade (1994), found that their short words were phonologically more similar than their long words, which can lead to poorer recall and that their short and long word lists did not differ significantly when the word pairs were repeatedly articulated.

In response to these criticisms, Caplan and Waters (1994) remeasured the speech rates for their stimuli in another experiment. They used 10 lists for the long and short word sets to assess their subjects. Subjects were instructed to read each list as fast as possible. They also rated the word pairs in the long-word and short-word lists in terms of phonological similarity. They found a significant difference between the mean speech durations of the lists. The phonological

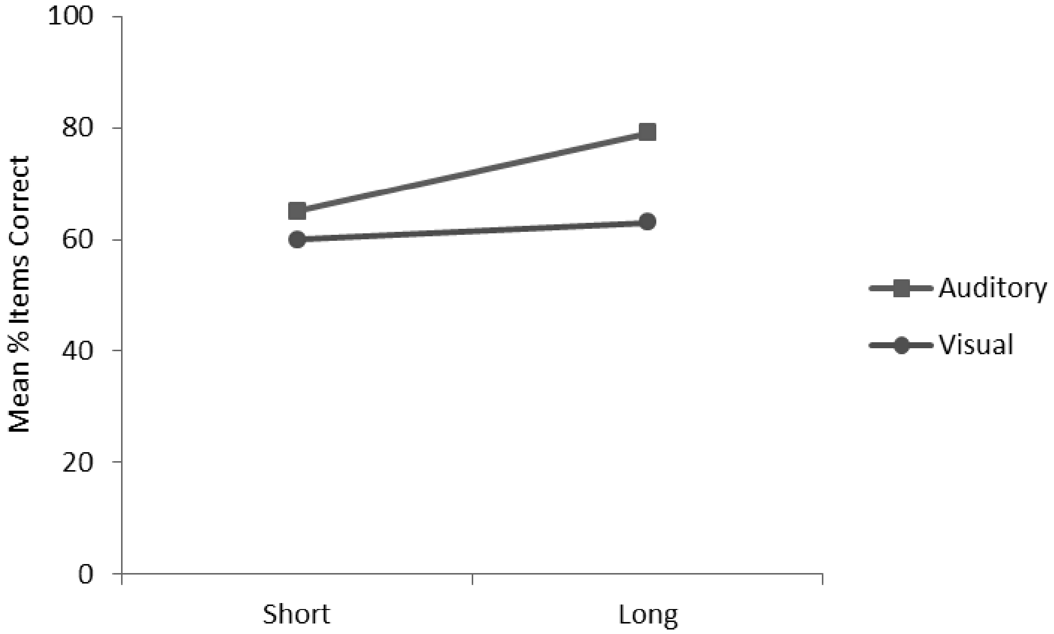


Figure 1.5 Mean percentage of items correctly recalled for words with lax vowel and tense vowels (Caplan et. Al.,1992).

difference ratings did not differ significantly either. Also, again, recall performance did not differ for the long-duration and short-duration lists.

Following this, Lovatt et. al. (2000), devised two sets of words that were matched on frequency, familiarity, number of phonemes, and phonemic similarity but varied on spoken duration. They presented their lists both visually and auditorily; and they measured serial recall both with both spoken and pointing recall. Subjects generally performed better with pointing recall but there was no interaction between recall type and word duration. These mixed results may indicate that for disyllabic stimuli, the word-lenght effect is not reliable.

Service (1998) took advantage of Finnish phonological structure to control the spoken duration of words and phonological complexity. The Finnish language consists of long and short versions of the same vowels and consonants. Long phonemes have longer spoken durations than short phonemes. So, using long phonemes increases the duration of the word, while keeping complexity constant (eg., / nu: k: i/, pronounced as nuukki, where u: and k: denote long phonemes. Service used non-words to assess memory span and found no difference between short non-words and long non-words. In another experiment, the spoken duration of words were held constant but the phonological complexity was manipulated. Service found that memory span was lower when the phonological complexity increased and concluded that the word length effect depended on phonological complexity, rather than duration.

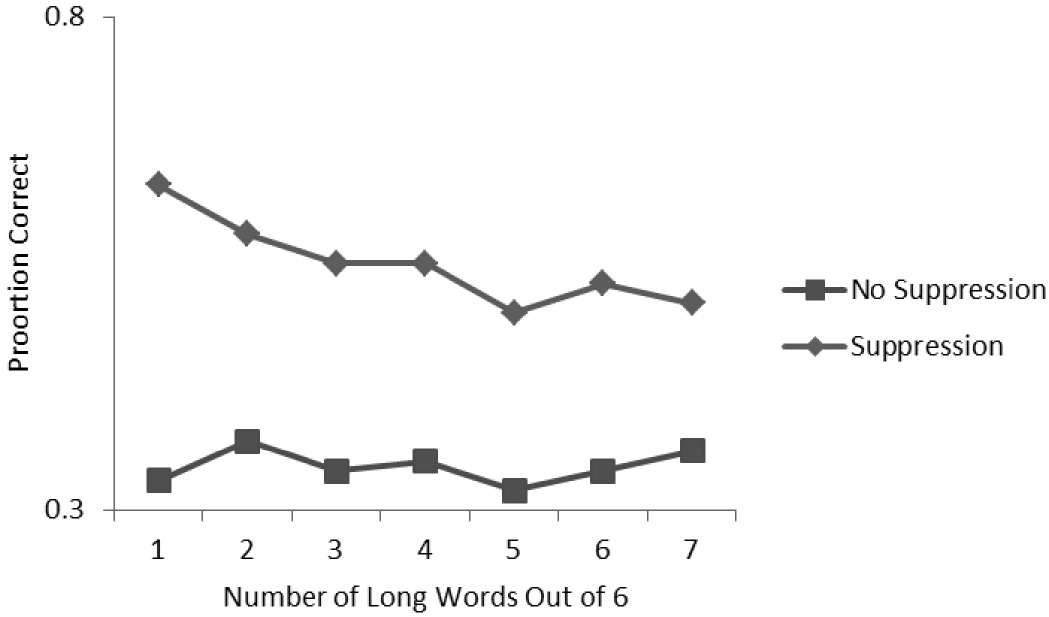


Figure 1.6 Mean Proportion correct as a funstion of list composition (Cowan et. al. 2003)

Another theoretical disparity in the causes of the word length effect is between the globalist and localist accounts of this phenomenon. Globalist accounts (e.g., Baddeley, 1986) propose that the lengths of some words in the list affect the recall performance on the other words on the list. Thus, overall features of some specific word list can influence the measured memory span. On the other hand, localist accounts holds that the specific length of each word from the list only affect the recall of that word itself (Neath and Nairne, 1995) (see Table 1.1). Both accounts predict that as the words get longer, overall performance decreases. However, they differ on how this effect occurs. To test this, Cowan, Baddeley, Elliott and Norris (2003), have devised 98 lists where each contained six words (zero, one, two, three, four, five or six short words and complementary long words in each case). They also included articulatory suppression to half of the trials. While they found an effect of list composition, they did not find any pairwise differences

These results indicate that the word length effect may not solely rely on spoken duration of words, despite being robustly influenced by it. In this thesis, we compare words of similar length, while manipulating the units of information those words convey. However, the problem with this manipulation is that it is quite difficult to control the effects of the type of words (verbs vs. nouns) or the frequency. These often covary with this manipulation.

Also, Neath, Bireta and Surprenant (2003) replicated the previous experiments. They were able to obtain the same result as Baddeley, Thompson and Buchanan (1975), using the same stimuli. They also found a reverse word

**Table 1**
**Proportions of Short and Long Items Recalled in Order in Experiments 1 – 4 and Pronunciation Time (in milliseconds)**

| | Proportion Recalled | Normal Pronunciation Time (msec) | Speeded Pronunciation Time (msec) |
|---|---|---|---|
| Experiment 1 | | | |
| Short | .403 | 484 | 390 |
| Long | .351 | 587 | 456 |
| Experiment 2 | | | |
| Short | .400 | 470 | 364 |
| Long | .513 | 570 | 416 |
| Experiment 3 | | | |
| Short | .411 | 490 | 353 |
| Long | .418 | 572 | 423 |
| Experiment 4 | | | |
| Short | .470 | 626 | 475 |
| Long | .472 | 744 | 543 |

Table.1.1 Result obtained by Neath et. Al (2003)

length effect similar to the Caplan et. al. (1992) study. However, when they replicated the procedure that Lovatt et. al. used (2000), the observed no difference between recall of long and short words. Also, when they used a new set of stimuli, they did not find an effect of word length. They concluded that the word length effect is not robust.

**Working memory capacity and chunking**

Slak (1970), conducted an experiment where he and another person were the only participants. Over time, they have trained themselves to recode chunks of three digits into syllables into CVC (consonant-vowel-consonant) triagrams. The first digit was decoded into the first consonant, the second digit was decoded into a vowel and the third digit became the last consonant of the triagram. They have learned thirty different transformation rules. The stimuli were read aloud as single digits or in another condition, as a series of syllables and recoded into their original three digit form. This procedure resulted in an increase in the number of digits that could be recalled. However, this invrease was not substantial. On the other hand, in the control condition, they mastered in recalling digits, and recalled as much as 9 digits. Using the recoding method, their spans reached to 14 digits where they would recall 27 digits, if recoding was perfect. However, we nnot precisely determine how many chunks were actually recalled.

Kleinberg and Kaufman (1971), used a different material to measure chunking. They had their subjects learn arrays of dots that were presented inside an 8 x 8 grid. A different name was given to each different dot-pattern serie. Some subjects were presented two distinct patterns which appeared in series of four dot-patterns. They gave a different letter name to each sequence that consisted of four patterns. Other subjects received four distinct patterns and a different letter name was given to each two-pattern sequence. There was another group of subjects that did not learn these patterns. Long series of patterns were presented to the subjects were told to recall them. Those who learned the recoding could recall about four letters, which makes four chunks.

These studies showed that memory span could be dramatically increased by using these rules. However, most studies during this time did not indicate how chunking occurred. Simon (1974), claimed that the number of chunks recalled cannot be determined unless we can independently identify those chunks.

However, the term chunking may be an oversimplification of what appears to be a network of complex associations. Cowan (2005), lists many complicated properties chunks can have. For instance, "Chunks may have a hierarchical organization", which means that people can chunk information on multiple levels. This way, they can form "superchunks" to overcome the capacity limit, by shifting their attention from one level to another. Generally, a chunk is thought to be similar to a categorical group of items (i.e furniture). However, "chunks may be the endpoints of a continuum of associations". For example, the words tree and dictator may not be closely associated. However, if you imagine a dictator that uses extreme force against protests about a tree being cut down in some imaginary country, you might be able to recall the words. Also, "chunks may include asymmetrical information" such that the association between a pair of words may not be symmetrical. If you see the word Gangnam you will probably think of the word style. On the other hand, if you see the word style it is less likely that you will think of the word Gangnam (perhaps "APA" if you are a psychologist). These are some of the issues Cowan (2005) have pointed out.

Cowan, Chen and Rouder (2005), conducted a rather complicated experiment to identify chunks. They trained their subjects with different word arrangements and either tested them with list recall first and cued recall second (Experimen 1); or vice versa (Experiment 2). This made up the two different experiments of the study. Table 1.2 illustrates the outline of their conditions and study. The words were randomly paired in each condition, such as shoedog, toe-brick, hat-grass, and car-fish. They tested their subjects on 8-item lists than included previously paired words. They found that serial recall and cued recall performance increased as the number of consistent pairings increased. This inrease can be atrributed to the proportion of two-word chunks that the subjects were exposed.

Chen and Cowan (2005), investigated the capacity limits in serial recall and free recall. They manipulated the length of lists that contained singletons or previously learned pairs. In the training condition, singletons were repeatedly presented until the subject could recall these words perfectly. For the training trials, a singleton or the first word of a previously learned pair was presented.

Subjects had to recall the second word in the pair or say that the word was previously presented as a singleton. Then feedback was given.

They then went onto the serial recall or the free recall phase. Because the training continued until perfect recall was achieved, Chen and Cowan (2005) assumed that the pair was recalled as a single chunk. They compared performance on lists that consisted of singletond and those that consisted of learned pairs. Thus, performance on a list that contained 5 singletons should ve equal to those that contained 5 learned pairs. On the free recall condition, performance on lists of 6 learned pairs were almost equal to the lists of 6 singletons. However, a length limit occured in serial recall.

In a similar experiment Chen and Cowan (2009) provided evidence for a constant capacity limit. The training phase was similar to their previous study (i.e. Chen and Cowan, 2005). For the recall phase, subjects were presented lists of 4, 6, 8, or 12 singletons or 4 or 6 learned pairs. To assess the role of phonological rehearsal, half the subjects engaged articulatory suppression. Without articulatory suppression, mean recall performance changed across different list types. When rehearsal was prevented with articulatory suppression, it resulted in a span of almost 3 chunks for all the list types (Figure 1.7).

| Training Phase |
|---|
| **Stlimuli** |
| Words with 3-4 letters, 3-5 phonemes, 1 syllable, a Kucera and Francis written words frequency higher than 12, a concreteness rating higher than 500. Random presentation of words and word pairs. |
| **Training Conditions (all intermixed)** |
| 0-*paired* condition: 8 items were presented 4 times singly.<br>1-*paired* condition: 8 items were presented 1 time in consistent pairs and 3 times singly.<br>2-*paired* condition: 8 items were presented 2 times in consistent pairs and 2 times singly.<br>4-*paired* condition: 8 items were presented 4 times in consistent pairs |
| **Procedure** |
| The task is to read each word alooud as it appears |
| **Serial-Recall Phase (Experiment 1, second phase; Experiment 2, third phase)** |
| **Stimuli** |
| Lists of 8 words presented in the same pairs as were used in the training phase.<br>All 8 words in a list from a single training condition.<br>In the 0-paired condition, pairings were not previously known to the subject.<br>In a no-study condition, words in the list did not appear in the training phase. |
| **Procedure** |
| Task is to recall the 8 words in a list in order by typing them into the keyboard. |
| **Cued-Recall Phase (Experiment 1, third phase; Experiment 2, second phase.** |
| **Stimuli** |
| The first word in a pair is presented. The pairings are the same ones used in serial recall and in the 1-, 2-, and 4-paired conditions, used previously in training. Words from all training conditions randomly intermixed. |
| **Procedure** |
| The task is to recall the second word in the pair by typing it to the computer.In Experiment 1, in the no-study and 0-paired conditions, the correct response was known only from the serial-recall phase. In Experiment 2, in the no-study condition and 0-paired conditions, the pairing had never yet been seen and a permitted response was N (word never seen yet) or S (word seen before but not in a pair. |

Table 1.2 The training and testing procedure used by Cowan et. al. (2005)

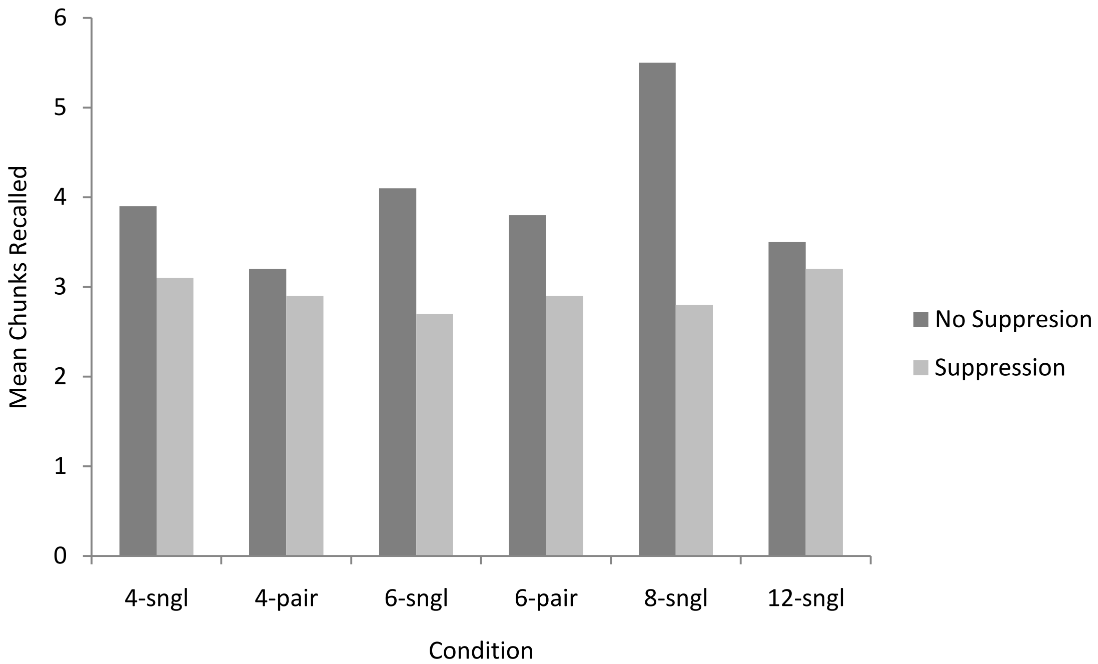


Figure 1.7 Mean number of chunks recalled with and without articulatory suppression for each type of lists (Chen and Cowan, 2009)

In general, chunking is thought to involve semantic associations between words that provide cues for one another. A different characteristic of agglutinative languages such as Turkish is that some words can convey more than one unit of meaning. In this thesis, we will use this property to determine whether chunking can involve a physical aspect, so that more information can be retained if a physical chunk (such as gel- (e)cek –(i)m; meaning, I will come). We will call this process physical chunking.

# CHAPTER 2

# EXPERIMENTS

## Experiment 1A

Although there are some discussions on working memory capacity (i.e. number of items that can be maintained in working memory), there's little research on the nature of this capacity. The majority of studies focuses on determining the exact number of items (or chunks) that can be held in working memory and the general finding is that this number is around 4 (Cowan, 2001). Generally, especially in studies of verbal working memory capacity, it is measured as the number of words that can be recalled immediately (such that, if 4 singular words can be recalled, working memory capacity is thought to be 4). This means that each word consists of only one piece of information. However, neuropsychological findings do not implicate a specific capacity within this domain as they suggest that retrieval from working memory does not differ from retrieval from long term memory.

As mentioned before, in some agglutinative languages such as Turkish, a single word (in this case, verb) can convey more than one unit of meaning (such as the "tense" and the "person" of the verb). In Experiment 1A , we took advantage of this feature to determine whether these kind of words yield a different kind of chunking mechanism and whether there the number of items held in verbal working memory is different for letters, nouns and root verbs or agglutinated verbs. We predicted that although there might be a difference between letters and other words, capacity for verbs and nouns would not differ; and that if the agglutination of verbs allows for a different kind of chunking mechanism, the capacity for root verbs (condition 1) and agglutinated verbs (condition 2) would not differ.

***Method***

<u>Participants</u>

Forty eight students taking the introductory psychology course at Boğaziçi University and a statistics course İzmir University of Economics participated in the study. All participants gave informed consent (see Appendix A) and received course credit for their participation. The subjects were assigned randomly to the two conditions.

Apparatus and Stimuli

All experiments, stimuli, timing operations and data collection were controlled by a PC running E-prime 1.2 software (Psychology Research Tools, Inc). The stimuli were presented on a white background on a 17-in CRT computer monitor with a viewing distance of approximately 57 cm. The resolution was set to 640 x 480. Hence, 1 pixel was approximately .05° of visual angle.

There were two different conditions (Root verbs and Agglutinated verbs) and within each condition there were three different tasks (Operation span (Ospan; Unsworth, Heitz, Schrock, & Engle, 2005), Nouns and Verbs). The primary measure of interest was the verbal working memory capacity for different kinds of verbs (root and agglutinated), which makes up our two different conditions. The ospan task was used as a standard control measure to determine if there was a difference among the participants in each condition in terms of working memory capacity. The "noun task" was also used as a control measure, but it was used to control for the different nature of the ospan and the verb tasks. The ospan task uses single letters to determine verbal working memory capacity, whereas the verb tasks use different verbs. So the noun task was employed to control for the effects of word length. In each condition, the

| | First | Second | Third |
|---|---|---|---|
| Condition 1 | Verb Task (Agglutinative) | Noun Task | Ospan Task |
| Condition 2 | Verb Task (Root) | Noun Task | Ospan Task |

Table 2.1 The presentation orders for three different tasks in condition 1 and condition 2

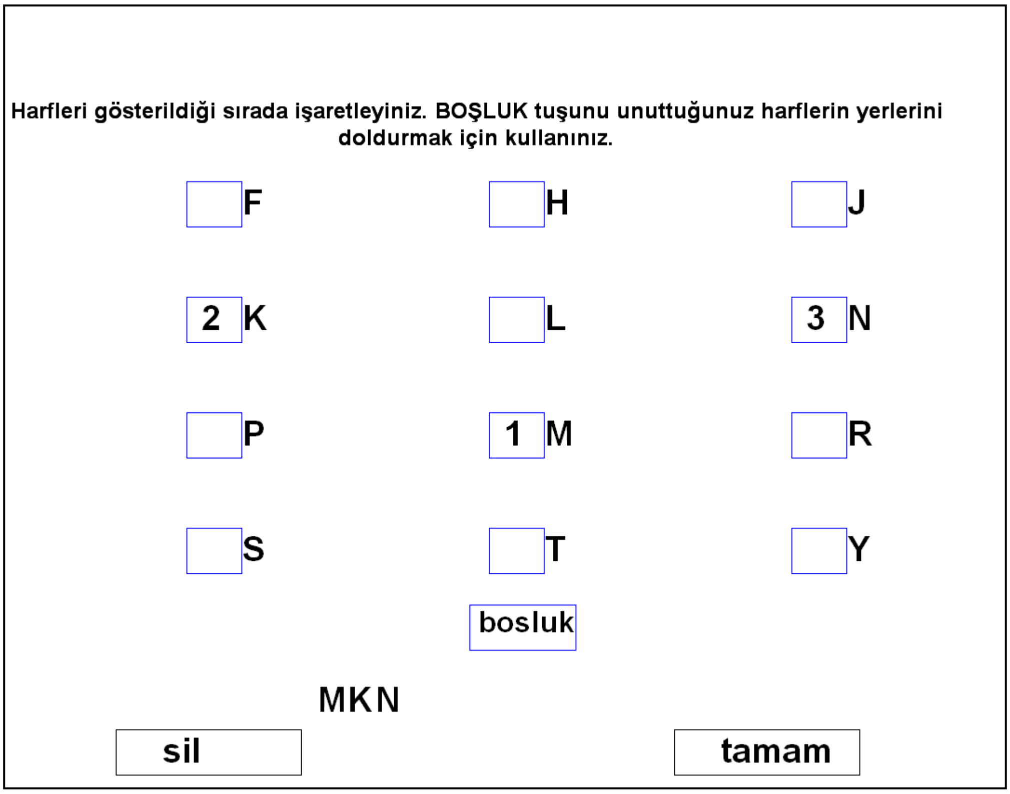

Figure 2.1 Sample response grid for the automated operation span task

tasks were presented in the same order: the verb task, the noun task and the ospan task.

<u>The Automated Span Task</u>

An automated version of Operation span task (Ospan; Unsworth, Heitz, Schrock, & Engle, 2005) was used to measure working memory capacity. In Ospan task, participants were presented with simple mathematical questions to solve while asked to remember letters for later recall. There were three sections of practice trials. In the first section, participants practiced with either 2 or 3 letters, one at a time for 1000 ms [Y1] and then asked to recall the letters in the exact order. They responded by clicking the letters they saw among the 12 letters (F, H, J, K, L, M, N, P, R, S, T, Y) presented to them, followed by clicking an "Exit" button to start the next trial. There were 4 trials in this section and feedback about how many letters were correctly recalled was provided after each trial.

In the second section, participants practiced with solving math operations. They were given a simple math operation (e.g., (4*3) + 4 = ?) at the center of the screen. After solving it they were asked to click. Then they were given an answer choice of a digit (e.g. 4) and asked to decide if it is correct or incorrect by clicking one of the buttons presented at the screen. They were instructed to respond as accurate and as quickly as possible. There were 15 practice trials and feedback was provided after each trial. The average response time of each participant was measured to be used as a baseline (average RT + 2.5 SD) in the experimental trials. By this way, it was possible to account for the individual differences in response times.

In the third practice session, participants practiced with both tasks simultaneously. First, they solved a series of the math problems, each followed by a letter. Then they recalled the letters in the exact order by clicking them among the 12 letters. In order to prevent rehearsals, participants instructed that if their response time was slower than their average in the math practice session, they will not be allowed to answer to the math operation and it will count as an error. There were 3 practice trails with set size 2 and no feedback provided this time. Only the percentage of correct math responses made until that trial was presented in red at the right corner of the screen and participants were told to try setting this number at least to 85.

The experimental trials were the same as those of the third practice session. The set sizes ranged from 3 to 7, with 3 sets from each set size. Therefore, there were 15 trials (75 letters and 75 math problems) in total in the experimental section. During the whole experiment, all responses were made by clicking the left mouse button.

We calculated the Ospan score which was the sum of the number sets in which all letters were recalled. The Ospan task is proposed to represent both storage and processing capacity of working memory (Engle, Kane, & Tuholski,


Figure 2.2 Sample response grid for the noun task.

1999). The completion of this task took approximately 20-25minutes. of at least 6 letters. Unfortunately, this tends to decrease the average frequency of the nouns, which might have an effect on working memory performance.

The Verb Tasks

The verb tasks were similar to the other two tasks (ospan and noun). The type of verb (root or agglutinated) determined which the subjects were assigned. In the agglutinated verb condition, subjects were presented agglutinated verb in Turkish (such as, gel –(e)cek –(i)m; meaning, I will come). Thus, each word consisted of three units of meaning: the verb, tense and the person. For convenience, the verbs were presented only in three different tenses, past simple, present simple andfuture. Also, the verb could be in first person singular, first person plural, second person singular, second person plural, third person singular (note: Turkish language does not convey gender in third person singular) and third person singular. So in total, there were there were 18 agglutination options (3 tenses X 6 persons; see Table 2.2). Verbs in other tenses tend to be longer, so these were selected to constrict the word lengths.

There were a total of 12 trials, with target words varying between 2 and 7. On each trial, subjects were presented the target words along with the simple math problems. At the end of each trial, subjects had to choose the target words from the 12 word-grid on the screen by clicking the words in the exact order they were presented. In the experimental session, the subjects did not receive any feedback, except for the percentage of correct math responses. In total, the subjects saw 144 words, with 54 of them being target words and 90 of them being non-target words.

Among the 144 words, each of the agglutination options appeared equally often. For target words, each appeared three times and for non-target words, each appeared five times.  Also, target words appeared in random positions in the 12-word trial grids.

| Person | Tense |
|---|---|
| First singular<br>Second Singular<br>Third Singular<br>First Plural<br>Second Plural<br>Third Plural | Past Simple<br>Present Simple<br>Future |

Table 2.2 Tenses and persons used for agglutination of verbs

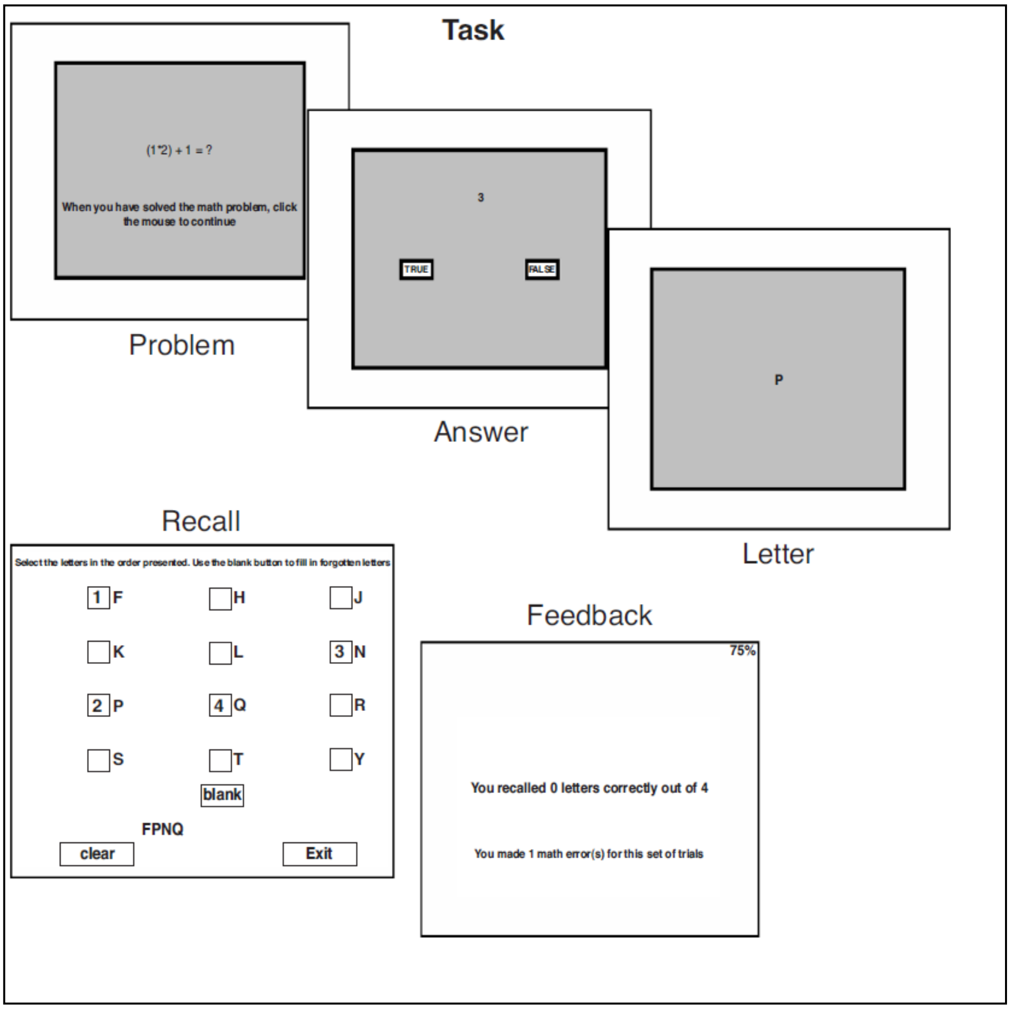


Figure 2.3 Procedure for the noun, verb and the ospan tasks. A math operation is presented to the subjects. After solving the operation, they clicked on the screen and a number is presented. Subjects decide whether this number is the correct answer for the operation. This is followed by a letter, noun or verb, depending on the task. Subjects are required to select the items from the set in correct order. Then a feedback is provided (from Unsworth et al., 2005).

***Results***

Correlational Analysis

First, in order to examine the relationship between participants' performances on each task, we conducted a series of correlational analysis for each condition separately. For Condition 1, the results show that all the correlations between our working memory span measures were statistically significant (see Table 2.3). This suggests that, all the tasks measure the same underlying construct, namely, working memory capacity.

For Condition 2, the correlations between verb roots and letters were also significant. However, the scores in the noun condition did not correlate with the other scores (see Table 2.4). This may be due to individual differences between groups. But before, we need to examine the t-test results.

| | | Agglutinative Verbs | | Letters | | Nouns | |
|---|---|---|---|---|---|---|---|
| | | Absolute Score | Total Score | Absolute Score | Total Score | Absolute Score | Total Score |
| Agglutinative Verbs | Absolute Score | - | | | | | |
| | Total Score | .847** | - | | | | |
| Letters | Absolute Score | .685** | .671** | - | | | |
| | Total Score | .598** | .669** | .944** | - | | |
| Nouns | Absolute Score | .639** | .686** | .676** | .666** | - | |
| | Total Score | .704** | .811** | .742** | .725** | .889** | - |

**p < .01.

Table 2.3. The Pearson Product-moment Correlations among Absolute Scores and Total Scores in Each Task for Condition 1.

| | | Verb Roots | | Letters | | Nouns | |
|---|---|---|---|---|---|---|---|
| | | Absolute Score | Total Score | Absolute Score | Total Score | Absolute Score | Total Score |
| Verb Roots | Absolute Score | - | | | | | |
| | Total Score | .890** | - | | | | |
| Letters | Absolute Score | .421* | .517** | - | | | |
| | Total Score | .534** | .564** | .915** | - | | |
| Nouns | Absolute Score | .330 | .190 | .285 | .280 | - | |
| | Total Score | .319 | .284 | .257 | .369 | .700** | - |

*$p < .05$, **$p < .01$.

Table 2.4 The Pearson Product-moment Correlations among Absolute Scores and Total Scores in Each Task for Condition 2.

Agglutinative Verbs vs. Nouns for Condition 1

In order to examine whether the WM capacity was affected by the type of the word being processed (Agglutinative Verbs or Nouns), we compared the performance in the verb Task and the noun Task in condition 1 for each dependent measure. First, a series of within subjects t-tests was conducted for Absolute Score and Total Score separately. We hypothesized that, if the retention of agglutinative verbs involved a different kind of chunking mechanism, the performances would not differ. Results revealed that performance was similar for Verb Task ($M = 15.44$, $SD = 8.34$) and Noun Task ($M = 16.00$, $SD = 8.11$) in terms of the Absolute Score, $t(24) = -.40$, $p = .69$, Cohen's $d = .07$, effects size $r = .03$. However, similar to our expectations, performance was significantly lower in the Verb Task ($M = 30.52$, $SD = 9.81$) compared to the Noun Task ($M = 33.84$, $SD = 10.27$) in terms of the Total Score, $t(24) = -2.69$, $p = .013$, Cohen's $d = .33$, effects size $r = .16$ (see Figure 2.4).

Then, we were interested whether two tasks differed in terms of the math performance. A series of within subject t-tests was conducted for each math measure. We hypothesized that if the retention of agglutinative verbs required more cognitive effort, math error would also be higher in the verb task. Contrary to our expectations, Math Error was higher in the Noun Task ($M = 8.24$, $SD = 5.63$) compared to the Verb Task ($M = 5.24$, $SD = 2.93$), $t(24) = -2.66$, $p = .014$, Cohen's $d = .67$, effects size $r = .32$. We further examined the nature of the error difference between two tasks. Results showed that the error difference resulted from the Speed Error rather than the Accuracy Error. Participants made more Speed Error in the Noun Task (M =3.28, SD = 4.73) compared to the Verb Task (M = 1.16, SD = 1.31), t(24) = -2.15, p = .042, Cohen's d = .61, effects size r = .29. However, their responses were similarly accurate in both Noun (M = 4.96, SD = 3.63) and Verb Tasks (M = 4.08, SD = 2.63), t(24) = -1.41, p = .17, Cohen's d = .28, effects size r = .14 (see Figure 2.4).

<u>Verb Roots vs. Nouns for Condition 2</u>

We replicated the above analysis for our second condition to examine whether the WM Capacity differed depending on the different type of word in the specific task (Verb Roots or Nouns). We expected that performance in the verb task would be higher, as the average word length was smaller for verb roots. Also, verb roots end to be more frequent than nouns, as we tried to match these words to agglutinated verbs in terms of length. In order to test our expectations, we conducted a series of within subjects t-test with Task Type (Verb Roots or Nouns) as within subject variable and Absolute Score and Total Score as dependent measures. Analysis based on the Absolute Score revealed that performance was significantly higher in the Verb Task (M = 20.12, SD = 7.48) than the Noun Task (M = 15.24, SD = 6.39), t(24) = 3.02, p = .006, Cohen's d = .70, effects size r = .33. However, performance was not different in terms of the Total Score between Verb (M = 34.20, SD = 8.34) and Noun (M = 34.04, SD = 6.00) Tasks, t(24) = .09, p = .928,

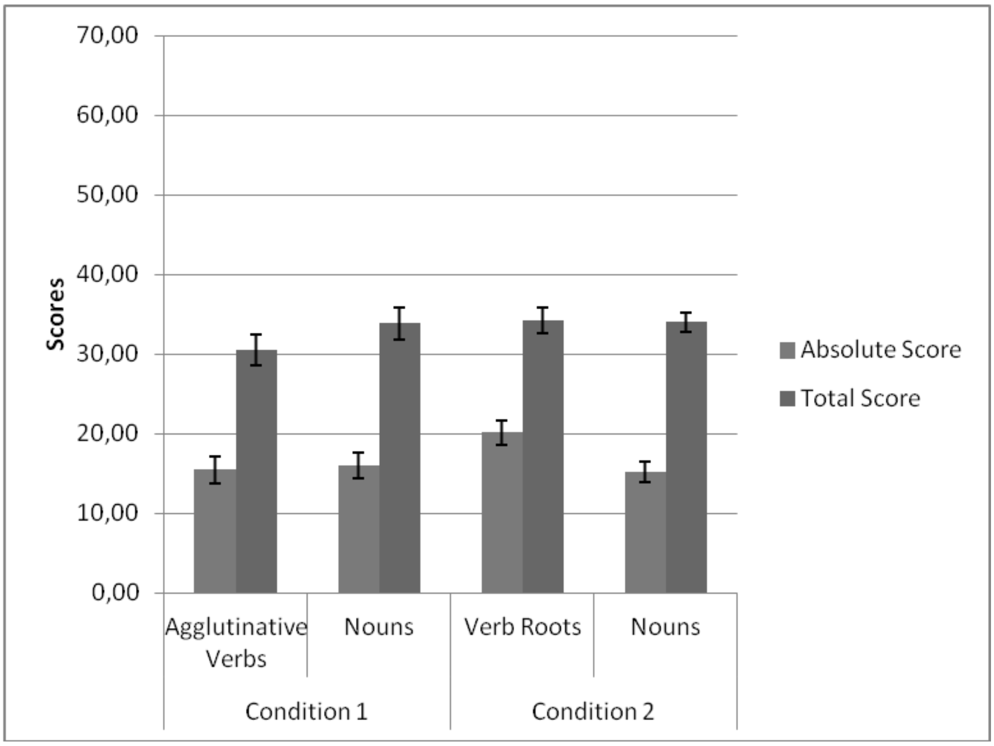


Figure 2.4 Absolute Score and Total Score for tasks in each condition[1]

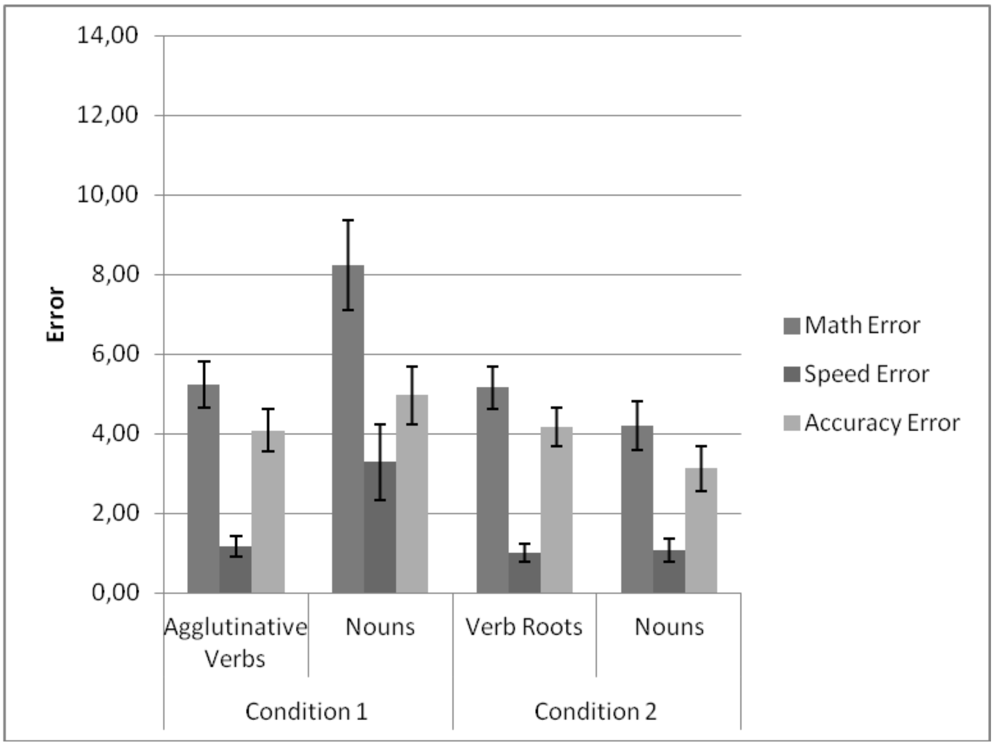

Figure 2.5 Amount of Math Error, Speed Error and Accuracy Error for tasks in each condition

Cohen's d = .02, effects size r = .01 (see Figure 2.4). Results suggest that while serial recall was better for verbs, memory span did not vary among the two tasks.

Then, we examined the performance differences between two tasks in terms of the math errors. A series of within subjects t-tests was conducted for each math measure. The results showed that there was a marginally significant difference between the performance in the two tasks in terms of the Math Error, t(24) = 2.02, p = .054, Cohen's d = .33, effects size r = .17. Error was higher in the Verb Task (M = 5.16, SD = 2.67) compared to the Noun Task (M = 4.20, SD = 3.01). When further investigated this difference, unlike to the first condition, we found that it resulted from the Accuracy Error rather than the Speed Error. Accuracy was significantly lower in the Verb Task (M = 4.16, SD = 2.46) than the Noun Task (M = 3.12, SD = 2.79), t(24) = 2.40, p = .025, Cohen's d = .40, effects size r = .19. However, there was no difference between Verb (M = 1.00, SD = 1.16) and Noun (M = 1.08, SD = 1.44) Task, in terms of the Speed Error, t(24) = -.25, p = .81, Cohen's d = .06, effects size r = .03 (see Figure 2.5). This pattern of results suggest a tradeoff between math performance and memory performance.

Agglutinative Verbs vs. Verb Roots

In order to examine whether WM Capacity differs depending on stimulus type (agglutinative verbs vs. verb roots), we conducted a series of between subjects t-tests with Condition (Agglutinative Verbs vs. Verb Roots) as the between subject variable. Our dependent variables were again Absolute Score, Total Score and

Math Error (Speed and Accuracy Error). We expected that if agglutination of verbs provided a different kind of chunking mechanism, performance would not differ. However, agglutinated verb are naturally longer in length than verb roots, so a word length effect may occur.

First, we found that Absolute Score was lower in the Agglutinative Verbs ($M = 15.44$, $SD = 8.34$) compared to Verb Roots ($M = 20.12$, $SD = 7.48$), $t(48) = -2.09$, $p = .042$, Cohen's $d = .59$, effects size $r = .28$. Additionally, although Total Score was also lower in the Agglutinative Verbs ($M = 30.52$, $SD = 9.81$) than Verb Roots ($M = 34.20$, $SD = 8.34$), it did not reach the significance level, $t(48) = -1.43$, $p = .159$, Cohen's $d = .40$, effects size $r = .20$. This suggests that serial recall is better for verb roots. However, we cannot determine whether this occurred as a result of the word length effect or as a result of the information load in agglutinative verbs. For the total score, the difference was not significant, suggesting a chunking mechanism for these words.

Second, we examined whether performance in these two conditions differ in terms of the math results. We found that there were no difference between the conditions in terms of the math error, $t(48) = .10$, $p = .920$, Cohen's $d = .03$, effects size $r = .01$. In other words, participants made similar error both in the Agglutinative Verbs ($M = 5.24$, $SD = 2.93$) than Verb Roots ($M = 5.16$, $SD = 2.67$). We also compared the conditions in terms of Speed and Accuracy Error separately. Again, both Speed and Accuracy Error was not different between Agglutinative Verbs (Ms = 1.16 and 1.31, SDs = 4.08 and 2.63, respectively) and Verb Roots (Ms = 1.00 and 1.56, SDs = 4.16 and 2.46, respectively), $t(48) = .46$, $p =$

.65, Cohen's d = .04, effects size r = .02 and t(48) = -.11, p = .91, Cohen's d = .10, effects size r = .05, respectively.

Ospan Analysis (Letters)

We utilized an Ospan task using letters as stimuli in order to collect a baseline measure from our participants in each condition. Data of three participants in Agglutinative Verbs condition was missing; therefore the total sample for this analysis was 47. We compared the conditions with between subjects t-tests and expected all dependent measures to be similar between conditions. We found that the conditions were similar both in terms of Absolute Score and Total Score, t(45) = -.998, p = .324, Cohen's d = .29, effects size r = .14 and t(45) = -1.31, p = .198, Cohen's d = .38, effects size r = .19, respectively (See Figure 2.6). Similarly, there were no difference between conditions in terms of Math Error, t(45) = 1.01, p = .32, Cohen's d = .29, effects size r = .14. (For Speed Error, t(45) = .36, p = .724, Cohen's d = .10, effects size r = .05; for Accuracy Error, t(45) = 1.40, p = .170, Cohen's d = .40, effects size r = .20 (see Figure 2.7). The results suggest that participants in each condition were similar in terms of the baseline measure of WM Capacity. Therefore we can safely compare the subjects in each condition.

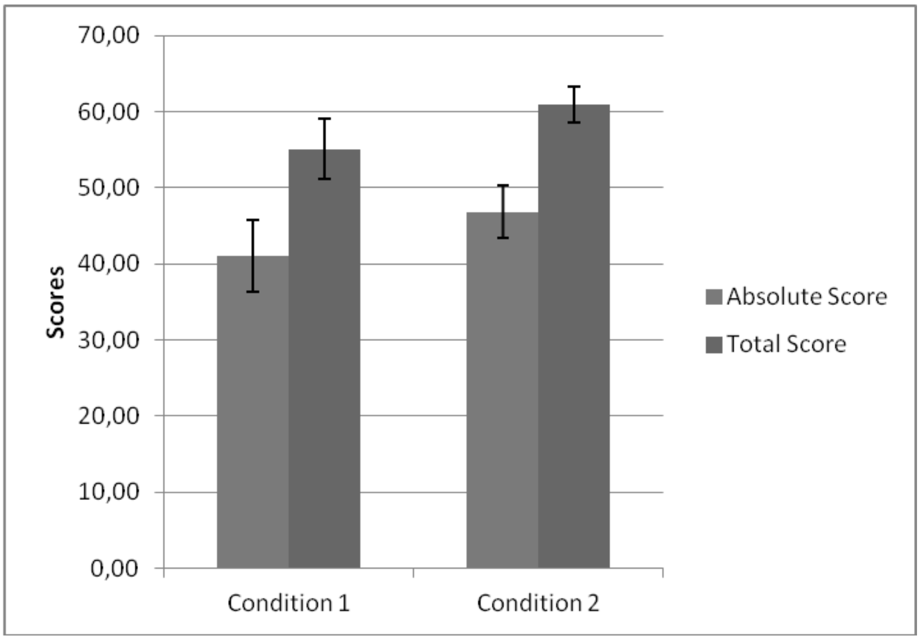

Figure 2.6. Absolute and Total Scores for Ospan Task (letters) in each condition.

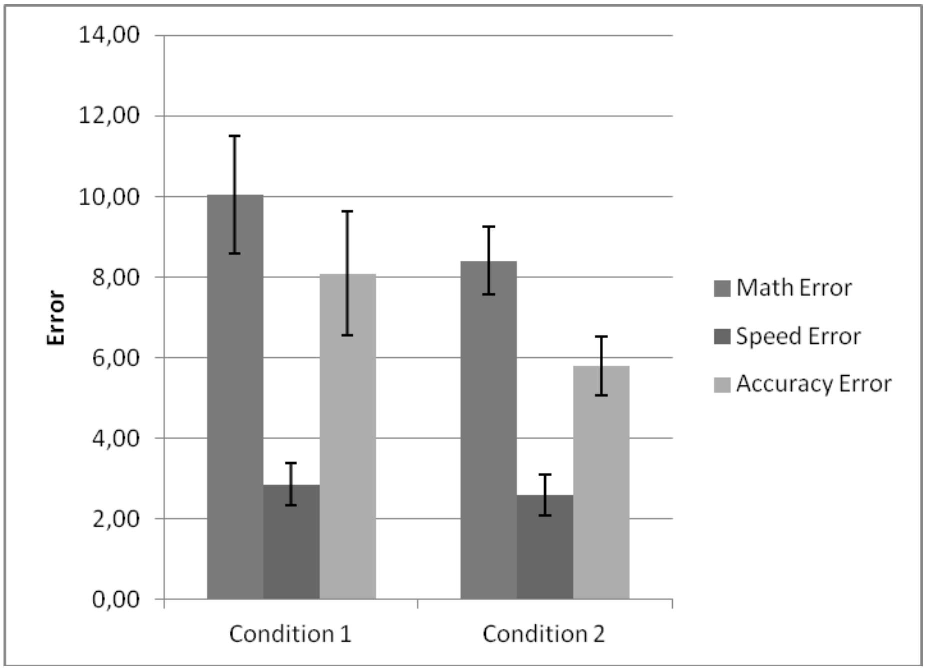


Figure 2.7. Amount of Math Error, Speed Error and Accuracy Error for Ospan Task (letters) in each condition.

Ospan Analysis (Nouns)

Similar to our baseline measure, we also compared participants' performances on the Noun Task in each condition. We again compared the conditions with between subjects t-tests and expected all dependent measures to be similar between conditions. Consistent with our expectations, we found that the conditions were similar in terms of both Absolute Score and Total Score, $t(48) = .37$, $p = .715$, Cohen's $d = .10$, effects size $r = .05$ and $t(48) = -.08$, $p = .933$, Cohen's $d = .02$, effects size $r = .01$, respectively. However, participants in the Agglutinative Verbs condition ($M = 8.24$, $SD = 5.63$) made more Math Error than those in the Verb Root condition ($M = 4.20$, $SD = 3.01$), $t(48) = 3.16$, $p = .003$, Cohen's $d = .89$, effects size $r = .41$. When we further examined the nature of math error, we found that the same pattern of results exist for both Speed and Accuracy Error ($t(48) = 2.22$, $p = .031$, Cohen's $d = .63$, effects size $r = .30$ and $t(48) = 2.01$, $p = .050$, Cohen's $d = .57$, effects size $r = .27$, respectively). These findings suggest that although the WM Capacity for this task were similar for participants in each condition, participants who completed the Agglutinative Verbs Task rather than the Verb Root Task before the Noun Task made more math error.

This pattern of results indicate that an order effect may have confounded our results. That is, because the tasks were given in a fixed order to all the subjects, the verb task in different conditions might have had a differential effect on subjects’ performance on the other two tasks (recall that the verb task was given first to all the subjects). However, this might indicate that the agglutinative verbs require more cognitive effort, which is reasonable.

## Experiment 1B

### *Method*

#### Participants

Forty eight students taking the introductory psychology course at Boğaziçi University participated in the study. All participants gave informed consent (see Appendix A) and received course credit for their participation. The subjects were assigned randomly to the two conditions.

#### Apparatus and Stimuli

All experiments, stimuli, timing operations and data collection were controlled by a PC running E-prime 1.2 software (Psychology Research Tools, Inc). The stimuli were presented on a white background on a 17-in CRT computer monitor with a viewing distance of approximately 57 cm. The resolution was set to 640 x 480. Hence, 1 pixel was approximately .05° of visual angle.

In experiment 1A, the grids that contained target words and non-target words all denoted different verbs. Especially for the agglutinated verb condition, this poses a problem. Subjects had to learn agglutinated verbs; however, resulting from the nature of the task, they could have chosen the target words just by recalling the verb roots. So, for this experiment, we added some distracter words that have the same verb roots, but a different agglutination. For example, if gel –(e)cek –(i)m (geleceğim; meaning, I will come) was a target word, the grid also contained some other form of the verb, such a gel -di –niz (geldiniz; meaning, you came). For convenience, not all the target words had a distracter in the grid. There were also distracters for non-target words, so that subjects could not just choose the verbs that had distracter forms. The number of target verbs and distracter verbs in each trial is shown in Table 2.5. The number of target words varied between 2-6 for this task. Then, scores from this task was compared to the verb task scores from experiment 1A. We will refer to this task as the distracter condition.

We also employed an automated operation opan task as a control measure, similar to our previous experiment. All subjects received the verb task first, then the automated operation span task.

***Results***

Correlational Analysis

Similar to the Experiment 1a, we conducted a series of correlational analysis with an aim to investigate the relationship between the participants' performances on each task in Experiment 1B.(see Table 2.5).

Analysis for Verbs

Absolute Score Proportion. In experiment 1A, the number of targets words in each trial varied between 2 and 7. So the total number of target words was 54. However, for the distracter task, this number was 40 because the number of targets varied between 2 and 6. This was done so that all the words (target and non-target words) could reasonably fit the grid. So, for this analysis we calculated the percentage (proportion) of number of target words recalled. A one-way between subjects ANOVA was conducted. Condition (Agglutinative Verbs, Verb Roots and Distracter) was the between subjects variable while the Absolute Score proportion was the dependent variable. There was a main effect of Condition, $F(2,72) = 3.46$, $MSE = .06$, $p = .037$, $\eta_p^2 = .088$ (see Figure 2.6). Post-hoc comparisons

| Trial | Target | Distracter | Non-target | Non-target Distracter | Total |
|---|---|---|---|---|---|
| 1 | 4 | 2 | 4 | 2 | 12 |
| 2 | 2 | 1 | 2 | 1 | 6 |
| 3 | 6 | 3 | 6 | 3 | 18 |
| 4 | 3 | 2 | 3 | 1 | 9 |
| 5 | 5 | 3 | 5 | 3 | 15 |
| 6 | 3 | 1 | 3 | 2 | 9 |
| 7 | 6 | 3 | 6 | 3 | 18 |
| 8 | 2 | 1 | 2 | 1 | 6 |
| 9 | 5 | 2 | 5 | 3 | 15 |
| 10 | 4 | 2 | 4 | 2 | 8 |

Table 2.5. Number of target, distracter, non-target and non-target-distracter words for the distracter task.

| | | Agglutinative Verbs | | Letters | |
|---|---|---|---|---|---|
| | | Absolute Score | Total Score | Absolute Score | Total Score |
| Agglutinative Verbs | Absolute Score | - | | | |
| | Total Score | .790** | - | | |
| Letters | Absolute Score | .269 | .489* | - | |
| | Total Score | .232 | .451* | .896** | - |

*p < .05, **p < .01.

Table 2.6 The Pearson Product-moment Correlations among Absolute Scores and Total Scores in Each Task for Experiment 1B.

Post-hoc comparisons showed that performance was higher in the Verb Roots (M = .37, SD = .03) compared to both Agglutinative Verbs (M = .29, SD = .03) and Distracter (M = .28, SD = .03), which were not different from each other (ps = .028 and .023, respectively). The results suggest that the agglutinative verb task and the distracter task did not differ and we can safely assume that the subjects did not use any kind of strategy to recall the words.

Total Score Proportion. A one-way between subjects ANOVA was conducted. Condition (Agglutinative Verbs, Verb Roots and Distracter) was the between subjects variable while the Total Score proportion was the dependent variable. There was not a main effect of Condition, $F(2,72) = 1.17$, $MSE = .024$, $p = .316$, $\eta_p^2 = .031$ (see Figure 2.8). Consistent with the results of experiment 1A, memory span did not differ among verb roots and agglutinative verbs, and adding the distracter task did not change this result.

<u>Analysis for Ospan (Letters)</u>

Absolute Score. In order to compare all groups of participants were similar in terms of our baseline measure, we conducted a one-way between subjects ANOVA with Condition (Agglutinative Verbs, Verb Roots and Cond3) as the between subjects variable and Absolute Score proportion as the dependent variable. Results showed that there was not a main effect of Condition, $F(2,69) = 1.33$, $MSE = 313.814$, $p = .27$, $\eta_p^2 = .037$ (see Figure 2.8).

Total Score. A one-way between subjects ANOVA was conducted. Results revealed that there was not a main effect of Condition, $F(2,69) = 1.99$, $MSE = 176.81$, $p = .145$, $\eta_p^2 = .055$ (see Figure 2.9). So we can safely say that the three groups did not differ in working memory capacity and any difference between these groups can be attributed to our experimental manipulation.

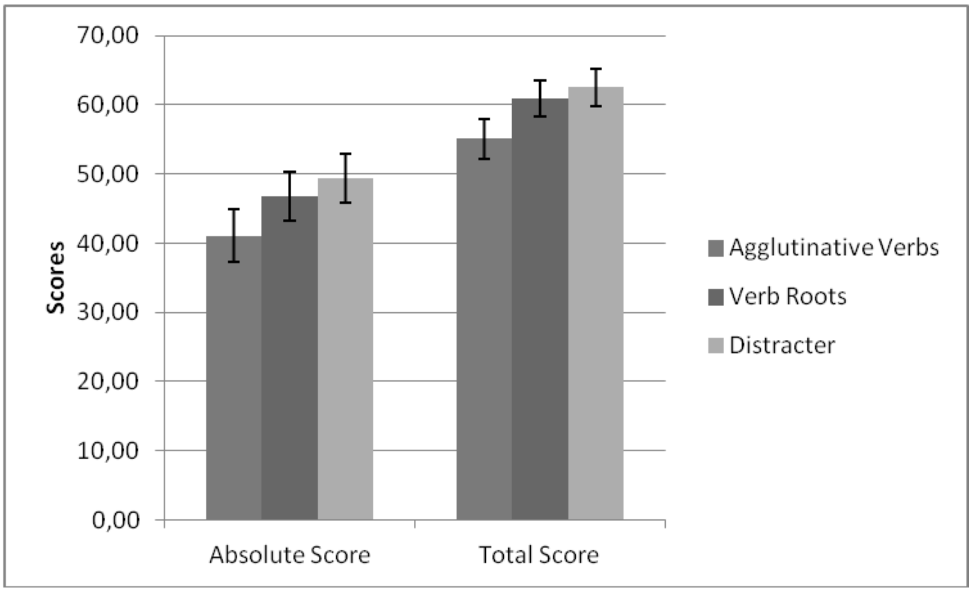


Figure 2.8 Absolute score and total score proportions for each condition

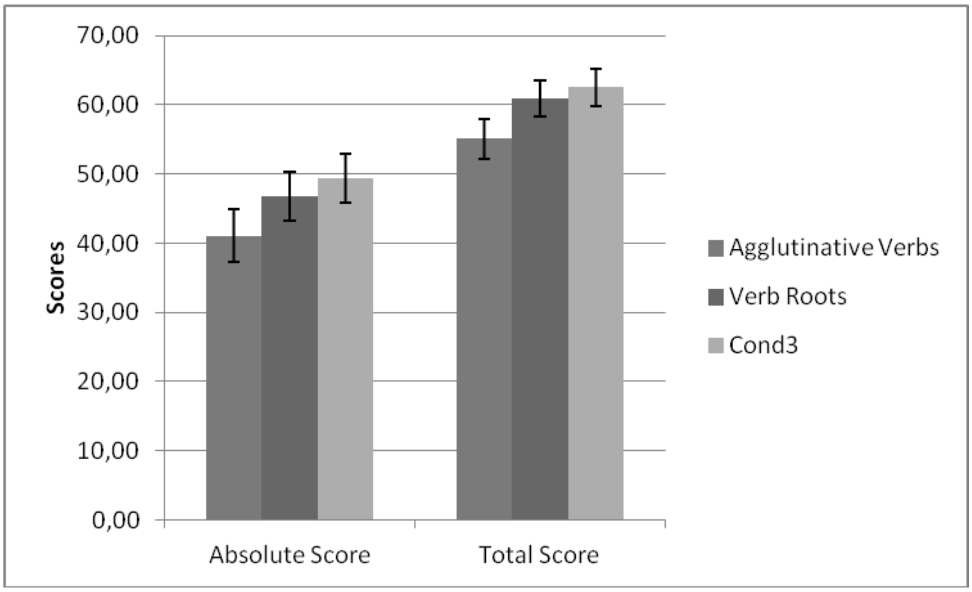


Figure 2.9 Absolute score and total score for each condition.

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# CHAPTER **3**

# DISCUSSION

Working memory capacity is limited by its nature and the search for a constant capacity limit has occupied memory research for a long time. The basic issue is whether this capacity is a constant, which are rare to find in the field of cognitive psychology. So, it is easy to understand the fascination and interest that arose after Miller (1956) has proposed that short term memory capacity was limited to "the magical number seven, plus or minus two."

Since then, many theoretical accounts for this capacity have been proposed (Cowan, 2001; Baddeley, 1986). However, the nature of this capacity has been disputed. Cowan provides us an analogy to explain the basis of a constant capacity:

> Imagine that the boat will take people only in vehicles and that the boat is limited only in how many vehicles it can take on board. The practical capacity of the boat might be defined as how many people it will hold. However, the answer depends on how many people are packed into each vehicle. If the boat

> remains at the dock until it is full (after which no more vehicles are admitted) and then departs on its journey, the number of people transported each time will vary within a certain range. However, a person will understand that variation better if he or she knows about the boat's fundamental limit in terms of vehicles. So, the limit in terms of vehicles is a narrow sense of capacity and understanding that limit lends insight to our understanding, even if we are ultimately more interested in the practical question of how many people can be transported. Of course, for practical purposes, someone also might want to know what other means of transportation are available for crossing the body of water or, in terms of working memory, what mental processes are available for holding information for a task at hand.

Given that the capacity estimations has been inconsistent throughout, and the great number of factors that affect this capacity has been discovered, it may seem reasonable to assume that there is not a constant limit but a variable process that is highly dependent on task characteristics. For verbal working memory, these characteristics may be the lexical properties of words in a given list (e.g., the frequency, length, concreteness or the imaginability), the method of retrieval (e.g., recall, recognition, word completion) or how these words are studied (e.g. the modality of presentation), to name a few. Even the congruency between the method of study and the method of retrieval can have an effect. The question is that what are we to make of it even if we find a constant. Cowan (2005), explains how we might find constancy in something that seems highly variable:

> In the analogy regarding the capacity of a ferry boat, suppose that one could not observe the cars going into the ferry (perhaps because it was proprietary information?), but only had an estimate of the people arriving at the city on the opposite shore, whether by ferry boat or by another means such as a bridge. That estimate would serve some practical purposes, such as planning the amount of food needed in the city. However, if one wanted to understand the fundamental capability of the system, a more controlled approach would have to be taken. For example, the city could temporarily close the bridge and also limit the ferry voyages to one person per vehicle. Then the number of people

arriving in the city would serve as an estimate of how many vehicles fit on the boat. This stretched analogy helps to dramatize the situation in human cognition in which a basic mechanism of working memory capacity, narrowly defined, is not apparent to the eye but can be investigated if we know enough about the processing system in which the mechanism is ensconced. One such basic mechanism is that associated with conscious awareness of the stimuli and a capacity-limited, primary memory.

As mentioned before, there has been a distinction between the item-based accounts and time-based accounts of working memory capacity. After Baddeley (1975, reported that shorter words tended to yield higher spans, a time based account became more favored. However, while the word length effect seems robust, it has been shown that this effect can be eliminated (e.g., Service, 1998) or even reversed (e.g. Caplan et. al. 1992). A working memory model that contains a phonological loop seems intuitive, but if the effects that are dependent on this component can be superseded by other types of variables, it can be reasoned that the capacity limit does not solely rely on this component. In this thesis we investigated a new variable that could affect working memory capacity, namely, the information load of words. To test these effects, we compared agglutinated verbs and nouns of the same length, and also agglutinated verbs and verb roots.

In experiments 1A and 1B, we investigated whether agglutinated verbs and verb roots yielded different capacity measures. For each task, we computed five different scores: (a) absolute span, which is the sum of all perfectly recalled sets; (b) total span, which is the total number of words recalled in the correct position; (c) math speed error, the number of math errors in which the subject could not provide an answer in time; (d) math accuracy error, in which the subject did not provide the right answer; (e) total math error, which is the total of accuracy and speed errors. All the analyses were based on these measures.

In general, the absolute span and total span measures yielded different results. The absolute span score was higher for verb roots. This is an expected result, since agglutinative verbs are always longer. This can be attributed to the word length effect. However, the total span scores were similar in both conditions. This suggests that while agglutinative verbs may require more cognitive effort, making it harder to perfectly recall a given set. On the other hand, the total span being similar reduces the probability that a word length effect occurred. There was also no difference between math errors among the two conditions. However, we also added a noun task to investigate and control for the word length effect. For this task, we included nouns that were similar in length to the agglutinated verbs in condition 1.

In condition 1, performance was similar for both tasks, in terms of the absolute score. However, total score was significantly higher in the noun task. Surprisingly, we see an opposite pattern of results in condition 2. Here, performance was better in the noun task, in terms of the absolute score. However, total score was similar in both tasks. This might suggest that agglutinative words generally require more cognitive effort, thus making it harder to perfectly recall a given set.

In condition 2 , performance was better in the noun task in terms of the absolute span score. However, performance did not different in terms of the total span between these two tasks. This is contrary to what we might expect considering the word length effect. This may be attributed to the higher imaginability and concreteness of the nouns.

We see that when speed error was more frequent in the noun task, total span score increased compared to the verb task in condition 1. This might indicate a tradeoff between span performance and math performance. However, we do not see this tradeoff in condition 2, such that while accuracy was lower in the verb task, total span score is higher.

The main weakness of this study was that it did not account for verb roots and agglutinations separately, which can have different mechanisms of retention. The retention of verb roots, which convey information about an action, may have more long-term memory involvement and the retention of agglutinations can be more dependent on covert rehearsal. For example, people may recall the root of an agglutinated verb, but not the agglutination. In experiment 1A, only recalling the root of an agglutinated verb was enough to provide a correct response. We added the distracter task in experiment 1B to discover whether the subjects used a strategy to only retain word roots. Given that the span performances did not differ among the agglutinative verb task and the distracter task, we can conclude that this was not the case. However, we did not measure the number of times subjects responded with the distracter word, instead of the target word. This distinction would help better distinguish between verb roots and agglutinated verbs. For further research, a task that subjects can recall the verb roots and agglutinations separately. Thus, we can get an implication of whether these two uses separate stores.

In general, when we compare the scores for the three different verb tasks (root, agglutinated and distracter), recall performance seems to be better for verb roots. However, considering the units of information (in this case, three), we might conclude that overall, this kind of physical chunking allows for more units of information to be retained in working memory.

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APPENDIX A

**Informed Consent Form**

Bilgilendirilmiş Onam Formu

Araştırmayı destekleyen kurum: İzmir Ekonomi Üniversitesi, Psikoloji Bölümü
Araştırmanın adı: Kelimelerdeki Bilgi Yükünün Çalışma Belleği Kapasitesine Etkisi
Araştırmacıların adı: Yalçın Akın Duyan
Adres: İzmir Ekonomi Üniversitesi Psikoloji Bölümü, 35330 İzmir
E-posta: yalcinduyan@gmail.com
Telefon: (506) 934 0757

Sayın Katılımcı,

Bu deney bireylerin çalışma belleği kapasitesini ölçmektedir. Sizden, bilgisayarda sunulacak olan bazı kelimeler üzerinde çalışmanız ve daha sonra bunları hatırlamanız istenmektedir. Deney, ortalama 1 saat sürecektir. Deneye katılmanız karşılığında size PSY 101 dersinden 1 kredi verilecektir.

Bu araştırma bilimsel bir amaçla yapılmaktadır, toplanan veriler yayın amaçlı kullanılacaktır ve katılımcı bilgilerinin gizliliği esas tutulmaktadır. Adınız ve performansınız hiçbir şekilde eşleştirilmeyecektir.

Bu araştırmaya katılmak tamamen isteğe bağlıdır. Katıldığınız takdirde çalışmanın herhangi bir aşamasında sebep göstermeden çalışmadan ayrılma hakkına sahipsiniz, bu durumda kredi alma hakkınızı kaybetmeyeceksiniz. Araştırmayla ilgili sorularınızı deneyin sonunda bize yöneltebilirsiniz.

Bu önemli çalışmada bize yardımcı olmak isterseniz, lütfen aşağıdaki "İzin Formu'nu doldurup imzalayınız. Eğer 18 yaşından küçük iseniz, lütfen bu formu velinize imzalatıp araştırmacıya teslim ediniz. Çalışma hakkındaki bilgilendirmeyi okudum ve anladım.
Çalışmaya katılmak istiyorum ☐ İstemiyorum ☐
Velisi veya vasinin adı, soyadı ve imzası:
……………………………………………. (18 yaşından küçük katılımcılar için)

Bilgilendirilmiş Olur Formu'nun bir örneği tarafıma verildi.

Adı Soyadı:.......................................................................................................
İmzası:..............................................................................................................
Adresi:..............................................................................................................
Telefonu: ..........................................................................................................
E-posta: ............................................................................................................
Tarih (gün/ay/yıl):...../......./.............

APPENDIX B

**Word Grids For The Agglutinated Verb Task**

Trial 1

| | | | |
|---|---|---|---|
| bilindim | ediliyor | bozulacak | yarattı |
| bırakacaksın | süreceğiz | çektin | diyor |
| başlıyorsun | tuttuk | tutuluyorsunuz | açılıyorum |

Target words: tutuluyorsunuz, süreceğiz, bozulacak, açılıyorum

Trial 2

| | | | |
|---|---|---|---|
| sayıldık | çaldın | denecek | toplayacaklar |
| görüşeceksin | basıyor | değiştik | dayandılar |
| geldiler | koşacağız | artırdım | gelişeceksin |

Target words: değiştik, denecek

Trial 3

| | | | |
|---|---|---|---|
| oynadım | azalıyorsun | büyüyorlar | söyledi |
| duracak | dinliyorlar | girdiniz | çevirdim |
| kalkacaksınız | arıyoruz | sordular | denildiniz |

Target words: çevirdim, girdiniz, söyledi, oynadım, sordular, büyüyorlar

Trial 4

| | | | |
|---|---|---|---|
| izliyorsun | dilediniz | sundular | kurulacaklar |
| korudunuz | üreteceğiz | katılacağız | dönecekler |
| bildin | iniyorlar | karışıyorum | ulaştık |

Target words: izliyorsun, karışıyorum, bildin

Trial 5

| | | | |
|---|---|---|---|
| çalışıyorlar | yazıyorsunuz | yayılacaksın | göreceğiz |
| anlatıyor | koydum | benzeyeceğiz | görünüyorsunuz |
| sunulacaklar | artıyorsun | uzandı | dolaşacağım |

Target words: sunulacaklar, çalışıyorlar, benzeyeceğiz, görünüyorsunuz, göreceğiz

Trial 6

| | | | |
|---|---|---|---|
| evlendin | çiziyorsunuz | oturuyorsunuz | kaçacaklar |
| öğrendi | taşıyacağız | yapıyor | uğraşıyorsun |
| oluştun | sanıyorsunuz | okuyacağım | attınız |

Target words: oluştun, öğrendi, attınız

Trial 7

| | | | |
|---|---|---|---|
| geçiyorsun | giyiyor | verecek | buluyorum |
| yetiyoruz | işleyecek | kaldım | korkuyorsunuz |
| bağlayacaksınız | içiyorlar | uğraştık | alınacak |

Target words: yetiyoruz, uğraştık, kaldım, giyiyor, bağlayacaksınız, geçiyorsun

Trial 8

| | | | |
|---|---|---|---|
| geçiriyorum | sağlayacağım | kapatacaksınız | bitiyorum |
| isteyecekler | kapanacağım | düşüyorsunuz | duyuyor |
| ayıracaksınız | yürüyoruz | yazılacağım | inanacaksınız |

Target words: ayıracaksınız, duyuyor, yürüyoruz, düşüyorsunuz, sağlayacağım, yazılacağım, isteyecekler

Trial 9

| | | | |
|---|---|---|---|
| kestiler | biniyoruz | yatıyorum | ayrılacaksınız |
| çıkıyoruz | kullandık | anladı | vardı |
| çıkardım | oynayacaklar | çekiliyoruz | bitirecek |

Target words: bitirecek, çıkıyoruz

Trial 10

| | | | |
|---|---|---|---|
| aldılar | sokacak | bekliyorlar | takıldın |
| sayıyorum | doğuyorsun | uyudum | göstereceksin |
| kazanacağım | kesildin | kılacaksın | yaşandı |

Target words: bekliyorlar, kesildin, aldılar, takıldın, göstereceksin

Trial 11

| | | | |
|---|---|---|---|
| tanıdın | götürdü | atıldın | getirdiler |
| uzatıyoruz | baktın | dönüştüler | konuşacaksın |
| gittiniz | ödeyeceksiniz | unutuyorum | sattı |

Target words: unutuyorum, sattı, konuşacaksın, dönüştüler

Trial 12

| | | | |
|---|---|---|---|
| düşündük | kuracağım | seçeceğiz | ekleyecek |
| kaldım | dinliyor | bulundunuz | yaşayacaksınız |
| bağırıyorlar | yanacaklar | istendiniz | içeriyorlar |

Target words: düşündük, dinliyor, yaşayacaksınız, ekleyecek, kuracağım, bulundunuz, yanacaklar

APPENDIX C

**Word Grids For The Root Verb Task**

Trial 1

| | | | |
|---|---|---|---|
| bilinmek | Edilmek | bozulmak | yaratmak |
| bırakmak | Sürmek | çekmek | demek |
| başlamak | Tutmak | tutulmak | açılmak |

Target words: tutulmak, sürmek, bozulmak, açılmak

Trial 2

| | | | |
|---|---|---|---|
| sayılmak | Çalmak | denmek | toplamak |
| görüşmek | Basmak | değişmek | dayanmak |
| gelmek | Koşmak | artırmak | gelişmek |

Target words: değişmek, denmek

Trial 3

| | | | |
|---|---|---|---|
| oynamak | Azalmak | büyümek | söylemek |
| durmak | Dinlemek | girmek | çevirmek |
| kalkmak | Aramak | sormak | denilmek |

Target words: çevirmek, girmek, söylemek, oynamak, sormak, büyümek

Trial 4

| | | | |
|---|---|---|---|
| izlemek | Dilemek | sunmak | kurulmak |
| korumak | Üretmek | katılmak | dönmek |
| bilmek | Inmek | karışmak | ulaşmak |

Target words: izlemek, karışmak, bilmek

Trial 5

| | | | |
|---|---|---|---|
| çalışmak | Yazmak | yayılmak | görmek |
| anlatmak | Koymak | benzemek | görünmek |
| sunulacaklar | Artıyorsun | uzandı | dolaşacağım |

Target words: sunulmak, çalışmak, benzemek, görünmek, görmek

Trial 6

| | | | |
|---|---|---|---|
| evlenmek | Çizmek | oturmak | kaçmak |
| öğrenmek | Taşımak | yapmak | uğraşmak |
| oluşmak | Sanmak | okumak | atmak |

Target words: oluşmak, öğrenmek, atmak

Trial 7

| | | | |
|---|---|---|---|
| geçmek | Giymek | vermek | bulmak |
| yetmek | Işlemek | kalmak | korkmak |
| bağlamak | Içmek | uğraşmak | alınmak |

Target words: yetmek, uğraşmak, kalmak, giymek, bağlamak, geçmek

Trial 8

| | | | |
|---|---|---|---|
| geçirmek | Sağlamak | kapatmak | bitmek |
| istemek | Kapanmak | düşmek | duymak |
| ayırmak | Yürümek | yazılmak | inanmak |

Target words: ayırmak, duymak, yürümek, düşmek, sağlamak, yazılmak, istemek

Trial 9

| | | | |
|---|---|---|---|
| kesmek | Binmek | yatmak | ayrılmak |
| çıkmak | Kullanmak | anlamak | varmak |
| çıkarmak | Oynamak | çekilmek | bitirmek |

Target words: bitirmek, çıkmak

Trial 10

| | | | |
|---|---|---|---|
| almak | Sokmak | beklemek | takılmak |
| saymak | Doğmak | uyumak | göstermek |
| kazanmak | Kesilmek | kılmak | yaşanmak |

Target words: beklemek, kesilmek, almak, takılmak, göstermek

Trial 11

| | | | |
|---|---|---|---|
| tanımak | Götürmek | atılmak | getirmek |
| uzatmak | Bakmak | dönüşmek | konuşmak |
| gitmek | Ödemek | unutmak | satmak |

Target words: unutmak, satmak, konuşmak, dönüşmek

Trial 12

| | | | |
|---|---|---|---|
| düşünmek | Kurmak | seçmek | eklemek |
| kalmak | Dinlemek | bulunmak | yaşamak |
| bağırmak | Yanmak | istenmek | içermek |

Target words: düşünmek, dinlemek, yaşamak, eklemek, kurmak, bulunmak, yanmak

APPENDIX D

**Word Grids For The Noun Task**

Trial 1

| | | | |
|---|---|---|---|
| tüketim | monitör | konservatuar | alışkın |
| sürpriz | mürekkep | barınak | pazartesi |
| bilimci | zencefil | aksesuar | mutluluk |

Target words: terslik, festival, eleştirmen, mühendis

Trial 2

| | | | |
|---|---|---|---|
| evrensel | zararlı | fazlalık | vejetaryen |
| peşinatsız | kapüşon | operasyon | müessese |
| erozyon | koridor | misafir | izlenim |

Target words: kapüşon, misafir

Trial 3

| | | | |
|---|---|---|---|
| karışık | şampuan | akvaryum | garanti |
| indirim | kelebek | duygulu | bilişim |
| yorgunluk | rüzgâr | geçerlik | gıcırtı |

Target words: kelebek, yorgunluk, duygulu, şampuan, geçerlik

Trial 4

| | | | |
|---|---|---|---|
| endüstriyel | karikatür | tanıtım | onursuz |
| enstruman | çiçekçi | arkadaş | nişancı |
| kanepe | mineral | atmosfer | üşengeç |

Target words: arkadaş, onursuz, kanepe, endüstriyel, mineral, tanıtım

Trial 5

| | | | |
|---|---|---|---|
| kırmızı | fotoğraf | karınca | dinamik |
| televizyon | protein | bunalım | insanlık |
| alüminyum | meşguliyet | oksijen | fermuar |

Target words: alüminyum, karınca, meşguliyet, fermuar, kırmızı

Trial 6

| | | | |
|---|---|---|---|
| tüketim | monitör | konservatuar | alışkın |
| sürpriz | mürekkep | barınak | pazartesi |
| bilimci | zencefil | aksesuar | mutluluk |

Target words: konservatuar, alışkın, monitör, pazartesi

Trial 7

| | | | |
|---|---|---|---|
| enerjik | soytarı | battaniye | mahcubiyet |
| gramafon | sanatçı | kararlı | konsantrasyon |
| uygarlık | rezervasyon | müftülük | hırçınlık |

Target words: kararlı, hırçınlık, gramafon, mahcubiyet, sanatçı, uygarlık

Trial 8

| | | | |
|---|---|---|---|
| sandalet | lokanta | meşrutiyet | çamaşır |
| süresiz | meteoroloji | enformasyon | başıboş |
| telefon | elektrik | tehlike | seyirci |

Target words: enformasyon, tehlike, elektrik, lokanta, seyirci, sandalet, telefon

Trial 9

| | | | |
|---|---|---|---|
| prensip | etnograyfa | atletik | sandalye |
| atmosfer | kahvaltı | arkeoloji | iskelet |
| şampanya | kalorifer | enginar | sempatizan |

Target words: sempatizan, kalorifer

Trial 10

| | | | |
|---|---|---|---|
| sarsıcı | hakimiyet | telekominikasyon | istihbarat |
| antropoloji | gürültü | bisiklet | mobilya |
| standart | yağcılık | pencere | çikolata |

Target words: antropoloji, çikolata, sarsıcı

Trial 11

| | | | |
|---|---|---|---|
| serbest | dostluk | anarşist | cinayet |
| sevgili | solaryum | rahatsız | horultu |
| hastahane | rezalet | kuyumcu | öğrenci |

Target words: kuyumcu, rezalet, öğrenci, sevgili, serbest, horultu, cinayet

Trial 12

| | | | |
|---|---|---|---|
| simülasyon | gerçeklik | laboratuar | bunaltı |
| gelişim | papatya | şiddetli | meyhane |
| meraklı | üretici | tabanca | federasyon |

Target words: meyhane, şiddetli, üretici

APPENDIX E

**Word Grids For The Distracter Verb Task**

Trial 1

| | | | |
|---|---|---|---|
| bozulacak | yarattı | açılıyorum | bozuldu |
| başlıyorsun | açılıyorsunuz | yarattınız | sürdü |
| süreceğiz | başlıyorum | tutulduk | tutuluyorsunuz |

Target words: bozulacak, süreceğiz, tutuluyorsunuz, açılıyorum
Distracters: bozuldu, sürdü, tutulduk, açılıyorsunuz

Trial 2

| | | | |
|---|---|---|---|
| değiştik | koştular | değiştiler | koşacağız |
| | denecek | sayıldık | |

Target words: denecek, değiştik
Distracters: değiştiler

Trial 3

| | | | |
|---|---|---|---|
| büyüyoruz | dinliyorlar | sordular | çevirdiler |
| arıyoruz | azalıyorsun | kalkacaksınız | oynadım |
| girdim | duracaksın | girdiniz | denildiniz |
| azalıyorsun | büyüyorlar | duracak | çevirdim |
| dinliyorsunuz | söylüyorsun | dinliyorsunuz | söyledi |

Target words: oynadım, büyüyorlar, söyledi, girdiniz, çevirdim, sordular
Distracters: büyüyoruz, söylüyorsun, girdim, çevirdiler

Trial 4

| | | | |
|---|---|---|---|
| diliyorlar | karıştık | katılacağız | bildin |
| katıldım | ulaştık | izliyorsun | izliyorlar |
| dilediniz | karışıyorum | dilediniz | karışıyorum |

Target words: izliyorsun, bildin, karışıyorum
Distracters: izliyorlar, karıştık

Trial 5

| | | | |
|---|---|---|---|
| yazıyorsunuz | çalışıyorlar | benzediler | görünüyorsunuz |
| dolaşacağım | göreceğiz | benzeyeceğiz | uzanıyorum |
| uzandı | sunulacaklar | çalıştınız | anlatıyor |
| | yazacaklar | | |

Target words: çalışıyorlar, göreceğiz, benzeyeceğiz, görünüyorsunuz, sunulacaklar
Distracters: çalıştınız, benzediler

Trial 6

| | | | |
|---|---|---|---|
| okuyoruz | attınız | öğreneceğiz | yaptılar |
| oluştun | kaçacaklar | öğrendi | atıyorsun |
| okudunuz | yapacaksınız | okudunuz | yapacaksınız |

Target words: öğrendi, oluştun, attınız
Distracters: öğreneceğiz, atıyorsun

Trial 7

| | | | |
|---|---|---|---|
| giyiyor | işledik | yetiyoruz | verecek |
| bağlayacaksınız | bulacaklar | alınacak | uğraştık |
| içiyorlar | verdiler | korkuyorsunuz | buluyorum |
| geçiyorsun | uğraşıyorum | kalıyorsunuz | geçtiler |
| | kaldım | işleyecek | |

Target words: geçiyorsun, giyiyor, yetiyoruz, kaldım, bağlayacaksınız, uğraştık
Distracters: geçtiler, kalıyorsunuz, uğraşıyorum

Trial 8

| | | | |
|---|---|---|---|
| bitirdik | bitirecek | yatıyorum | anladı |
| | çıkıyoruz | anlıyoruz | |

Target words: çıkıyoruz, bitirecek
Distracters: bitirdik

Trial 9

| | | | |
|---|---|---|---|
| aldılar | sayacaklar | kazandık | takılacak |
| kesildin | alıyorsunuz | kılacaksın | bekliyorlar |
| uyudum | takıldın | kazanacağım | uyuyoruz |
| göstereceksin | sayıyorum | bekledik | sokacak |

Target words: aldılar, bekliyorlar, takıldın, göstereceksin, kesildin
Distracters: alıyorsunuz, bekledik, takılacak

Trial 10

| | | | |
|---|---|---|---|
| unutuyorum | götürdü | gittiniz | dönüştüler |
| satacaklar | konuşacaksın | ödeyeceksiniz | sattı |
| tanıyacak | tanıdın | unutacaksın | götürüyorum |

Target words: dönüştüler, konuşacaksın, unutuyorum, sattı
Distracters: unutacaksın, satacaklar

APPENDIX F

## Instructions For The Automated Operation Span Task

>>>Recall Instructions<<<

Bu çalışmada ekranda gördüğünüz harfleri hatırlamaya çalışacaksınız. Aynı zamanda sizden basit matematik soruları cevaplandırmanız istenecek.

Öncelikle deneyin nasıl uygulanacağını görmek için biraz alıştırma yapacaksınız.

İlk olarak, harfler ile ilgili kısmı çalışacağız.

Bu alıştırma aşamasında harfler birer birer ekranda belirecek.

Lütfen her harfi gösterildiği sıra ile hatırlamaya çalışınız.

Size 2 veya 3 harf gösterilecek. Daha sonra ekranda 12 harf belirecek. Her harfin yanında bir kutu olacak. Bir önceki ekranda size sunulan harfleri, bu 12 harf içinden gösterildiği sırada seçmeye çalışın.

Bunu yapmak için 'mouse' ile harflerin yanındaki kutulara tıklamanız yeterli. Seçtiğiniz harfler ekranın altında belirecek.

Gösterilen tüm harfleri doğru sırada seçtiğinizde sağ alt köşedeki TAMAM kutusuna basınız.

Hata yaparsanız, ekrandaki SİL kutusunun üzerine tıklayarak baştan başlayabilirsiniz.

Eğer harflerden birini unutursanız, BOŞLUK kutusunun üzerine tıklayarak o harfin yerini belirtebilirsiniz.

Önemli olan harfleri DOĞRU sırada hatırlamak. Eğer unuttuğunuz harf varsa bu harfin sırasını belirtmek için BOŞLUK kutusunun üzerine tıklayabilirsiniz.

Herhangi bir sorunuz var mi?

Hazır olduğunuzda alıştırmalara başlamak için 'mouse'a tıklayınız.

>>>Recall Practice<<<<

Harfleri gösterildiği sırada işaretleyiniz. BOŞLUK tuşunu unuttuğunuz harflerin yerlerini doldurmak için kullanınız.

>>>Math Instructions<<<

Şimdi, deneyin matematik kısmı için biraz alıştırma yapacağız.

Ekranda aşağıdaki gibi bir matematik sorusu belirecek:

(2 * 1) + 1 = ?

Soruyu görür görmez, sorunun doğru cevabını hesaplamalısınız.

Yukarıdaki soruda doğru cevap 3.

Doğru cevabı hesapladığınızda 'mouse'a tıklayınız.

Bir sonraki ekranda bir sayı göreceksiniz. Sayının altında DOĞRU ve YANLIŞ yazılı iki kutu olacak.

Eğer ekrandaki sayı DOĞRU yanıt ise DOĞRU, yanlış yanıt ise YANLIŞ kutusuna 'mouse' ile tıklayınız.

Örneğin, gördüğünüz soru

(2 * 2) + 1 = ?

ve ardından ekranda gördüğünüz sayı 5 ise

DOĞRU kutusunu işaretleyiniz -çünkü bu gerçekten de DOĞRU olan cevap.

Gördüğünüz soru:

(2 * 2) + 1 = ?

ve ardından ekranda gördüğünüz sayı 6 ise

YANLIŞ kutusunu işaretleyiniz -çünkü bu yanlış cevap.

Kutulardan birini işaretledikten sonra bilgisayar soruyu doğru veya yanlış cevapladığınızı belirtecek.

Matematik sorularını DOĞRU cevaplandırmanız ÇOK ÖNEMLİ. Aynı zamanda matematik sorularını olabildiğince çabuk çözmeye çalışmalısınız.

Herhangi bir sorunuz var mi?

Hazır olduğunuzda alıştırmalara başlamak için 'mouse' ile tıklayarak ilerleyebilirsiniz.

>>>Math Practice<<<

Soruyu cozdugunuzde mouse ile bir sonraki ekrana ilerleyiniz.

>>>Session Instructions<<<

Şimdi deneyin ilk iki aşamasını aynı anda yapacaksınız.

Bundan sonraki alıştırmada yine matematik soruları göreceksiniz. Her bir matematik sorusunu çözüp cevaplandırdığınızda ekranda bir harf belirecek. Bu harfi hatırlamaya çalışın.

Bilgisayar, bir önceki aşamada matematik sorularını cevaplarken soruları ortalama ne kadar sürede çözdüğünüzü hesapladı. Eğer bu bölümde soruları çözmek için daha uzun zaman harcarsanız, bilgisayar otomatik olarak sorunun harf kısmına atlayacak (yani DOĞRU/YANLIŞ kısmını geçecek) ve matematik sorusunu çözememiş olduğunuzu kaydedecek.

Bu yüzden matematik sorularını en DOĞRU ve en HIZLI şekilde cevaplamanız çok önemli.

Harf ekrandan silindikten sonra yine bir matematik sorusu belirecek.

Her aşamanın sonunda bir hatırlama ekranı belirecek. Burada yine 'mouse'u kullanarak gördüğünüz harfleri belirteceksiniz. Lütfen harfleri DOĞRU sıra ile hatırlamaya çalışın.

Matematik sorularını HIZLI ve DOĞRU çözmeniz çok önemli. Matematik sorusunun cevabını hesaplamadan bir sonraki ekrana geçmeyiniz.

Bu kısımda matematik sorusunu DOĞRU çözüp çözmediğiniz size bildirilmeyecek.

Ama hatırlatma ekranının sonunda harfleri DOĞRU hatırlayıp hatırlamadığınız ve o ana kadar çözdüğünüz tüm matematik sorularındaki DOĞRU oranınız belirtilecek.

Herhangi bir sorunuz var mı?

Geri bildirim olarak ekranın sağ üst kösesinde kırmızı bir sayı goreceksiniz. Bu sayı tüm matematik sorularındaki ortalama başarınızı belirtecek.

Bu sayıyı en az yüzde 85'de tutmanız ÇOK önemli.

Araştırmanın amacı için başarı düzeyi en az yüzde 85 olan verileri kullanabiliyoruz.

Herhangi bir sorunuz var mi?

Mouse'a tıklayarak alıştırma yapmaya başlayabilirsiniz

>>>Experimental Practice<<<

Harfleri gösterildiği sırada işaretleyiniz. BOŞLUK tuşunu unuttuğunuz harflerin yerlerini doldurmak için kullanınız.

Alıştırma aşaması sona erdi.

Asıl deney de az önce tamamladığınız alıştırmalar gibidir.

Öncelikle çözülecek matematik problemini, ardından hatırlamanız gereken harfi göreceksiniz.

Daha sonra bir hatırlama ekranı belirecek. Burada yine 'mouse'u kullanarak gördüğünüz harfleri sırasıyla belirteceksiniz. Lütfen harfleri DOĞRU sıra ile hatırlamaya çalışın. Eğer bir harfi unutursanız, BOŞLUK kutusunun üzerine tıklayarak o harfin yerini belirtebilirsiniz.

Bazı bölümlerde daha fazla matematik problemi ve harf olacak.

Matematik sorularını DOĞRU cevaplandırmanız ve harfleri DOĞRU sıra ile hatırlamanız ÇOK ÖNEMLİ.

Aynı zamanda matematik sorularını olabildiğince çabuk çözmeye çalışmalısınız.

Lütfen matematik sorularında başarı düzeyinin en az yüzde 85 olması gerektiğini unutmayın.

Herhangi bir sorunuz var mı?

Hazır olduğunuzda 'mouse' ile tıklayarak deneye başlayabilirsiniz.

>>>Experimental Session<<<

APPENDIX G

**Instructions For The Verb Task**

>>>Recall Instructions<<<

Bu çalışmada ekranda gördüğünüz kelimeleri hatırlamaya çalışacaksınız. Aynı zamanda sizden basit matematik soruları cevaplandırmanız istenecek.

Öncelikle deneyin nasıl uygulanacağını görmek için biraz alıştırma yapacaksınız.

İlk olarak, kelimeler ile ilgili kısmı çalışacağız.

Bu alıştırma aşamasında kelimeler birer birer ekranda belirecek.

Lütfen her kelimeyi gösterildiği sıra ile hatırlamaya çalışınız.

Size 2 veya 3 kelime gösterilecek. Daha sonra ekranda 12 kelime belirecek. Her kelimenin yanında bir kutu olacak. Bir önceki ekranda size sunulan kelimeleri, bu 12 kelime içinden gösterildiği sırada seçmeye çalışın.

Bunu yapmak için 'mouse' ile kelimelerin yanındaki kutulara tıklamanız yeterli. Seçtiğiniz kelimeler ekranın altında belirecek.

Gösterilen tüm kelimeleri doğru sırada seçtiğinizde sağ alt köşedeki TAMAM kutusuna basınız.

Hata yaparsanız, ekrandaki SİL kutusunun üzerine tıklayarak baştan başlayabilirsiniz.

Eğer kelimelerden birini unutursanız, BOŞLUK kutusunun üzerine tıklayarak o kelimenin yerini belirtebilirsiniz.

Önemli olan kelimeleri DOĞRU sırada hatırlamak. Eğer unuttuğunuz kelime varsa bu kelimenin sırasını belirtmek için BOŞLUK kutusunun üzerine tıklayabilirsiniz.

Herhangi bir sorunuz var mi?

Hazır olduğunuzda alıştırmalara başlamak için 'mouse'a tıklayınız.

>>>Recall Practice<<<<

Kelimeleri gösterildiği sırada işaretleyiniz. BOŞLUK tuşunu unuttuğunuz kelimelerin yerlerini doldurmak için kullanınız.

>>>Math Instructions<<<

Şimdi, deneyin matematik kısmı için biraz alıştırma yapacağız.

Ekranda aşağıdaki gibi bir matematik sorusu belirecek:

(2 * 1) + 1 = ?

Soruyu görür görmez, sorunun doğru cevabını hesaplamalısınız.

Yukarıdaki soruda doğru cevap 3.

Doğru cevabı hesapladığınızda 'mouse'a tıklayınız.

Bir sonraki ekranda bir sayı göreceksiniz. Sayının altında DOĞRU ve YANLIŞ yazılı iki kutu olacak.

Eğer ekrandaki sayı DOĞRU yanıt ise DOĞRU, yanlış yanıt ise YANLIŞ kutusuna 'mouse' ile tıklayınız.

Örneğin, gördüğünüz soru

(2 * 2) + 1 = ?

ve ardından ekranda gördüğünüz sayı 5 ise

DOĞRU kutusunu işaretleyiniz -çünkü bu gerçekten de DOĞRU olan cevap.

Gördüğünüz soru:

(2 * 2) + 1 = ?

ve ardından ekranda gördüğünüz sayı 6 ise

YANLIŞ kutusunu işaretleyiniz -çünkü bu yanlış cevap.

Kutulardan birini işaretledikten sonra bilgisayar soruyu doğru veya yanlış cevapladığınızı belirtecek.

Matematik sorularını DOĞRU cevaplandırmanız ÇOK ÖNEMLİ. Aynı zamanda matematik sorularını olabildiğince çabuk çözmeye çalışmalısınız.

Herhangi bir sorunuz var mi?

Hazır olduğunuzda alıştırmalara başlamak için 'mouse' ile tıklayarak ilerleyebilirsiniz.

>>>Math Practice<<<

Soruyu cozdugunuzde mouse ile bir sonraki ekrana ilerleyiniz.

>>>Session Instructions<<<

Şimdi deneyin ilk iki aşamasını aynı anda yapacaksınız.

Bundan sonraki alıştırmada yine matematik soruları göreceksiniz. Her bir matematik sorusunu çözüp cevaplandırdığınızda ekranda bir kelime belirecek. Bu kelimeyi hatırlamaya çalışın.

Bilgisayar, bir önceki aşamada matematik sorularını cevaplarken soruları ortalama ne kadar sürede çözdüğünüzü hesapladı. Eğer bu bölümde soruları çözmek için daha uzun zaman harcarsanız, bilgisayar otomatik olarak sorunun kelime kısmına atlayacak (yani DOĞRU/YANLIŞ kısmını geçecek) ve matematik sorusunu çözememiş olduğunuzu kaydedecek.

Bu yüzden matematik sorularını en DOĞRU ve en HIZLI şekilde cevaplamanız çok önemli.

Kelime ekrandan silindikten sonra yine bir matematik sorusu belirecek.

Her aşamanın sonunda bir hatırlama ekranı belirecek. Burada yine 'mouse'u kullanarak gördüğünüz kelimeleri belirteceksiniz. Lütfen kelimeleri DOĞRU sıra ile hatırlamaya çalışın.

Matematik sorularını HIZLI ve DOĞRU çözmeniz çok önemli. Matematik sorusunun cevabını hesaplamadan bir sonraki ekrana geçmeyiniz.

Bu kısımda matematik sorusunu DOĞRU çözüp çözmediğiniz size bildirilmeyecek.

Ama hatırlatma ekranının sonunda kelimeleri DOĞRU hatırlayıp hatırlamadığınız ve o ana kadar çözdüğünüz tüm matematik sorularındaki DOĞRU oranınız belirtilecek.

Herhangi bir sorunuz var mı?

Geri bildirim olarak ekranın sağ üst kösesinde kırmızı bir sayı goreceksiniz. Bu sayı tüm matematik sorularındaki ortalama başarınızı belirtecek.

Bu sayıyı en az yüzde 85'de tutmanız ÇOK önemli.

Araştırmanın amacı için başarı düzeyi en az yüzde 85 olan verileri kullanabiliyoruz.

Herhangi bir sorunuz var mi?

Mouse'a tıklayarak alıştırma yapmaya başlayabilirsiniz

>>>Experimental Practice<<<

Kelimeleri gösterildiği sırada işaretleyiniz. BOŞLUK tuşunu unuttuğunuz kelimelerin yerlerini doldurmak için kullanınız.

Alıştırma aşaması sona erdi.

Asıl deneyde az önce tamamladığınız alıştırmalar gibidir.

Öncelikle çözülecek matematik problemini, ardından hatırlamanız gereken kelimeyi göreceksiniz.

Daha sonra bir hatırlama ekranı belirecek. Burada yine 'mouse'u kullanarak gördüğünüz kelimeleri sırasıyla belirteceksiniz. Lütfen kelimeleri DOĞRU sıra ile hatırlamaya çalışın. Eğer bir kelimeyi unutursanız, BOŞLUK kutusunun üzerine tıklayarak o kelimenin yerini belirtebilirsiniz.

Bazı bölümlerde daha fazla matematik problemi ve kelime olacak.

Matematik sorularını DOĞRU cevaplandırmanız ve kelimeleri DOĞRU sıra ile hatırlamanız ÇOK ÖNEMLİ.

Aynı zamanda matematik sorularını olabildiğince çabuk çözmeye çalışmalısınız.

Lütfen matematik sorularında başarı düzeyinin en az yüzde 85 olması gerektiğini unutmayın.

Herhangi bir sorunuz var mı?

Hazır olduğunuzda 'mouse' ile tıklayarak deneye başlayabilirsiniz.

>>>Experimental Session<<<