AN INVESTIGATION OF THE RELATIONSHIP BETWEEN WORKING MEMORY CAPACITY AND VERBAL AND MATHEMATICAL ACHIEVEMENT

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ABSTRACT

AN INVESTIGATION OF THE RELATIONSHIP BETWEEN WORKING MEMORY CAPACITY AND VERBAL AND MATHEMATICAL ACHIEVEMENT

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This study aims to find out the relationship between Working Memory Capacity and Verbal and Mathematical Achievement. The participants were 60 students at Hacettepe University School of Foreign Languages Department of Basic English. For measuring working memory capacity, one simple (Digit Span Task) and one complex (Reading Span Task) were used. Verbal achievement of the participants was measured both in their native language (Turkish) and their foreign language (English). For measuring their native language achievement, the participants' Turkish scores in Yükseköğretime Geçiş Sınavı 2010 (Transition to Higher Education Examination); and for measuring their foreign language achievement, the participants' scores in Hacettepe University School of Foreign Languages Department of Basic English Elementary Groups Achievement Exams I and II were used. For measuring their mathematical achievement, the participants' Mathematic scores in Yükseköğretime Geçiş Sınavı 2010 (Transition to Higher Education Examination) were used. The data was analyzed using a statistical package program (SPSS Version 18.0). The data analysis results revealed that there is a relationship between working memory capacity and verbal and mathematical achievements of the participants. It was tentatively concluded that, as the working memory capacity of the participants increase, so might their achievement in verbal and mathematical subjects. This result was discussed in terms of its implications, which may be that, if working memory capacity could be improved; the cognitive processes which the working memory is responsible for might also improve.

Keywords: Working Memory Capacity, Verbal Achievement, Mathematical Achievement, Reading Span Task, Digit Span Task

ÖZ

İŞLER BELLEK KAPASİTESİ VE SÖZEL VE MATEMATİKSEL BAŞARI ARASINDAKİ İLİŞKİNİN İNCELENMESİ

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Bu çalışma, işler bellek kapasitesi ve sözel ve matematiksel başarı arasındaki ilişkiyi incelemeyi amaçlamaktadır. Çalışmaya, Hacettepe Üniversitesi Yabancı Diller Yüksek Okulu İngilizce Hazırlık Birimi'nde eğitim görmekte olan 60 öğrenci katılmıştır. İşler bellek kapasitelerini ölçmek üzere, bir basit (Sayı Dizisi Testi) ve bir karmaşık (Okuma Uzunluğu Testi) kullanılmıştır. Katılımcıların sözel başarıları, hem anadilleri (Türkçe) hem de yabancı dilleri (İngilizce) olarak ölçülmüştür. Anadillerindeki başarılarını ölçmek üzere, katılımcıların Yükseköğretime Geçiş Sınavı 2010 Türkçe bölümündeki sonuçları; yabancı dildeki başarılarını ölçmek üzere ise Hacettepe Üniversitesi Yabancı Diller Yüksek Okulu İngilizce Hazırlık Birimi Başlangıç Grupları Achievement I ve II sınavları kullanılmıştır. Matematiksel başarılarını ölçmek için ise, katılımcıların Yükseköğretime Geçiş Sınavı 2010 Matematik bölümündeki sonuçları kullanılmıştır. Toplanan veriler, bir istatistik programı (SPSS sürüm 18.0) ile analiz edilmiştir. Analiz sonuçları, işler bellek kapasitesi ve sözel ve matematiksel başarı arasında bir ilişkinin varlığını ortaya koymuştur. Bu sonuç, kişilerin işler bellek kapasitesi arttıkça, sözel ve matematiksel başarılarının da artabileceği ihtimali yönünden yorumlanmıştır. Bu yorum, işler bellek kapasitesinin artırılabilmesi ile işler belleğin sorumlu olduğu diğer birçok bilişsel sürecin de iyileştirilebilmesi önerisiyle sonuçlandırılmıştır.

Anahtar Kelimeler: İşler Bellek, İşler Bellek Kapasitesi, Sözel Başarı, Matematiksel Başarı, Okuma Uzunluğu Testi, Sayı Dizisi Testi

Ailem'e…

To my family…

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LIST OF ABBREVIATIONS

WM:	WORKING MEMORY
PL:	PHONOLOGICAL LOOP
CE:	CENTRAL EXECUTIVE
VSSP:	VISUO-SPATIAL SKETCHPAD
EB:	EPISODIC BUFFER
WMC:	WORKING MEMORY CAPACITY
STM:	SHORT TERM MEMORY
LTM:	LONG TERM MEMORY
STS:	SHORT TERM STORE
LTS:	LONG TERM STORE
PWM:	PHONOLOGICAL WORKING MEMORY
VSWM:	VISUO-SPATIAL WORKING MEMORY
VWM:	VERBAL WORKING MEMORY
EWM:	EXECUTIVE WORKING MEMORY
RSPAN:	READING SPAN TASK
OSPAN:	OPERATION SPAN TASK
DSPAN:	DIGIT SPAN TASK
AE1:	ACHIEVEMENT EXAM I
AE2:	ACHIEVEMENT EXAM II
YGST:	YÜKSEKÖĞRETİME GEÇİŞ SINAVI (TURKISH)
YGSM:	YÜKSEKÖĞRETİME GEÇİŞ SINAVI (MATHEMATIC)
L1:	FIRST/NATIVE LANGUAGE
L2:	SECOND/FOREIGN LANGUAGE

CHAPTER 1

INTRODUCTION

"Without an understanding of what the mind was designed to do
in the environment in which we evolved;
the unnatural activity called formal education
is unlikely to succeed."
(Steven Pinker, How the Mind Works, 1997, p. 342)

1.0. Presentation

In this chapter, background to the study, the purpose and significance of the study and the research questions to be investigated are presented and discussed.

1.1. Background to the Study

> Eight-year-old Jennifer listened carefully as the teacher said, *"After you are done with your math worksheet, get out your reading book and finish answering the questions on page fifteen, at the bottom of the page."* Other children quickly went to work but Jennifer timidly raised her hand and asked the teacher to repeat the directions. Even though she is a bright child, routine oral directions such as this are hard for Jennifer to follow. Was Jennifer having trouble paying attention or did she simply forget what was said? (Young, 2000, p. 1)

It is more than probable that most teachers have many students like Jennifer, as depicted in the anecdote. The number of students who have trouble following instructions; paying attention to in-class activities; or having trouble in learning many school subjects is incontrovertible. Was Jennifer having trouble paying attention or did she simply forget what the teacher said? The fact is that Jennifer is a bright child who has problems with her *Working Memory* (Young, 1999, p.1)

Although it stemmed from the ideas of John Locke as early as 1690s; the term *Working Memory* evolved in literature only more than a few decades ago (Dehn, 2008). Traditionally, working memory (WM) has been conceptualized as an active memory system that is responsible for the temporary maintenance and simultaneous processing of information. Alternatively, WM has been defined as the use of temporarily stored information in the performance of more complex cognitive tasks (as cited in Dehn, 2008, p. 2); or as a mental workspace for manipulating activated long-term memory representations (Stoltzfus, Hasher, & Zacks, 1996). Overall, WM is viewed as a comprehensive system that unites various short- and long-term memory subsystems and functions (Baddeley, 1986)

At this point, it might be of importance to note that, although many cognitive psychologists and memory experts view short-term (STM) and WM as interchangeable or consider one to be a subtype of the other; working memory and short-term memory are distinguishable constructs. Dehn (2008) explains the chief differences as the following:

- STM passively holds information; WM actively processes it.
- STM capacity is domain specific (verbal and visual); WM capacity is less domain specific.
- WM has stronger relationships with academic learning and with higher-level cognitive functions.
- STM automatically activates information stored in long-term memory; WM consciously directs retrieval of desired information from long-term memory.
- STM has no management functions; WM has some executive functions.
- STM can operate independently of long-term memory; WM operations rely heavily on long-term memory structures.
- STM retains information coming from the environment; WM retains products of various cognitive processes.

Since it has the role of actively holding and processing information; WM helps us to explain the processing of many cognitive functions within our brain not on only in terms of academic subjects, but also in terms of everyday life. As Braver (2005) explains:

> Every day we have occasion to keep particular pieces of critical information briefly in mind, storing them until the opportunity to use them arrives. Here are some examples: remembering a phone number between the time of hearing it and dialing it ("1 646 766-6358"); figuring a tip (the bill is $28.37, call it $30; 10 percent of that is $3.00, half of that is $1.50, $3.00 plus $1.50 is $4.50, the 15 percent you're aiming for); holding driving directions in mind until you get to the landmarks you've been told to watch for ("take the first left, continue for one mile, past the school, bear right, left at the four-way intersection, then it's the third building on the left- you can pull into the driveway"). Sometimes a problem offers multiple possible solutions, such as when you must look ahead along various possible sequences of moves in a chess game, and sometimes, as when you must untangle the structure of a complex sentence like this one, it is straightforward but nonetheless requires holding bits of information in mind until you can put it all together. In situations like these, not only do we need to keep certain bits of information accessible in mind, but also we need to perform cognitive operations on them, mulling them over, manipulating or transforming them. These short-term mental storage and manipulation operations are collectively called working memory (p. 240)

The most influential WM model has been that of Baddeley and Hitch's WM model which they came up with in 1974. In their model, they proposed a WM model comprising of three components: the central executive (CE), and two slave systems: the phonological loop (PL) and the visuo-spatial-sketchpad (VSSP). The CE was envisioned as a control system of limited attentional capacity that is responsible for the manipulation of information within working memory and for controlling two subsidiary storage systems: the PL and the VSSP. The PL was assumed to be responsible for the storage and maintenance of information in a phonological form, while the VSSP was dedicated to the storage and maintenance of visual and spatial information (Repovš&Baddeley, 2006, p. 7). Based on a number of empirical findings a fourth component, the episodic buffer, was added recently (Baddeley, 2000). The episodic buffer is assumed to be a limited capacity store that is capable of multi-dimensional coding, and that allows the binding of information to create integrated episodes.

As Baddeley (2012) explains, the research on WM has been developed along two different but complementary approaches. The first one is the dual-task neurophysical approach, Baddeley and Hitch's (1974) model being the most influential one. In this type of approach, there is the application of dual-tasks, for instance remembering a list of digits while reasoning (Fortkamp, 1999); and thus this type of approach also uses neuropsychological evidence to explain the slave subsystems.

The second approach, as Baddeley (1992) calls *psychometric approach* (p. 342), deals with correlations occurring between working memory capacity and the performance of complex cognitive tasks. Within this approach, the working memory is conceptualized as a single unitary device and the storage and processing functions of working memory compete for its capacity during the performance of complex cognitive tasks (Daneman and Carpenter, 1980)

As regards the research carried out with an aim of investigating the relationship between WM and academic achievement in various subjects; it is clear that WM plays an undeniably important role in mathematical achievement in children with specific arithmetic learning difficulties (McLean&Hitch, 1999); low arithmetical achievement (D'Amicoa&Guarnera, 2005; Iuculano, Moro&Butterworth, 2011; Passolunghi&Siegel, 2001); mathematics difficulties (Andersson&Lyxell, 2007; Peng, Congying, Beilei&Sha, 2012); and Fetal Alcohol Spectrum Disorders (Rasmussen&Bisanz, 2011). Mathematical achievement and WMC was also investigated in children with no specified deficits as well (Holmes&Adams, 2006; Miller&Bichsel, 2004; Smedt et. al., 2009; Zheng, Swanson&Marcoulides, 2011)

Regarding native language, WM also plays a crucial role in children in terms of vocabulary (Baddeley, Gathercole&Papagno, 1998; Gathercole et. al., 1992; Gathercole et. al., 1999); and spoken language (Adams&Gathercole, 2000); and in adults in terms of verbal achievement (Verbal Scholastic Aptitude Test – Daneman&Carpenter, 1980; Friedman&Miyake, 2004); and reading comprehension (Cohen-Mimran&Sapir, 2007; Turner&Engle, 1989).

In a close relationship with native language (Dufva&Voeten, 1999; Hulstijn&Bossers, 1992; Palladino&Cornoldi, 2004), foreign language acquisition and WMC is also intimately related in terms of vocabulary acquisition

(Gupta&MacWhinney, 1997; Masoura&Gathercole, 1999, 2005), reading comprehension (Daneman&Carpenter, 1980; Payne, Kalibatseva&Jungers, 2007; Turner&Engle, 1989); listening comprehension (McInnes et. al., 2003; Sung et. al., 2008); speech production (Finardi&Prebianca, 2006; Fortkamp, 1999); written language production (Kellogg, Olive&Piolat, 2007; Swanson&Berninger, 1996) and overall language proficiency (Gilabert&Muñoz 2010; Kormos&Sáfár, 2008).

1.3. Purpose and Significance of the Study

Despite this large number of studies investigating the relationship between WM, language and mathematical achievement; there are some drawbacks and controversial issues which need to be further researched. For example, in terms of the relationship between mathematical achievement and WMC, the first drawback to be taken into account is that most of the studies are carried out with children (primary school) or even very young children (4-5 years old). The reason for this might be that, as Bull and Espy (2006) explains, mathematics competence in young children is described by proficient counting, whereas in a college student, mathematics competence is marked by solving complex trigonometric problems and integrating equations (p. 63). Thus, not surprisingly, because of the greater complexity of algebra and geometry, developmental models are lacking, more progress has been made in understanding the development of children's basic arithmetic skills. Therefore, the studies on WM and mathematics which work with adult or young adults as participants are scarce.

Secondly, there is some controversy between the relationship of different components of WM (i.e. phonological loop, viuso-spatial sketchpad, central executive and episodic buffer) to mathematical achievement. For example, while the central executive and the visuo-spatial sketchpad are generally found to be influential in mathematical achievement, the role of the phonological loop remains unclear. While some studies support the role of the phonological loop (Andersson&Lyxell, 2007; Peng, Congying, Beilei&Sha, 2012; Rasmussen&Bisanz, 2011; Zheng, Swanson&Marcoulides, 2011); others concluded that the phonological loop is not the major factor in explaining arithmetical difficulties (D'Amicoa&Guarnera, 2005; Holmes&Adams, 2006; Iuculano, Moro and Butterworth, 2011; McLean&Hitch, 1999). Age is also another factor that is rarely taken into account when investigating the relationship between the components of WM and mathematics. In their studies, Smedt et. al., for instance, concluded that although the central executive was a unique predictor of both first and second-grade mathematics achievement; there were age-related differences with regard to the contribution of the slave systems to mathematics performance: the visuo-spatial sketchpad was a unique predictor of first-grade, but not second-grade, mathematics achievement; whereas the phonological loop emerged as a unique predictor of second-grade, but not first-grade, mathematics achievement.

When it comes to the relationship between WMC and language, despite the number of studies carried out in native language, studies on foreign language are relatively fewer. Moreover, when the studies on foreign language is considered, very few of them focus on overall language proficiency rather than separate language areas or skills. Among these studies, while some of them found correlation between WMC and overall language proficiency (Kormos&Sáfár, 2008); others did not (Gilabert&Muñoz 2010). Again, the role of the phonological loop is also debatable in these studies. For example, in some studies, measures of the phonological loop (i.e. simple span tasks such as digit or word span) do not correlate with language measures (Daneman&Carpenter, 1980; Turner&Engle, 1989); whereas in other studies it does (Baddeley, Papagno&Vallar, 1988; Masoura&Gathercole, 1999, 2005). As Dehn (2008) agrees, "some authors claim that forward digit span is measuring attention; others say it is measuring short-term memory, and still others classify it as a working memory measure. Consequently, it is usually unclear as to which memory components the scales actually measure." (p. 6)

When carrying out correlational studies with WMC, it was mentioned that age was to be taken into account regarding mathematics. By the same token, the proficiency level of the participants is of importance regarding language. For example, as Kormos&Sáfár (2008) found out, the phonological short-term memory capacity plays a different role in the case of beginners and pre-intermediate students in intensive language learning. As regards the students who were beginners at the beginning of the school year, there was found no significant correlation between measures of phonological short term memory and achievement on various components of the language test. Unfortunately the studies which investigate the relationship between WMC and both native and foreign language are mostly carried out with children and mostly with low proficiency levels.

Although rarely, measures of central executive (i.e. complex span tasks such as Reading Span Task, Operation Span Task) may also show insignificant correlations with language skills. For example, as Fortkamp (1999) concluded in her study, Speaking and Reading Span tests did not correlate with any L2 fluency task (Oral Reading Task).

The relationship between foreign language and mathematical achievement; and foreign language and verbal achievement also needs further research. As Swanson and Sachse-Lee (2001) explains, a growing body of empirical and theoretical work has shown that children's difficulties in mathematical word problems are strongly related to deficient language and comprehension strategies (p. 295). Palladino and Cornoldi (2004), on the other hand, concluded in their study that children with foreign language learning difficulties (FLLD) typically seem to have problems with L1 learning; and Hulstijn and Bossers (1992) also support the relationship between foreign language and native language achievement. However, these two relations of foreign language to mathematics and native language need further investigation.

All taken together, the following conclusions could be drawn: first of all, the role of the WM components (especially the phonological loop measured by simple span tasks) in mathematical achievement is not clear enough and there are fewer studies carried out with young adult participants than with children; second of all, studies investigating the relationship between WMC and overall foreign language and overall native language achievement (verbal achievement) are relatively few and mostly carried out with children and with low proficiency level participants; third of all, the role of the WMC (in terms of its phonological loop and the central executive components measured by simple and complex span tasks, respectively) is controversial both in verbal achievement and mathematical achievement. Finally, the relationship of foreign language achievement to native language an mathematical achievement needs further research in relation to WM or different components of WM.

By taking all these controversies about WM and its relation to other academic subject and areas, and by taking into account the fact that the studies investigating about WM is very scarce in Turkey; this study is carried out with an aim to investigate the relationship between Working Memory Capacity, Verbal Achievement and Mathematical Achievement of young adults (i.e. undergraduate students), whose native language is Turkish and who are learning English as their foreign language.

1.4. Research Questions

The main and sub-research questions of the study are given below:

What is the relationship between working memory capacity and verbal and mathematical achievement?

1. Is there a relationship between working memory capacity and native language verbal achievement?
2. Is there a relationship between working memory capacity and foreign language verbal achievement?
3. Is there a relationship between working memory capacity and mathematical achievement?
4. Is there a relationship between foreign language achievement and mathematical achievement in relation to working memory capacity?
5. Is there a relationship between foreign language achievement and native language achievement in relation to working memory capacity?

CHAPTER II

REVIEW OF LITERATURE

2.0. Presentation

In this chapter, types of memory and working memory (WM) in particular are reviewed as defined in the literature and the studies investigating the relationship between WM, WMC, verbal achievement and mathematical achievement are presented.

2.1. Types of Memory

> One of the unmistakable characteristics of an immature science is the looseness of definition and use of its major concepts. In experimental psychology, we can measure our progress by the number and generality of empirical facts and the power and scope of our theories, and we can assess the lack of progress by the degree of ambiguity of our most popular terms. The concept of memory is a good case in point, although perception of learning, motivation, emotion, and thought could serve as equally relevant illustrations. What exactly do we mean by *memory*? (Tulving, 1972, p. 381 – italics added)

Memory can simply be defined as "the amount of previously learned material that has been retained" (Brink, 2008, p.1) or as "the ability of something to retain information"; thus changing its input-output function, i.e. the output it produces in response to a given stimulus (Cardinal, 2004, p.1). Although it was proposed as early as 1890 by the great American psychologist William James, and again by Donald Hebb in 1949 that memory can be fragmented into subcomponents; it was not until 1970s that many psychologists felt the necessity to assume more than one kind of memory. However, since the process of subdividing 'memory' is based on neuro-scientific as well as psychological evidences, the number of forms of memory has changed over the years because of the fact that there are some major controversies in this area of *memory* in the area of cognitive neuroscience. As Baddeley (1999) agrees, experimental evidence for the fractionation of human memory has only developed principally over the last 30 years.

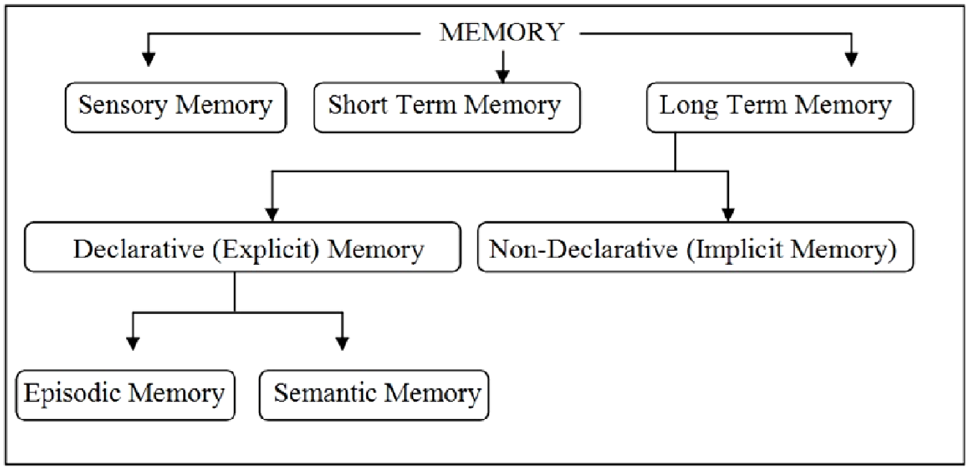

Figure 2.1: Types of memory

2.1.1. Sensory (Iconic) Memory

Sensory memory – as the name implies – acts as a kind of buffer for stimuli received through the five senses of sight, hearing, smell, taste and touch, which are retained accurately, but very briefly. It is the shortest-term element of memory. According to Cowan (2009), sensory memory means temporarily remembering how certain things look, sound, feel, taste, or smell. For example, the ability to look at something and remember what it looked like with just a second of observation is an example of sensory memory.

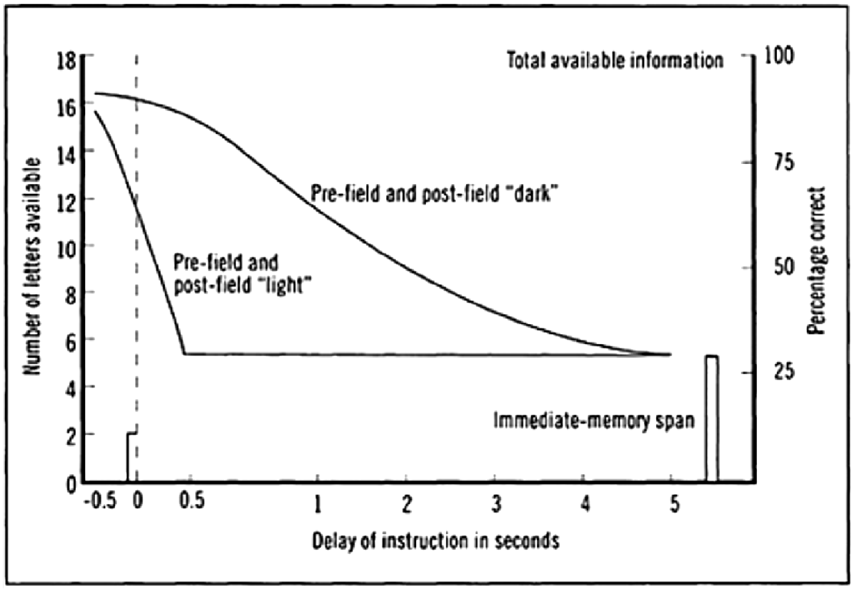

Figure 2.2: Loss of information from visual sensory memory. In this experiment, 16 letters were presented visually. When the letters were preceded and followed by a dark visual field, the sensory or iconic memory trace lasted for several seconds. When the field before and after was bright, information was lost in half a second. (based on Sperling, 1963 – as cited in Baddeley, 1999, p. 11)

Incoming sensory information appears initially to enter a very short-term, high-capacity *sensory store*. Its existence was first shown by Sperling (1960). He flashed a 4x3 matrix of letters for 50 milliseconds. If participants were asked to report all the letters (‘whole report’), they reported 4.32 letters correctly out of 12, but if they were cued by a series of tones, presented after the visual array, to report only the top, middle, or bottom row (‘partial report’); they reported 3.04 out of 4 for each row. This implies that they had access to at least 9-10 out of 12 letters for a short time. It appears that this ‘*sensory* (or) *iconic* memory’ lasts about half a second: if the tone was delayed for a second or so, participants were no better off than in the ‘whole report’ condition. From here, as Cardinal (2004) explains, information appears to pass into a lower-capacity but slightly longer-lasting buffer, often known as short-term memory (STM).

2.1.2. Short Term Memory

Although STM is mostly explained as "a system for storing information over brief intervals of time" (Baddeley, 1999, p. 20); the most influential model of STM was that of Atkinson and Shiffrin (1968), who proposed that information came in from the environment into a temporary short-term storage system which served as an antechamber to the more durable LTM. In their model, it is assumed that the information comes is from the environment via sensory systems into a limited capacity *short-term store* (STS), which is pictured as a crucial bottleneck between perception and LTM.

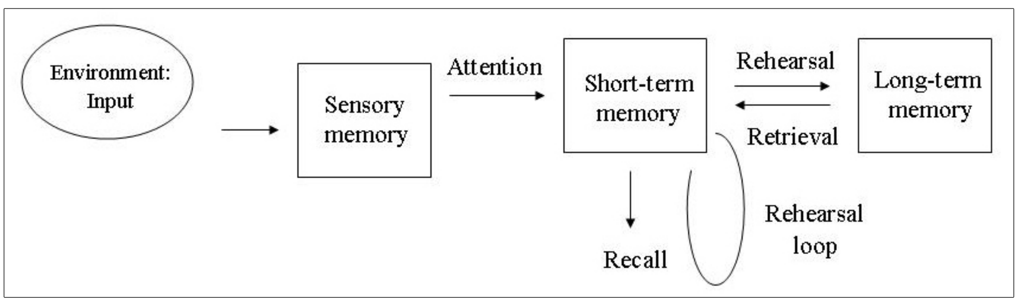

Figure 2.3: The multi store model of Atkinson and Shiffrin (1968)

STM has two aspects which are of crucial importance: (1) limited capacity and (2) limited duration. As regards capacity, there are two ways in which it is tested, one being span, the other being recency effect. Miller's (1956) "Magic number 7 – Plus or minus two" provides evidence for the capacity of short term memory. Most adults can store between 5 and 9 items in their short-term memory. This idea was put forward by Miller (1956) and he called it the magic number 7. He though that short term memory could hold 7 (plus or minus 2 items) because it only had a certain number of "slots" in which items could be stored.

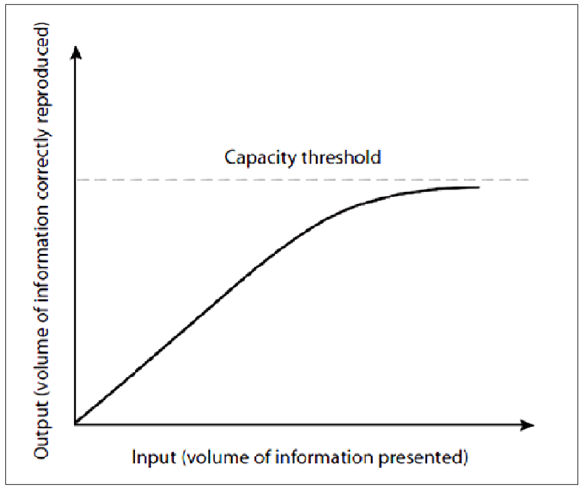

Figure 2.4: Illustration of capacity restrains on human brain (from Miller, 1956, p.87)

However, Miller didn't specify the amount of information that can be held in each slot. Indeed, if we can "chunk" information together we can store a lot more information in our STM. Baddeley (1999) supports this claim by stating that the capacity of STM is determined by the number of chunks rather than by the number of digits; and he gives the following example of chunking:

> Try reading off and repeating back the following sequence of letters: I A R F T S K B G N I. Were you able to repeat it correctly? If you were, you have a remarkably good immediate memory. Now try the next sequence, which in fact comprises exactly the same letters: F R I K B A S T I N G. No prizes for getting that one correct. What is the difference between the two sequences? The first comprised 11 unrelated letters, and although it is possible to chunk a few of them together into a single sound, ARF for example, in general the number of chunks remaining would be likely to exceed the six or seven that our short-term memories can hold. The second sequence can very easily be chunked into three speech sounds, or possibly even two if you regard B A S T I N G as a single word. The task would have been even easier had the 11 letters made up an already existing word such as I N T E L L I G E N T. (p. 23)

According to Atkinson and Shiffrin (1968), the duration of STM seems to be between 15 and 30 seconds, Items can be kept in short term memory by repeating them verbally (acoustic encoding), a process known as *rehearsal* (or *subvocal repetition*). In other words, information in STM will quickly disappear forever unless we make a conscious effort to retain it, and this effort is important in the sense that STM is a necessary step toward the next stage of retention: LTM.

2.1.3. Long Term Memory

LTM is probably the most common term that comes to mind when memory is the subject. In the most basic sense, remembering your name, how to speak, where you lived as a child, or where you were last year or even two minutes ago are all considered to depend on LTM. When it comes to the question of whether or not LTM is a unitary system is still controversial (Baddeley, 1999). Nevertheless, it is commonly accepted that LTM is a complex storage system with several different types of storage distributed throughout the brain (Dehn, 2008). Information is generally believed to be stored as visual images, verbal units, or both; and as a result, long-term storage is generally partitioned into visual and auditory or verbal memory.
According to Dehn (2008), while the retention and reconstruction of visual images is the main characteristic of visual memory; auditory and verbal memories are more complex, with several subtypes. LTM can be primarily divided into *declarative (or explicit)* memory and *non-declarative (implicit)* memory. Basically, declarative memory refers to memory for facts or events, and non-declarative to the rest (Baddeley, 1999).

2.1.3.1. Declarative (Explicit) Memory

Declarative memory refers to remembering personal events, cultural history, semantic information and other facts that we can be explicitly aware of and thus report, or "declare", either verbally or non-verbally (Purves, et.al., 2008, p. 354). In 1972, psychologist Endel Tulving made a distinction between two types of declarative memory: *episodic* memory and *semantic* memory.

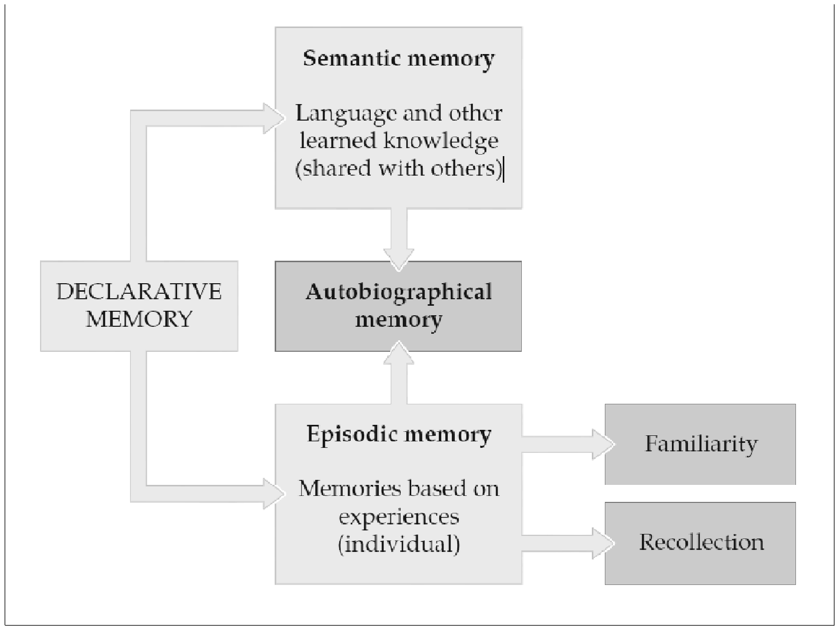

Figure 2.5: A taxonomy of declarative memory functions (Purves, et.al, 2008, p. 354).

As Tulvin (1972) explains, *episodic memory* refers to memory for personal experiences and their temporal relations; while *semantic memory* is a system for receiving, retaining and transmitting information about meaning of words, concepts and classification of concepts (p. 402). To illustrate, remembering getting soaked in the London rain last Tuesday is an example of episodic memory, but knowing that it often rains in England is an example of semantic memory because it need not be acquired as a result of a personal experience of getting wet (Cardinal, 2004).

2.1.3.2. Non-Declarative (Implicit) Memory

Basically, non-declarative memory means knowing *how* to do something. It is generally thought of as skill or habit memory. However, it should be taken into account that, non-declarative memory is not itself a brain-system construct. Rather, it is an umbrella term that encompasses several different kinds of non-declarative memory (Squire, 1998). As Baddeley (2004) agrees, the various types of implicit memory anatomically appear to reflect different parts of the brain, depending upon the structures that are necessary for the relevant processing. All in all, these forms of non-declarative are all *non-conscious*. Memory is expressed through performance and does not require any reflection on the past or even the knowledge that memory is being influenced by past events. As one of the differences between declarative and non-declarative memory is that declarative memory is knowledge about the external world, and it is either true or false; non-declarative memory is about performance, and it is neither true nor false (Squire, 1998).

2.2. The History of Working Memory

In his latest article, Baddeley (2012) expresses that the term "working memory" evolved from the earlier concept of short-term memory and Andrade (2001) agrees that the roots of working memory are in theories of short-term memory and those theories focused on the temporary storage of information, rather than on the role that temporary storage or transformation played in general cognition. Despite these facts, the origins of the working memory construct may actually be traced to the early days even before the rise of psychology.

First and foremost, one of the earliest recorded references to a concept similar to working memory is found in the writings of the seventeenth-century British philosopher John Locke in 1690:

> The next faculty of mind […] is that which I call *retention* […] This is done in two ways. First by keeping the idea which is brought into it, for some time actually in view, which is called *contemplation*. The other way of retention is the power to revive again in our minds those ideas which, after imprinting, have disappeared, or have been as it were laid aside out of sight. […] This is *memory* which is as it were the storehouse of our ideas. (Book II, chap. X, paras. 1-2 – cf. Logie, 1996, p. 31 – italics added)

Based on this passage, Logie (1996) explains that the two terms: "the idea in view" and "the storehouse of ideas" are believed to reflect what we understand today from working memory in the sense of its being a 'temporary workspace' and 'storage', respectively.

About two centuries later in 1885, Ebbinghaus (1885) took a few steps further and explained that every kind of mental states, such as sensations, feelings, ideas do not fade away after they are experienced. Rather, they continue to exist and thus they are stored in what is called *memory*.

Ebbinghaus (1885) also carried out a study on himself, seeking to find out the ways of how people learn. He obtained a remarkable set of results. He reported that he could perfectly recall lists of 7 or fewer nonsense syllables upon a single presentation, but that lists of 8, 9, and 10 syllables required approximately 5, 9, and 12 repetitions, respectively. Conway, et. al. (2007) finds it interesting that Ebbinghaus (1885) had so little to say about this dramatic finding by proposing no special mental state or faculty associated with immediate recall of short sequences (p. 5).

The following year, Jacobs (1887) reported the first empirical paper on the memory span task, collecting the data from a collegiate school with students between the ages of 8 and 20. In the study, students were presented with lists of auditory nonsense syllables, letters, or digits to repeat. The largest set that each student perfectly reproduced was termed his or her span of *"prehension"* – from the analogy of "apprehension" and "comprehension" (p.79). Jacobs (1887) found that span increased not only with chronological age but also with higher school grades. As he put forward: "Under these circumstances we might expect that 'span of prehension' should be an important factor in determining mental grasp, and its determination one of the tests of mental capacity." (p. 79). This finding is probably the reason why his study is still regarded as one of the first systematic individual differences studies of memory (Conway, et. al. 2007).

Later in 1890, William James would be the first psychologist to propose two types of memory: primary and secondary. He defined primary memory as current contents of consciousness and as a "rearward portion of the present space of time" (p. 647), so it has the disadvantage of having a sharp capacity limit. As for the secondary memory, or *memory prose* as James (1890) calls, it is the 'knowledge of a former state of mind after it has already once dropped from consciousness' (p. 648); in other words, it is the vast amount of information stored for a lifetime.

Dehn (2008) argues that although the terms short-term and long-term memory were probably coined by Thorndike as early as 1910; during the first half of the twentieth century, memory was generally viewed as a unified construct, with short-term memory included in what we now consider long-term memory (p. 10). It was not until 1949 that Hebb proposed a clear distinction between long term and short term memory in a sense that short term memory was related to temporal electrical activity and long term memory involved durable changes in the nervous system (Baddeley, 2003).

In 1958, Brown (1958) explained *immediate memory* as 'necessary to retain information while continuing to carry out other activities' (p. 12) and they carried out a study consisting of three experiments in order to test the hypothesis of decay of the memory trace. The results of the study showed that forgetting occurs over a few seconds if rehearsal is prevented. However these results were also attributed to the comparison between long-term and short-term memory. Two years later in 1960, Miller, Galanter, and Pribram (1960) would be the first to use the expression "working memory" in their book *Plans and the Structure of Behavior* in which they were interested in how knowledge is translated into action. They argued that human beings are capable of forming, hierarchically structuring, and executing *plans*:

> The parts of a Plan that is being executed have special access to consciousness and special ways of being remembered that are necessary for coordinating parts of different Plans and for coordinating with the Plans of other people. When we have decided to execute some particular Plan, it is probably put into some special state or place where it can be remembered while it is being executed. Particularly if it is a transient, temporary kind of Plan that will be used today and never again, we need some special place to store it. The special place may be on a sheet of paper. Or (who knows?) it may be somewhere in the frontal lobes of the brain. Without committing ourselves to any specific machinery, therefore, we should like to speak of the memory we use for the execution of our Plans as a kind of quick-access, "working memory." (p. 65)

The key phrases in the passage "a special state or place where it [a plan] can be remembered while it is being executed" and "the memory we use for the execution of our Plans." imply a unique system responsible not only for the storage of plans but also for their implementation. Thus, from their explanation, it can be clearly understood that Miller, Galanter, and Pribram (1960) considered working memory fundamentally similar to the sense as how we understand it today.

2.3. Models of Working Memory

Although there are many types of WM models that have been proposed in literature, most influential models are Atkinson and Shiffrin's (1968) Working Memory Model; Baddeley and Hitch's (1974) Working Memory Model and Cowan's (1988) Working Memory Model.

2.3.1. Atkinson and Shiffrin's (1968) Working Memory Model

Although Miller, Galanter, and Pribram (1960) first coined the term, the origins of the concept or working memory are mostly traced to a later publication by Atkinson and Shiffrin (1968) which contained a detailed analysis concerning the structure and functioning of human memory.

In their model, they proposed three major structural components: a sensory register, a STS, and a LTS. The sensory register – also known as *immediate memory* or the *sensory memory* – constantly receives information most of which receives no attention. Thus, this incoming data remains in the sensory store for a very brief period. When a person's attention is focused on the sensory store, the data is then transferred to the short-terms store, which is a limited-capacity, temporary storage system. As for moving information from STM to LTM, which is relatively permanent and unlimited in capacity, Atkinson and Shiffrin (1968) argued that this happens through rehearsal. They explained two major purposes of rehearsal in their memory system. The first is "lengthening of the time period information stays in the long term store" and the second is "increasing the strength built up in a long term store" (p.35). They proposed a direct relationship between rehearsal in short-term memory and the strength of the long-term memory – the more the information is rehearsed, the better it is remembered. Thus in a way, the temporary STS system in their model served as a gateway to the more durable LTM.

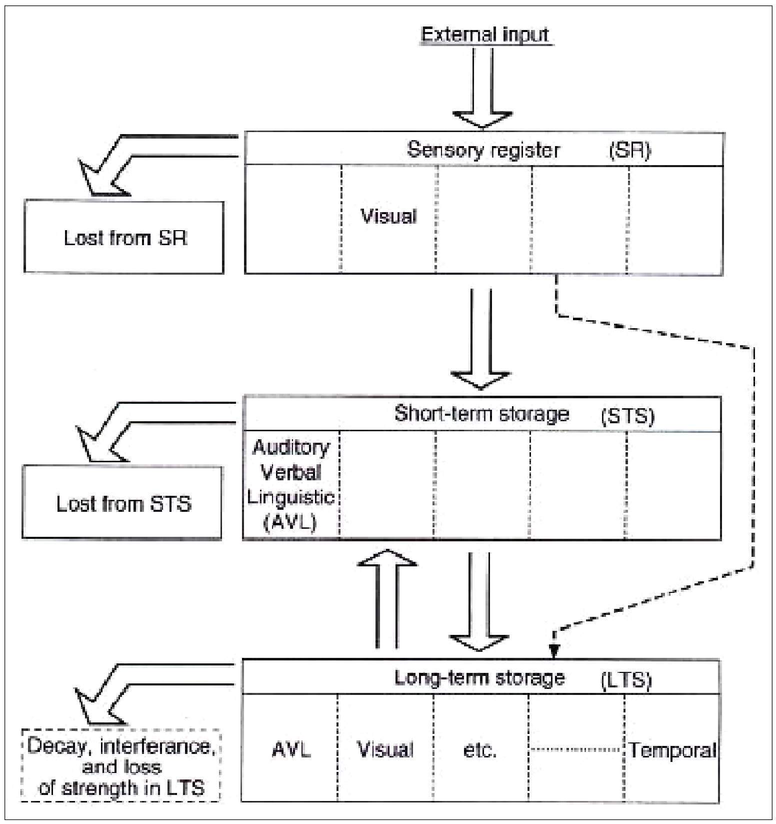

Figure 2.6: Structure of the memory system (from Atkinson and Shiffrin, 1968, p. 17)

Atkinson and Shiffrin (1968) regarded the STS as a "working memory"; because, as they explained, the information which enters the STS is assumed to decay and disappear completely, but the time required for the information to be lost is considerably longer than for the sensory register (p. 16). As Baddeley (2003) also agrees, this temporary system served as a WM, a workspace necessary not only for long-term learning, but also for many other complex activities such as reasoning and comprehension.

2.3.2. Baddeley and Hitch's (1974) Working Memory Model

Baddeley (2012) explains that although many neuropsychological studies supported the memory model of Atkinson and Shiffrin (1968); their study was criticized for three main reasons:

> *First,* the model assumed that merely holding information in STM would guarantee transfer to LTM, whereas […] the nature of processing is crucial, with deeper, more elaborate processing leading to better learning. *Second,* its assumption that the STS was essential for access to LTM proved to be inconsistent with neuropsychological evidence. Patients with a digit span of only two items and an absence of recency in free recall should, according to Atkinson and Shiffrin, have a defective STS that should lead to impaired LTM. This was not the case. *Third,* given that Atkinson and Shiffrin assumed their STS to be a working memory, playing an important general role in cognition, such patients should have major intellectual deficits. They did not. One patient, for instance, was an efficient secretary, and another ran a shop and a family. (p. 5 – italics added)

In 1974, these paradoxes led Baddeley and Hitch to come up with what is known and what is most cited WM model today. The two British psychologists developed the idea of a "working memory *within* short-term memory" (Dehn, 2008, p. 14). Their model is the most influential and most cited WM model even today.

In their study, Baddeley and Hitch (1974) set off with two basic questions: first, if there is any evidence that the tasks of reasoning, comprehension and learning share a common WM system and second, if such a system exists, how it is related to the current conception of STM (p. 49). To answer these questions, Baddeley and Hitch carried out 10 series of experiments with which they investigated the effects of a concurrent serial recall task on performance in reasoning, comprehension, and free recall, because they expected that "Such a concurrent memory load might reasonably be expected to absorb some of the storage capacity of a limited capacity working memory system" (p. 50). In other words, as the sequence length increased; the amount of uncommitted STM remaining would – as they expected – diminish, which would thus result in an increasing degree of interference with the various tasks.

However, contrary to this hypothesis, Baddeley and Hitch (1974) found that three digit load – which requires 50% of the normal capacity of STM – had no effect on language comprehension, and only a small effect on retrieval from long-term storage. Moreover, a one- or two-digit load had no effect on logical reasoning time. However, a six-digit load impaired performance on all three tasks, but did not do so dramatically. In other words, they found out that the reasoning, comprehension, and retrieval tasks loaded a component of WM that was *separate* from the verbal short-term store used for digit span (Andrade, 2001, p. 8). All these results ipso facto led Baddeley and Hitch (1974) to come up with the decision that the idea of a unitary STS was too simple. Instead, they proposed the three-component model shown in Figure 2.7. As originally proposed, Baddeley and Hitch's multifaceted model comprised three aspects of WM: a phonological loop, a visuospatial sketchpad, and a central executive that controlled the other two subsystems, referred to as *slave systems*.

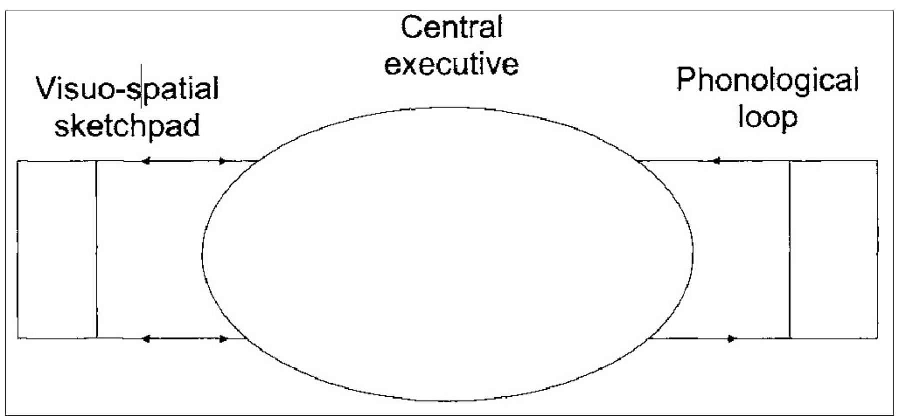

Figure 2.7: The original Baddeley & Hitch (1974) WM model.

2.3.2.1. The Phonological Loop

In their study Baddeley and Hitch (1974) had found out that subjects were able to hold a concurrent memory load of up to three items with essentially no effect upon their performance, comprehension or free recall. In order to explain this fact, they put forward a speech-based subsystem, which they described as "a phonemic response buffer which is able to store a limited amount of speech-like material in the appropriate serial order" (p. 77).

The phonological loop (also called *the articulatory loop*) is one of the most important and the most extensively researched area of Baddeley and Hitch's (1974) working memory model. The PL, as proposed in the earliest model, is comprised of two components: a phonological store and an articulatory rehearsal process. *The phonological store* holds memory traces over a matter of seconds, during which they decayed, unless refreshed by the second component, the articulatory rehearsal. *The articulatory researsal* then is responsible for retrieving and re-articulating the contents held in this phonological store and in this way to refresh the memory trace (Baddeley, 2003; Repovs and Baddeley, 2006). In this sense, the PL closely resembles earlier conceptions of STS in Atkinson and Shiffrin's (1968) model, for it consists of a limited duration, speech-based representation and is dependent on articulatory rehearsal for the maintenance of information.

According to Baddeley (1998a) the clearest evidence for the phonological store comes from a phenomenon known as *the phonological (or acoustic) similarity effect*. In his study, Conrad (1964) studied the recall of visually presented single consonants and he found out that errors tended to involve consonants that sounded, rather than looked, similar. That is to say, *V* was liable to be misremembered as *B* and *F* as *X*. In another study carried by Conrad and Hull (1964), it was found that when participants were required to remember sequences of consonants, they made far more errors with phonologically similar lists such as *T, P, G, V, D* than with dissimilar sets such as *K, W, Y, R, F*.

Interestingly enough, although the similar effect occurred for words, Baddeley (1966) found out that the similarity of meaning has little effect. That is, the words which are similar in meaning but different in sound such as *big, huge, large, wide, tall* are only slightly less well recalled than a dissimilar list such as *old, wet, strong, smooth, thin*.

Baddeley (2003) also argues that evidence for the rehearsal system is provided by *the word length effect,* which again involves presenting subjects with a sequence of items and requiring immediate serial recall. As he explains, memory for a five-word sequence drops from 90% when these are monosyllables to about 50% when five syllable words are used, such as *university, opportunity, international, constitutional, auditorium.* This robust finding was initially interpreted as reflecting the decay of a memory trace over time, with long words taking longer to rehearse hence allowing more decay than short (Repovs and Baddeley, 2006)

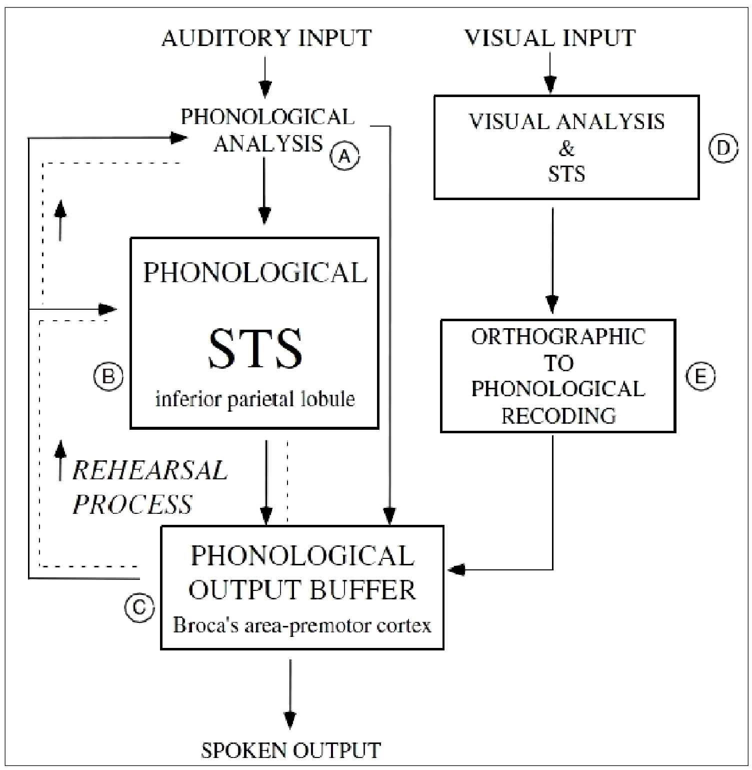

Figure. 2.8: A proposed structure for the PL. Auditory information is analyzed (A) and fed into a short-term store (B). Information from this system can pass into a phonological output system (C) which can result in spoken output, or in rehearsal. This in turn may recycle information, both subvocally into the STS, and when rehearsal is overt, into the ears. Visually-presented material (D) may be transferred from an orthographic to a phonological code (E) and hereby registered within the phonological output buffer. (from Vallar and Papagno, 2002, p. 250)

2.3.2.2. The Visuo-Spatial Sketchpad

In literature, it has been agreed that the visuo-spatial component of WM has received much less attention (Baddeley, 1998a; Dehn, 2008; Logie, 1996; Pearson, 2001; Repovs and Baddeley, 2006). As Pearson (2001) agrees, the visuo-spatial component of Baddeley and Hitch's (1974) WM model may be considered as the 'underdeveloped youngest child, over-shadowed by both the more popular verbal sibling and the ambitious parental executive' (p 33).

Logie (1996) explains that as the PL is linked to the speech system, so the visuo-spatial sketchpad has been linked to the control and production of physical movement. Moreover, as Baddeley (1986) argues, like the PL, the VSSP consists of a passive temporary store and an active rehearsal process. Decay in the temporary visuo-spatial store seems to be as rapid as phonological decay, taking place within a matter of seconds. The rate of forgetting seems to be a function of stimulus complexity and of how long the stimulus is viewed. Refreshment of the visual trace appears to result from eye movement, manipulation of the image, or some type of visual mnemonic (as cited in Dehn, 2008, p. 19).

Although VSSP storage was originally described as a unified subcomponent, psychological data later suggested that the sketchpad is capable of holding two kinds of information about objects: *visual* and *spatial.* Whereas spatial information comprises of location, motion, direction of an object; visual information includes shapes or colors (Baddeley, 1998b; Pearson, 2001).

2.3.2.3. The Central Executive

In the most basic sense, the CE is responsible for regulating and coordinating the slave systems, i.e. the PL and the VSSP along with all of the cognitive processes involved in working memory performance, such as allocating limited attentional capacity. In the original WM model of Baddeley and Hitch (1974); the CE had comprised of a pool of general-purpose processing capacity that could be used to support either control processed or supplementary store. The CE had such capacious responsibilities that it was even called a "homunculus", a little person who makes all the awkward decisions and, hence, that it adds nothing in explanatory value. Baddeley (1996) explains the initial understanding of the CE by remarking that:

> It is probably true to say that our initial specification of the central executive was so vague as to serve as little more than a ragbag into which could be stuffed all the complex strategy selection, planning, and retrieval checking that clearly goes on when subjects perform even the apparently simple digit span task […] the central executive was just a convenient *homunculus* – a little man who sits in the head and in some mysterious way makes the important decisions. (p. 6).

Thus, Baddeley (1996) admits that although it was initially neglected on purpose, by the mid 1980s, the fact that the CE component of WM is the least studied component of the WM model had become an embarrassment for them. Thus, Baddeley (1996) fractioned the ce into four parts: first of all, by taking into account the evidence from the impact of reducing attention on complex tasks such as chess, he decided that the CE had to be able to focus attention. Second, Baddeley and his friends got some results from their researches on Alzheimer's disease, by finding out that the CE had the capacity to divide attention between two important targets or stimulus streams. Third of all, the executive capacity had the ability to switch between the tasks, such as adding or subtracting while concurrently taking on a verbal task. Although initially it was assumed that the CE was purely attentional system with no storage capacity; when considering the simple fact that the memory span for unrelated words is around 5, increasing to 15 when the words make up a sentence, Baddeley (1996) assigned the CE with its the fourth and last capacity, which was to interface with LTM. Baddeley (2012) further explains that this enhanced span for sentence based sequences seemed to reflect an *interaction* between phonological and semantic systems rather than a simple additive effect; but as he asked himself "How might this interaction occur?" (p. 15).

When Baddeley (2012) also took Daneman and Carpenter's (1980) study into consideration – in which they required participants to read out a sequence of sentences and then recall the final word of each, thus measuring their working memory capacity and predicting performance on reading comprehension – he explains his feelings as such:

> Such results were gratifying in demonstrating the practical significance of working memory, but embarrassing for a model that had no potential for storage other than the limited capacities of the visuo-spatial and phonological subsystems. In response to these […] I decided to add a fourth component the episodic buffer. (p. 15)

2.3.2.4. The Episodic Buffer

When he first came up with the term, Baddeley (2000a), explained the EB as "a limited-capacity temporary storage system that is capable of integrating information from a variety of sources" (p. 421). He further explained that the EB was *episodic* in a sense "that it holds episodes whereby information is integrated across space and potentially extended across time" and it was *buffer* in a sense that it serves as "an interface between a range of systems, each involving a different set of codes" (p. 421).

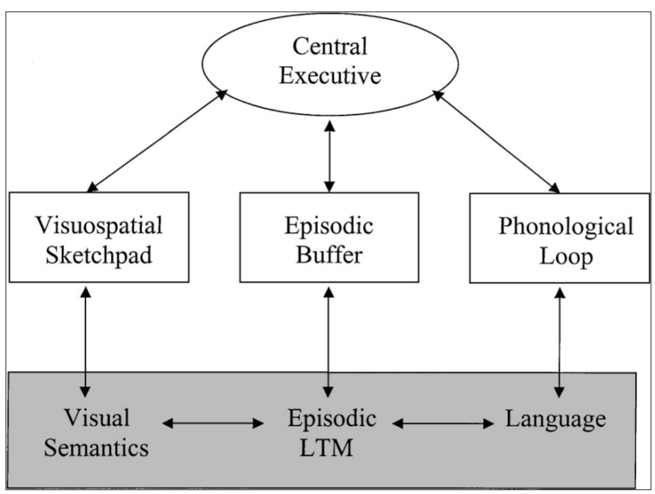

Figure 2.9: The multi-component working memory model after the fourth component: the episodic buffer (from Baddeley, 2000a, p. 421).

Starting off with this idea that the EB has the characteristic of holding integrated representations (episodes) or chunks in a multidimensional code; Baddeley, Allan and Hitch (2011) carried out a study in which they investigated the effects of a range of attentionally demanding concurrent tasks on the capacity to encode and retain both individual features and bound objects and as a result of their study, they came up with the following framework of the WM, at the heart of which is the EB.

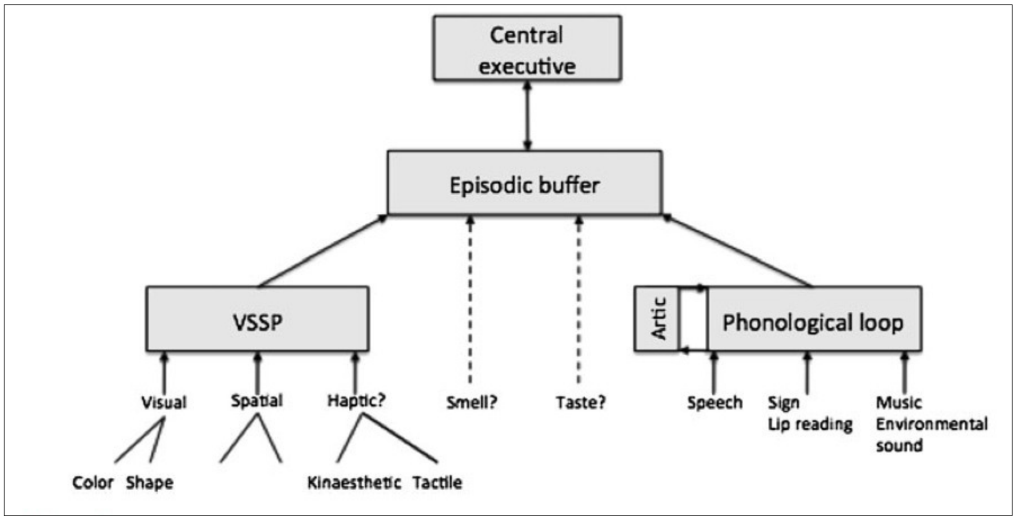

Figure. 2.10: A revised model of working memory (Baddeley, Allan and Hitch, 2011, p. 1399)

As Baddeley et. al. (2011) explains, the EB is at the heart of this framework because of its capacity to bind information from a number of different dimensions into unitized episodes or chunks. From this point on, Baddeley et. al (2011) mostly speculate about the further duties loaded on the EB, since they did not have any concrete empirical studies carried on:

> We *speculate* that smell and taste may also have access to the system, although currently know of *no direct evidence* on this issue. Our current *speculations* continue to assume that conscious access to the phonological loop or sketchpad may operate via the buffer. The visuo-spatial and verbal subsystems are themselves *assumed* to act as lower level buffers allowing, in one case, information from visual, spatial, kinaesthetic and tactile information to be combined (p. 41).

Baddeley (2012) calls this model as a "speculative" one (p. 22); and he raises many intriguing question about the CE and the three slave systems: the PL, the VSSP and the EB. Baddeley and Hitch's (1974) model has been the most famous and cited model of WM since it was first put forward; and with this brand new speculative model, there will doubtlessly be many fruitful studies on the concept of WM.

2.3.3. Cowan's (1988) Working Memory Model

In 1988, Cowan set off with the idea that the original multistore model of WM of Broadbent's (1958), which was made more explicit by Atkinson and Shiffrin (1968), brought several theoretical difficulties into existence. The original model of Broadbent (1958) was combined of a sensory store, a short-term and a long-term store. The information was first in the sensory store in an unanalyzed form, and then some of this information could be selected and processed in the STM store, from where the selected information was finally filed into the LTS (Cowan, 1988).

Cowan (1988) puts forward several problems with this model. First, he proposes that the order of stores is problematic. As he argues, pattern recognition and coding processes need contact with the information in the LTM. Thus, it seemed unlikely to that these processes enter the STS without getting into a contact with the LTS. Secondly, Cowan argues that, the contents of the subject's awareness are supposed to be in the STS. However, some information may be coded in LTM without first entering the awareness. Third, when it comes to transferring information from one store to another, Cowan believes that in order for an input to be analyzed in terms of known or new information; it requires much more interaction between the two memory stores to shift and select this input, than it was already envisioned.

Therefore Cowan (1988) put forward a new concept of short-term storage which consists of "the elements within the long-term store that are currently in a heightened state of activation" (p. 165). That is to say, with the incoming stimuli, the features and concepts in the LTM can be automatically activated. It follows from this that the contents of awareness and of STS are identical. Nevertheless, since he found the concept of short-term storage central to most issues in information processing, Cowan did not explicitly associate awareness and the STS. Rather, he defined the STS as the sum of all activated information and for the awareness issue; he put forward the term “selective attention”. As Cowan (1997) further explains, the concept of attention is crucial to the information-processing models; and a person’s *attending* on information can happen through that person’s conscious *awareness* (p. 44).

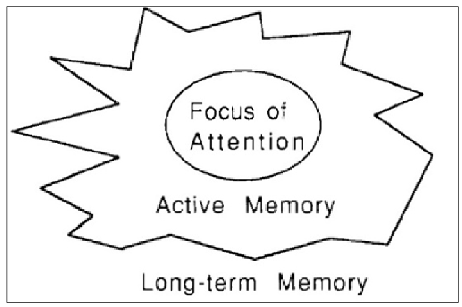

Figure. 2.11: A schematic diagram of the memory system as discussed by Cowan (1988). Short-term memory has been defined either as the currently active memory or as the focus of attention (as cited in Cowan, 1993, p. 163).

The concept of CE also did not go unnoticed, and Cowan (1988) initially eliminated its “homoncular notion”; instead, he used the term to refer all types of information processing and all types of transfer from one storage to another, that are under voluntary control, which included:

a) the selection of information channels from STM
b) scanning STM to select among items recently entered from the stimulus or from LTM
c) the maintenance of information in STM through various types of rehearsal
d) LTM searches leading to more elaborate storage of STM information in LTM
e) problem-solving activities including principled LTM retrieval and a recombination of STM units to form new associations (p. 171).

All taken together, Cowan's model consists of four elements: (1) central executive, (2) long-term memory (3) activated memory, which refers to a subset of long-term memory in state of temporal activation, and (4) the focus of attention. When a stimulus is presented to the subject, it enters first to a sensory store and stays there for up to several hundred miliseconds. Different from Broadbent's (1958) and Atkinson and Shiffrin's (1968) model, during this period, the information in the LTS becomes activated. Thus, stimulus coding takes place and the activated set of codes from LTM are stored in the STS. The activated codes in the STS enter the focus of attention, that is, they make an attention call to the central executive, which directs the process of voluntary attention.

Later in 1999 Cowan, called this model of his as "embeddes processes model", which is organized into two embedded levels. The first level consists of LTM representations that are activated and the second level is called the focus of attention (Cowan, 2005).

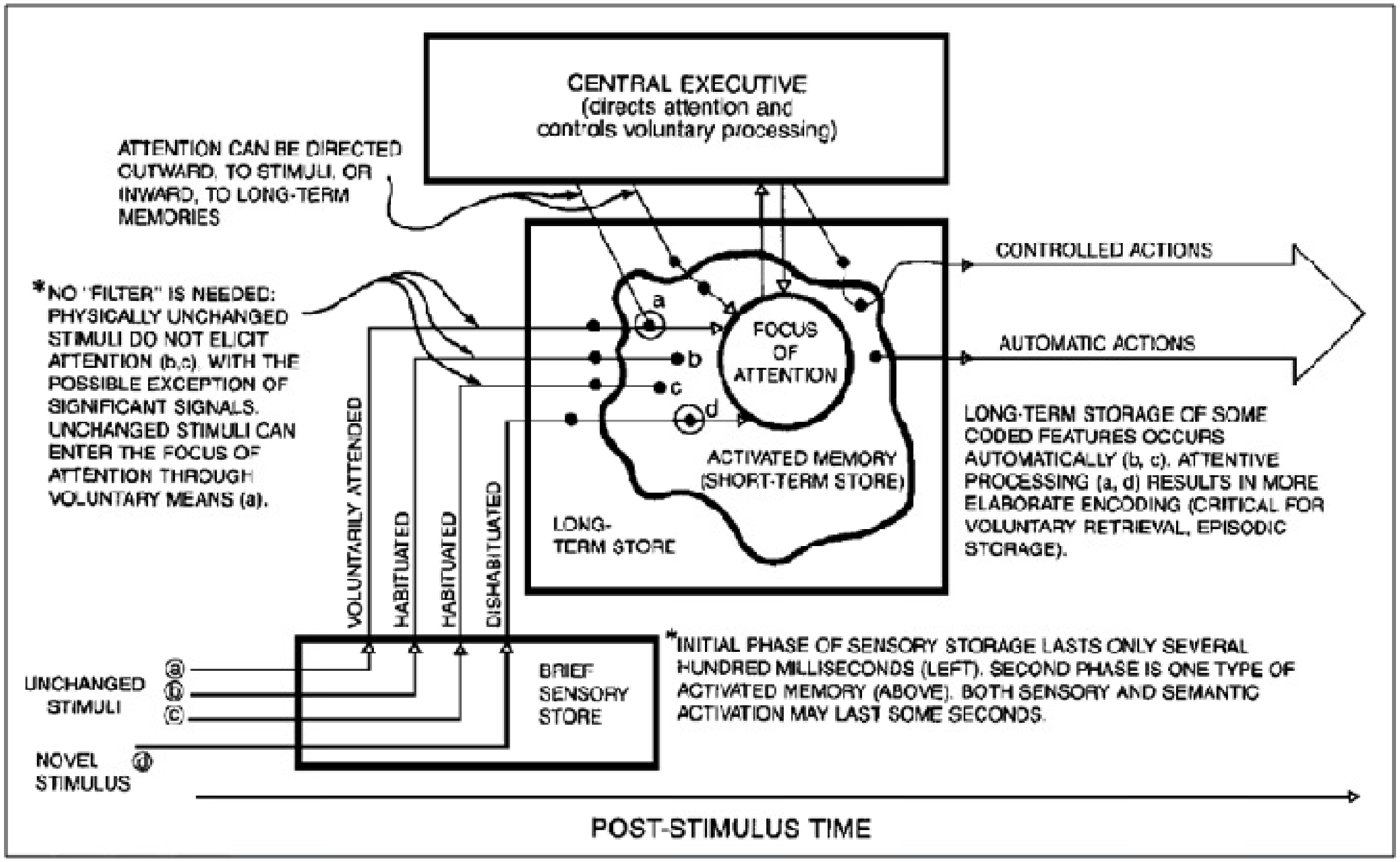

Figure 2.12. Cowan's (1988) revised model of the information-processing system (p. 180)

2.4. Working Memory and Long-Term Memory

Miller et al. (1960) interpreted WM as a distinct component of the human information processing system from the LTS (or "dead storage": p. 65); and Atkinson and Shiffrin (1968) put forward a clear distinction between STS, which served as the WM, and LTS, which was supposed to represent a basic structural feature of the memory system. Thus, by late 1960s, STM and LTM were reflected as distinct structural components.

It is true that the capacity limitation of WM is one of the things that distinguishes it from LTM (Klingberg, 2009). In LTM, we memorize events which we have been involved. For example, we can remember what we ate yesterday for dinner, where we had gone for holiday last year; or we can simply recall the meaning of a word or the capital of Iceland. That is to say, we use our LTM to memorize something, direct our attention at something else for a few minutes or years, and then retrieve them again at our will. However, WM does not function this way. In the most basic sense, WM is used to keep information active for a few seconds, while LTM can keep it stored for years and years.

Despite this, as Richardson (1996) explains, Norman (1968) was the first to point out that WM and LTM are difficult to separate, by arguing that STM and LTM might constitute different aspects of a single storage mechanism rather than two physically different systems. He proposed that short-term storage might consist in the temporary activation of traces within the storage system, and that long-term storage would consist in permanent structural changes within the same system.

From then on, WM and LTM were considered to be very interactive, having two-way influences on each other, in a sense that long-term knowledge is necessary for recalling and enhancing WM and WM facilitates the building and retrieval of long-term structures (Cowan, 1988, 1993, 2005; Ericcson&Kintsch, 1995; Dehn, 2008).

There are also several studies which supported this relationship. In their studies Jeneson and Squire (2012), for instance, found out that that, when the material to be learned exceeds WMC, is difficult to rehearse, or if attention is diverted, performance depends on LTM even when the retention interval is brief. Moreover, in their study in which described a functional magnetic resonance imaging study of humans engaged in LTM and WM tasks, Lewis-Peacock and Postle (2008) argued that short-term retention of information can be supported by the temporary activation of LTM representations.

2.5. Working Memory and Short-Term Memory

The relationship between WM and SMT is rather indistinct, because it is a known fact that WM got its roots from the research of STM (Baddeley 2000b). In the most basic sense, it can be said that STM merely holds information; while WM actively processes it. Dehn (2008) explains further differences between these two types of memory as the following:

> - STM passively holds information; WM actively processes it.
> - STM capacity is domain specific (verbal and visual); WM capacity is less domain specific.
> - WM has stronger relationships with academic learning and with higher-level cognitive functions.
> - STM automatically activates information stored in long-term memory; WM consciously directs retrieval of desired information from long-term memory.
> - STM has no management functions; WM has some executive functions.
> - STM can operate independently of long-term memory; WM operations rely heavily on long-term memory structures.
> - STM retains information coming from the environment; WM retains products of various cognitive processes. (p.3)

Despite these differences, throughout the history of research memory, the distinction made between these two terms is not very clear-cut. As Dehn (2008) agrees, many cognitive psychologists and memory experts view STM and WM as interchangeable or consider one to be a subtype of the other; whereas other theorists and researchers contend that WM and STM are distinguishable constructs.

2.6. Working Memory Capacity and Its Measurement

Since WM is crucial to any cognitive factor, individual differences in WMC is one of the most intriguing topics of interest in psycholinguistics. Since WM involves both a storage and a processing system, along with different operations carried out by different mechanisms – i.e. phonological loop, central executive, etc., how to measure WMC and how to be sure which component the measure is measuring is of crucial importance and there are many controversies and debatable issues about WMC in literature. However, in the most basic sense, as Dehn (2008) explains, "simple span is presumed to measure short-term memory, whereas complex span is considered a measure of working memory" (p. 132); and "whereas simple-span tasks are used to measure phonological short-term memory, complex-span activities measure verbal and executive working memory" (p.133).

2.6.1. Simple Span Measures

According to Conway (2005), there are two definitions of WMC. The first definition, the *broad* definition, is that WMC is simply the ability to remember things in an immediate-memory task (a task with no delay between the end of the presentation of items to be recalled and the period of recall itself). This definition doubtlessly covers the concept of STM and simple span measures of STM. Two of most common and widely implemented simple span measures are simple word span and digit span tasks. In these tasks, subjects are given a list of words/digits and they are asked to read out every item one after another and then recall them. If a subject recalls six of the words/digits, his capacity would be six words/digits; if a subject recalls three words/digits, his capacity would be three words/digits. . According to Ardila (2003), the ability to repeat words in an unknown language has been observed to predict success in learning that language. Conversely, decreased digit span and inability to repeat pseudowords have been related with failure in L2 acquisition. Not only digit span, but also word span and semantic span should be considered in WM analysis (p.233).

2.6.1.1. Digit Span Task

In fact, the classic digit span test goes back to the 1880s to John Jacobs, a school teacher, who carried out the first systematic experimental on the problem. He was interested in measuring the mental capacity of his pupils and thus he devised a technique, the digit span, in which the subject is presented with a sequence of digits and required to repeat them back in the same order. The length of the sequence is steadily increased until a point is reached at which the subject always fails; the sequence length at which the subject is right half the time is defined as his or her digit span. This digit span task has played an important role in psychology ever since (Baddeley, 1999). In the most basic sense, in a DSPAN, the participants are presented with a series of digits, beginning with three digits (e.g., '8, 3, 4’) and then they are required to immediately recall them back in the order they were presented. When they do this successfully, they are given a longer list (e.g., '9, 2, 4, 0'). The length of the longest list a person can remember is that person's digit span.

2.6.1.2. Word Span Task

As the name implies, word span is a series of words the subjects must recall in order. Like digits, they are typically presented at the rate of one per second. The words should be unrelated and categorical groupings should be avoided so that verbal WM and long-term representations have less impact on performance. Also, the words should be relatively short, typically one or two syllables in length. Because of the influence of total articulation time on retention, spans with a greater number of syllables are more difficult to maintain than spans with fewer syllables (Dehn, 2008)

Dempster (1981) argued that if STM is important to real-world tasks such as reading and if memory span is an index of STM, memory span should correlate with measures of reading. However, simple span measures do not consistently correlate with measures of reading comprehension. As Daneman and Carpenter (1980) further comments, one explanation for this lack of correlation may be that digit span and word span tests do not sufficiently tax the processing component of WM; since WM refers to a system involved in the temporary storage and processing of information, and it supports higher cognitive brain function such as language comprehension, learning, and reasoning (Baddeley, 1986; Just & Carpenter, 1992). Therefore, work on individual differences in WM, stems from studies that show that unlike traditional STM measures, measures of WM correlate with performance on complex cognitive tasks (Engle & Oransky, 1999).

2.6.2. Complex Span Measures

Although there are various models of WM, they all virtually assume that WM has a limitation in the amount of information that can be kept active at a given time; and it is generally assumed that this limitation affects consequent processing, i.e that higher level processing is limited to some extent by the limitations of the WM. (Turner & Engle, 1986). This capacity limit refers to the observation that people's performance declines rapidly with an increase in memory demand in a wide variety of experimental tasks. As Oberauer and Kliegl (2006) explains, by memory demand what is meant is that the number of independent items which must be held simultaneously available for processing. This definition overlaps with Cowan's (2005) *narrow definition* of the term WMC, which he explains as "the amount that an individual can hold in mind at one time" (p. 3).

This variation between individuals in terms of their WMC enables us to verify specific hypotheses about the way in which limited capacity affects cognitive functioning the WM is responsible for (Stoltzfus, Hasher, & Zacks, 1996). In these kinds of researches the strategy is to use some measure of WMC and to correlate performance on that task with performance on other cognitive tasks that are of interest, such as language-comprehension. This process is also called a dual-task paradigm combining a memory span measure with a concurrent processing task, sometimes referred to as "complex span". Daneman and Carpenter's (1980) "Reading Span Task" was the first complex span task used in the language-comprehension literature to measure WMC.

2.6.2.1. Reading Span Task

Daneman and Carpenter (1980) set off with the idea that although many theorists have suggested that WMC plays a crucial role in reading comprehension, traditional measures of STM, like DSPAN and word span, are either not correlated or only weakly correlated with reading ability. The reason for this lack of correlation, as they suggest, is that when reading, people must store pragmatic, semantic, and syntactic information from the preceding text and use it in disambiguating, parsing, and integrating the subsequent text (p.450). Since STM is a passive storage buffer, it is only WM which can handle this complex processes while reading with its both storage and processing function. For this reason, simple span measures (i.e, word span, digit span) are not sufficient to anticipate reading comprehension.

By taking these into consideration, Daneman and Carpenter (1980) devised a measure that taxed both the processing and storage functions of WM: the Reading Span Test. Daneman and Carpenter explains the procedure as follows:

> In this test, subjects had to read a series of sentences aloud at their own pace and recall the last word of each sentence. The test was constructed with 60 unrelated sentences, 13 to 16 words in length. Each sentence ended in a different word. Two examples are: *"When at last his eyes opened, there was no gleam of triumph, no shade of anger." "The taxi turned up Michigan Avenue where they had a clear view of the lake."* Each sentence was typed on a single line across the center of an 8 x 5-in. index card. The cards were arranged in three sets each of two, three, four, five, and six sentences. Blank cards were inserted to mark the beginning and end of each set. The experimenter showed one card at a time to the subject. The subject was required to read the sentence aloud. As soon as the sentence was read, a second card was placed on top of the first and the subject read the new sentence. The number of sentences in a set was increased from trial to trial and the subject's reading span was the maximum number of sentences he could read while maintaining perfect recall of the final words. The procedure was repeated until a blank card signaled that a trial had ended and that he was to recall the last word of each of the sentences in the order in which they had occurred. Subjects were given several practice items at the two sentence level before the test began. They were warned to expect the number of sentences per set to increase during the course of the test. The span test contained three sets each of two, three, four, five, and six sentences. Subjects were presented increasingly longer sets of sentences until they failed all three sets at a particular level. Testing was terminated at that point. The level at which a subject was correct on two out of three sets was taken as a measure of the subject's reading span. (pp. 453-454)

By this test, Daneman and Carpenter had the following idea that, if good readers use less processing capacity in comprehending the sentences, they should be able to produce more sentence final words than poor readers (p. 452). In their study, Daneman and Carpenter (1980) found strong correlations with three reading comprehension measures, including Verbal Scholastic Aptitude Test and tests involving fact retrieval and pronominal reference: (1) answering fact questions, (2) pronoun reference questions and (3) the Verbal SAT. Based on these results of their study, Daneman and Carpenter (1980) mainly suggested that the subjects' efficiency in processing skills could be the reason of individual differences in reading comprehension. That is to say, good readers would have more available WMC than poor readers while reading because of their more efficient reading skills.

2.6.2.2. Operation Span Task

Turner and Engle (1989), brought an alternative to this view, suggesting that this WMC measured by RSPAN is somehow specific to reading skills. Therefore, they questioned that a good reader may have less WM available when performing a non-reading task than a poor reader who is skilled at the non-reading task (p. 128). To tackle with this issue, Turner and Engle (1989) carried out a study, asking "Is Working Memory Task Dependent?" and they devised another measure of WMC: the Operation Span Task.

Different from the RSPAN, the OSPAN task requires participants to verify simple mathematical strings (e.g. (3x4) + 11 = …) while also trying to remember unrelated words. Memory span was defined as the maximum number of items (digits/words) recalled. In their study, Turner and Engle (1989) also used RSPAN and sentence-digit span test in which a to-be-remembered digit followed each sentence in the series. With these 3 span tests, it was aimed that whether the relationship between these span measures and reading comprehension is dependent or independent of specific processing strategies required by the secondary task. As the results of 2 Experiments carried out in this study by Turner and Engle (1989) suggested, good readers remember more words and digits than poor readers, regardless of whether the background task required reading or arithmetic skills. Therefore, a complex span reflecting WMC does not need to be "reading" related to prove a significant correlation with reading comprehension.

According to Payne, Kalibatseva and Jungers (2009), WMC is typically assessed by complex span tasks that "require updating information to be remembered while participants are engaged in additional processing" (p. 1). At this point, it may be necessary to recall that WM has different components (i.e. phonological loop, visuo-spatial sketchpad, episodic buffer and central executive) and these components are measured and assessed in different ways. As Juffs (2006) explains, theories of working memory can be divided into two main approaches: the first is called 'phonological working memory: PWM' (Baddeley & Hitch, 1974) and the second one is the second is “reading span memory” (Daneman & Carpenter, 1980); or “verbal working memory: VWM”.

As explicitly explained further by Juffs (2006), PWM tests measure the capacity of an individual to remember a series of unrelated items with covert “inner speech” rehearsal. This ability is measured by requiring participants to remember lists of unrelated digits, real words, or non-words. On the other hand, VWM claim to measure the resources available to simultaneously store and process information. VWM tests require participants to read aloud lists of sentences written on cards (or on a computer) and then recall the final word of each sentence without covert rehearsal. According to Juffs (2006) the key difference between the tests for PWM and VWM is that the VWM requires both processing and storage, whereas the PWM only requires the participant to repeat polysyllabic words or repeat a string of unrelated words correctly. Therefore, PWM and VWM are traditionally treated as separate (Baddeley & Hitch, 1974; Carpenter, Miyake, & Just, 1994; Daneman & Carpenter, 1980; Roberts & Gibson, 2003; Sawyer, 1999) because scores on the tests do not correlate (as cited in Juffs, 2006, p. 90).

As Dehn (2008) further explains, VWM consists of complex WM operations in which analysis, manipulation, and transformation of verbal material takes place. In other words, In contrast to PWM, VWM is viewed as higher level, meaning-based processing, whereas PWM is simple, passive processing, more phonologically based (p. 59).

Last but not the least, Dehn (2008) expresses some of his thoughts about WMC issues in his book. He states that there is now a general consensus among WM that no single factor determines complex WMC and performance because of three reasons: (1) there are most likely separate resources, with separate limits for storage and processing, while at the same time some shared general resources (2) other cognitive factors clearly impact capacity. The ability to control attention and inhibit interference, as well as processing speed and the extent of LTM activation, all play a role (3) the influence of strategies and processing efficiency is acknowledged but largely undetermined (p. 48)

When all are taken into consideration, it may seem pointless to make an effort to measure WMC. However, in the following pages of his book, Dehn (2008) modulates his own argument about capacity issue by stating that:

> Until research and measurement tools allow us to further delineate working memory processes, it might be safest to define working memory as what simple and complex working memory span tests measure. This somewhat circular definition is not an attempt to evade the challenge of delimiting the construct. The reality is that our understanding of working memory is built mainly on attempts to measure it. Furthermore, the ‘‘relationships’’ between working memory and academic learning are actually correlations between working memory test scores and measures of academic performance. Thus, the demands of the testing tasks inform us about the nature of the cognitive process we are attempting to measure (p. 59).

In short, although there might not be a concrete and stable consensus on what WMC actually is and how to measure this capacity, there are surely and commonly accepted domains regarding WM and its components even in different models of WM. Furthermore, these different components are believed to be functioning differently and there are different names given to these different processes (i.e. PWM, VSWM, VWM, EWM, etc.). The idea that varied simple and complex measures of WMC tap on these different components is also agreed upon. As Dehn (2008) agrees, until new research and measurement tools for WM processes are brought into being, it will be safest to define WMC as what simple and complex WM span tests measure.

2.7. Working Memory and First/Native Language

Acquisition of a first/native language (L1) is a process which is probably the most attention-given issue in terms of both parental and academic perspective. The central problem in accounting for the acquisition of L1 is to explain how a child is able to master the extremely complex series of rules that prescribe the possible combinations of linguistic elements making up the language to which the child is exposed (Adams and Willis, 2001). Despite the fact that most children present a rapid, seemingly effortless language development; some children fail to develop language normally. That is, they demonstrate varying degrees of language comprehension and production problems with deficits in vocabulary, grammatical morphology and syntax. Despite there is no evidence of general intellectual impairment nor physical, social or emotional problems, such children are often classified as having Specific Language Impairment (SLI), which may result from a wide variety of linguistic and cognitive deficits (Adams and Gathercole, 2000)

One of these deficits is explained in terms of Working Memory. According to Gathercole, Service, Hitch, Adams and Martin (1999), vocabulary knowledge is crucial as children and their language abilities develop; because a child can process neither the meaning nor the syntactic structure of utterances longer than a single word if they do not contain at least some recognizable content words. Especially the phonological loop component of WM is effective in learning new words because it promotes learning of phonological patterns of new words, and stored knowledge of the phonological structure of the language supplements the phonological loop (Masoura and Gathercole, 1999). In other words, existing vocabulary knowledge will indirectly contribute to the learning of new vocabulary.

As Baddeley, Gathercole and Papagno (1998) agrees, phonological loop is important in acquiring vocabulary since the loop is specialized for the retention of verbal information over short periods of time – it comprises both a phonological store, which holds information in phonological form, and a rehearsal process, which serves to maintain decaying representations in the phonological store (p. 158). It follows from this that there is a natural relationship between the phonological loop and word learning which is easiest to observe during childhood; because childhood represents the most intensive period of new-word learning for most people. There are a number of studies carried out in terms of this relationship between working memory and first language acquisition.

Gathercole, Service, Hitch, Adams and Martin (1999) investigated the nature and generality of the developmental association between phonological short-term memory and vocabulary knowledge in two studies. To this aim, they studied with four-year-old children testing them on immediate memory measures which required either spoken recall (non-word repetition and digit span) or recognition of a sequence of non-words. Study 1 investigated whether the link between vocabulary and verbal memory arises from the requirement to articulate memory items at recall or from earlier processes involved in the encoding and storage of the verbal material. The phonological memory-vocabulary association was found to be as strong for the serial recognition as recall-based measures. In Study 2, Gathercole et. al.(1999) found out that that the association between phonological memory skills and vocabulary knowledge was strong in teenaged as well as younger children. The results of both studies indicated that phonological memory constraints on word learning remain significant throughout childhood and it is phonological short-term memory capacity rather than speech output skills which constrain word learning.

To investigate this relationship between WMC and L1, Adams and Gathercole (2000) explored whether individual differences in spoken language acquisition are due to limitations in short-term memory abilities. To this aim, they examined the relationship between speech production skills and working memory abilities 97 four-year-old children. Adams and Gathercole used the Children's Test of Nonword Repetition (CNRep; Gathercole and Baddeley 1996) to assess phonological memory skills and Raven's Coloured Progressive Matrices to measure general intellectual ability. Afterwards, two experimental groups each of 15 children were constructed on the basis of their performance on these tests. The results indicated that children with better non-word repetition skills produced spoken language that contained a greater number of unique words and, on average, longer utterances than did children with poorer non-word repetition skills. In addition, the range of syntactic constructions in the speech of children with better phonological memory abilities was greater than that found in the speech of children with poorer phonological memory abilities.

In terms of vocabulary development, related to the phonological loop, Gathercole, Willis, Emslie and Baddeley (1992) set off to examine the nature of the developmental association between phonological memory and vocabulary knowledge and thus carried out a longitudinal study spanned a period of just over 4 years, with a total of 118 children (though 80 children's score was analyzed). The first data was collected as the children were 4 years and 7 months and then they were retested at the same time of year at ages 5, 6, and 8 years. The data collection methods were The Raven Colored Progressive Matrices for nonverbal intelligence, The Short Form of the British Picture Vocabulary Scale for vocabulary, and non-word repetition test for phonological short-term memory. The results indicated that scores on the phonological memory and vocabulary tests for the first 3 years tested in the course of this four-wave longitudinal study – ages 4,5, and 6 – were significantly associated with one another, even after differences caused by age and nonverbal intelligence had been controlled. Hence, Gathercole et. al. commented that children with good phonological memory abilities produce phonological memory traces that are highly discriminable and persistent; and moreover phonological memory skills are seen as exerting a direct influence on the ease of acquiring a new vocabulary item.

When L1 acquisition is considered, many studies are carried out with children. However, there are also studies looking into the relationship between native adults' WMC and their verbal language abilities are considered. As one of the most important leading studies in the field, Daneman and Carpenter (1980) investigated individual differences in WM and reading. To this aim, they worked with 20 subjects who were Carnegie-Mellon University undergraduates, taking a psychology course. They were all native speakers of English. First, they used Reading Span Test – which was originally devised by Daneman and Carpenter (1980) – and they also used various reading comprehension measures, including verbal SAT scores. The results showed that the span test was correlated with the traditional assessment of comprehension, i.e. the Verbal SAT scores. The span test was even more closely related to performance on the two specific tests of reading comprehension, i.e. the fact questions and the pronominal reference questions.

In their study, Friedman and Miyake (2004), for example, worked with 168 native-English participants who were undergraduates at the University of Colorado at Boulder. One of their areas of research was the relationship between WMC of the students and their verbal SAT scores. They found out the relatively high correlations of reading span scores with reading comprehension and Verbal SAT scores.

From another aspect, Turner and Engle (1989) considered that there should be a relationship between working memory capacity and reading comprehension regardless of the specific processing component of the span task. All that is necessary is that the processing component place some demand on attentional resources. Thus they devised the Operation Span Task and again looked for the relationship between WMC verbal SAT scores in adults. As for the results, Turner and Engle (1989) found that operation span correlated with VSAT as well as reading span.

Regarding studies with adult participants, Cohen-Mimran and Sapir's (2007) study is intriguing, since it is carried out with adult native speakers of Hebrew. Cohen-Mimran and Sapir (2007) wanted to investigate which reading disabilities in young adults are related to deficits in specific aspects of temporary storage of verbal information, namely, memory span and the central executive component of working memory. To this aim, 32 native Hebrew-speaking young adults with and without reading disabilities were administered a battery of memory tasks. These tasks included Digit Span Forward and Backward tests and a new version of the Token Test (TT) which is aimed at detecting subtle deficits in auditory verbal working memory. Results showed significantly poorer performance of the reading disabled participants than the controls on the memory tests, especially on tasks that tax the central executive.

The relationship between L1 acquisition and second/foreign language (L2) acquisition is evident. As Hulstijn and Bossers (1992) explains:

> The assessment of proficiency in a foreign or second language has also become a firmly established part of educational practice and policy. In the Netherlands, for instance, it has been observed that many immigrants from non-Western countries perform poorly in courses in which Dutch is taught as a second language with a view to preparation for college entry. Many educators interpret such results simply as stemming from insufficient second language (L2) proficiency (insufficient knowledge of vocabulary and grammar) and have made a plea for greater provision of L2 instruction facilities. However, poor performance on an L2 test may be due in part to general language skills. Poor performance on an L2 reading test, for instance, may be caused by insufficiently automatised word recognition skills or poorly developed text comprehension skills, deficiencies which manifest themselves in first language (L1) reading performance as well. Furthermore, poor performance on L2 speaking tasks may very well stem from generally deficient oral language production skills, which manifest themselves to the same extent in L1 speaking tasks. In short, individual differences between L2 learners in performance on L2 tasks need not solely be due to differences in L2- specific knowledge or skills; they may also be due to differences in general language processing skills (apart from factors of a non-linguistic nature such as attitude and motivation). (p. 342)

Taking these into account, Hulstijn and Bossers (1992) carried out a study involving two experiments and they worked with 65 Dutch and 50 Turkish 9 to 11 grade students. In the two experiments, as for data collection tools, Dutch learners of English performed reading aloud tasks in L2 (English) and Ll (Dutch); and 50 Turkish learners of Dutch performed reading comprehension tasks in L2 (Dutch) and Ll (Turkish) as well as L2 vocabulary and grammar tests. The results of the first study showed that most of the differences in L2 performance due to grade level (grade 9 vs 11) and academic level (higher vs lower) disappeared when performance in Ll was taken into account. The results of the second study, provided support for the involvement of both an L2-specific (vocabulary and grammar) and a non-L2-specific component (as indicated by Ll reading performance) in L2 reading comprehension.

Palladino and Cornoldi (2004) took a different point of view and they worked on students with L2 learning difficulties (FLLD) which is described as "having an average or above-average level of intelligence and adequate scholastic achievement but a specific impairment in foreign language learning" (p. 138). As further explained by Palladino and Cornoldi (2004), these children with FLLD typically seem to have problems with L1 learning. In their studies, Palladino and Cornoldi (2004) also carried out two experiments with seventh and eighth grade 18 Italian children with difficulties in learning English as a L2. They were compared with control groups of 24 children matched for age, education, school, and intelligence; but who differed for L2 learning ability. The results clearly indicated that verbal working memory is specifically poor in the FLLD group, as measured with both a forward digit span (Experiment 1) and a non-word repetition task (Experiment 2). These results supported the relationship between L2 vocabulary knowledge and phonological working memory, with results for first language learning difficulty in L2 disability. Furthermore, the results of their study also showed that foreign language learning is related not only to L2 phonological WM problems but also to native-language phonological working memory problems; implying that students with a L2 difficulty have related problems in their L1.

Dufva and Voeten (1999) also investigated the relationship between native and foreign language acquisition in a longitudinal study. They aimed to examine the effects of phonological memory and L1 literacy acquisition on learning English as a foreign language. Thus, they worked with 160 Finnish elementary school children from the first to the third grade, when they start to study English. The results showed that both L1 literacy (word recognition and comprehension skills) and phonological memory were found to have positive effects on learning English as a foreign language. More precisely, these three skills explained as much as 58% of the variance in the beginning stage of English proficiency (measured as listening comprehension, communicative skills, and active vocabulary).

It can be concluded that WM and L1 is associated both regarding children and adults, in terms of language acquisition and reading comprehension, respectively. Whereas during young ages, WMC plays an important role in language acquisition since WM facilitates vocabulary learning; in older ages WM comes into scene when native speakers has to show their reading comprehension abilities; from aforementioned studies, these relationships are fairly clear. Moreover, L1 acquisition and foreign language learning is closely associated. This association is related to the fact that poor performance in second or foreign language may be due to poor performance in general language skills in L1.

2.8. Working Memory and Second/Foreign Language Achievement

Besides the native language, several aspects of second or foreign language (L2) learning and comprehension depend on WM, both phonological and verbal WM. For instance, Service (1992) found that verbal working memory accounted for 47% of the variance in the learning of a L2. Verbal WM is required to understand spoken language; to comprehend what is said read; to write sentences, paragraphs, and stories (Young, 2000). In research reviewed by Engle (1996) and Engle, Tuholski, et al. (1999), WMC has documented significant relationships with reading decoding, reading comprehension, language comprehension, spelling, following directions, vocabulary development, note-taking, written expression, reasoning, complex learning; and grade point average (as cited in Dehn, 2008, p.93)

As it was explained previously, vocabulary development – i.e., learning new words – is obviously affected by WM. It follows from here that the syntactic development of children is also affected by WM (Young, 2000; Kormos and Sáfár, 2008). Syntax refers to the order of words in sentences. For example, the difference between the following sentences, *"The dog bit the boy",* and *"The boy bit the dog"* is due to the order of the words, or the syntax. It is important to note that this syntactic development of children results nearly in all skills of a language. Such as reading, listening (and note taking), writing, speaking. To give an example, research with school-aged children who have reading problems show that they also have syntactic comprehension problems linked to WMC (Ellis & Sinclair, 1996; Swanson & Ashbaker, 2000; Young, 2000). In the classroom, students with limited WMC may become lost listening to lectures that introduce new concepts and vocabulary. In the adolescent and college student population, many studies have traced problems with note taking and reading comprehension to limitations in WM. Studies on adults with reading disability also identified them as having WM deficits (Young, 2000, p. 2).

WM and L2 Vocabulary Learning

Gupta and MacWhinney (1997) propose that learning new words is one of the most crucial processes in human development. As they further explain, without a system for learning words we could never acquire language, and without language, human culture could not be developed and could not be maintained (267). In the most basic sense, vocabulary is doubtlessly essential for each receptive (i.e. reading and listening) and productive (i.e. speaking and writing) language skills. Therefore, vocabulary is the most attention-paid area of interest regarding the relationship between WM and L2. Baddeley, Papagno and Vallar (1988), for instance, carried out a study with a 26 year old Italian woman, who had a very pure short term memory deficit after a left hemisphere stroke. Comparing the subject‘s learning capacity with that of matched controls with a series of experiments, they observed that her learning pairs of meaningful words in her native Italian language was quite normal; however, she was incapable of learning to associate a familiar word with an unfamiliar item from another language (Russian) through auditory presentation. Thus, they concluded that the phonological loop can be useful aid in learning new words.

Masoura and Gathercole (1999) also investigated the relationship between short-term memory skills and children's abilities to learn the vocabulary of a foreign language taught in school. To this aim, they worked with 45 Greek children who were learning English as a foreign language. Various measures were used to assess phonological STM, nonverbal ability, native and foreign vocabulary. The results of the study showed that knowledge of native and foreign vocabulary shared highly significant associations with the phonological short-term memory measures.

In 2005, Masoura and Gathercole again carried out a study with Greek children who had been studying English at school for a period of 3 years on average, this time to investigate the factors influencing existing vocabulary knowledge and the capacity to learn new words in a second language. In their study, Masoura and Gathercole (2005) came up with two important conclusions. First, there was a close relationship between children's phonological short-term memory skills and their current knowledge of English vocabulary, fitting well with the view that in the initial stages of learning vocabulary in a new language; phonological memory plays a crucial role in supporting the construction of stable long-term memory representations of the phonological structures of new words. Second, the speed of learning new English words in a paired-associate learning task was quite independent of phonological short-term memory skills, but strongly related to the extent of the children's current knowledge of vocabulary.

WM and L2 Reading Comprehension

As for the relationship between L2 reading comprehension and WM, the leading scholars in the field – whose Reading Span Test is still a valid measure of WMC – Daneman and Carpenter's study in 1980 presents significant results in terms of WM and its relationship to reading comprehension. In their study, Daneman and Carpenter (1980) found strong correlations between WMC and three reading comprehension measures, including Verbal Scholastic Aptitude Test and tests involving fact retrieval and pronominal reference. Based on these results of their study, Daneman and Carpenter (1980) mainly suggested that the subjects' efficiency in processing skills could be the reason of individual differences in reading comprehension. That is to say, good readers would have more available WMC than poor readers while reading because of their more efficient reading skills.

These impressive results of Daneman and Carpenter's (1980) study could be because the Reading Span Task required remembering words; so they could have shown better correlations with reading comprehension measures. This idea was challenged by Turner and Engle in their study in 1989 – in which they proposed another important measure of WMC, i.e. Operation Span Task. Turner and Engle found that measures of reading comprehension were predicted by the sentence-word and operation-word spans, but not by the sentence-digit or the operations-digit spans. This suggested that the residual capacity of working memory was independent of the particular skills (reading or arithmetic) involved in the secondary processing task. Turner and Engle also showed that measures of reading comprehension were not associated with simple measures of word span or digit span, thus replicating findings obtained earlier by Daneman and Carpenter (1980).

Payne, Kalibatseva and Jungers (2007) also carried out a study with a purpose to examine the relative contributions of WMC first language and domain experience on L2 reading comprehension in Spanish. To his end, they tested three different hypotheses regarding three different models ("knowledge is power", "independent influences" and "rich get richer"). They worked with 73 college students, by using several measures such as language experience, Counting Span Task, English Reading Comprehension and Spanish Reading Comprehension. The results of the study showed that both types of variables (domain experience and L1 and WMC) significantly predict L2 comprehension.

WM and L2 Listening Comprehension

Given that language acquisition begins with silent period in children, listening is probably the most essential skill when learning L2 as well. Despite this importance, and despite the fact that it is also a receptive skill, listening has not received as much attention as the reading skill regarding the studies on Working Memory.

In their studies in which they investigated listening comprehension and working memory abilities in 77 children with attention-deficit hyperactivity disorder (ADHD); McInnes, Humphries, Hogg-Johnson&Tannock (2003) found out that the children with ADHD, with adequate language abilities for their age as measured by commonly used standardized language tests, showed evidence of comprehension deficits when listening to spoken expository passages. McInnes et. al. (2003) explained these result by commenting that ADHD children's poorer performance in comprehending and monitoring their listening for errors on the instructions task, for example, may have been associated with their spatial span and working memory deficits, which would limit their ability to visualize and hold enough information to determine which steps were out of order.

Working with another type of language impairment, i.e. aphasia; Sung et. al. (2008) investigated the relationship between working memory capacity and auditory and reading comprehension tasks for aphasic individuals. To this aim, they implemented Computerized Revised Token Test, a listening span task and Porch Index of Communicative Ability to measure overall aphasia severity. The results revealed that WMC, as measured with listening span task, significantly predicted performance on an auditory comprehension task of the Computerized Revised Token Test.

WM and L2 Speech Production

In her study, which is based on Daneman‘s (1991), Fortkamp (1999) tried to examine whether WMC correlated with fluent L2 speech production. To this aim, she worked with 16 participants, using the Speaking and Reading Span Tests to measure their WMC both in Portugese and English. She also used the Speech Generation Task, the Oral Reading Task and the Oral Slip Tasks to measure their L2 fluency. The results of the study were threefold: (1) the Speaking Span Test in English correlated better with L2 fluency (Speech Generation Task), than in Portugese; (2) Speaking and Reading Span tests did not correlate with any L2 fluency task (Oral Reading Task); and (3) concerning the correlation of WMC with L2 speech errors – assessing fluency at the articulatory level, no significant correlations were found between individuals‘ WMC and L2 spoonerisms (spoonerism: transposition of initial consonants in a pair of words).

By using a picture description task to assess speech production, Finardi and Prebianca (2006) investigated the relationship between working memory capacity and L2 speech production. To this aim, they worked with 12 EFL intermediate level graduates, by using two working memory tests (i.e. the speaking span test and the operation-word span test), along with a picture description task. The data analysis revealed only one instance of significant correlation which was found between WMC and L2 speech production measures, particularly between the speaking span test and speech rate.

WM and L2 Writing Skills

Since it is a productive skill like speaking; writing also did not go unnoticed in literature. Kellogg, Olive and Piolat (2007), for example, were interested in examining the degree to which specific components of working memory (WM) support written language production. Since written expression is a complex cognitive activity that requires the integration of several cognitive processes and memory components and since written production is slow compared with speech, Kellogg et. al (2007) wanted to investigate whether it is feasible to measure performance on a concurrent task that uses executive attention plus either verbal, visual, or spatial storage. To this aim, they worked with 60 college students, having them write definitions of 10 nouns while concurrently performing a WM task that required the detection of a visually presented target and a speeded decision regarding whether to respond. As for the results, Kellogg et. al concluded that, in addition to heavy reliance on executive and verbal working memory, phonological short-term memory contributes to writing by briefly storing phonological representations of the words or sentence under construction. They also proposed that visual working memory is involved in the planning phase of written language production and during recalling definitions of concrete nouns (but not abstract nouns). In short, written expression places so many demands on working memory that several aspects of written language production are probably competing for the same working memory resources (Kellogg, Olive, & Piolat, 2007; Olive, 2004).

Swanson and Berninger (1996) also examined the relationship between WM and writing ability. They worked with 50 children, who were fifth-graders by measuring WMC with sentence span task and using Test of Written Language-TOWL as a measure for writing. The results indicated that there is a relationship between WM and writing skill, although the magnitude of the correlations with the various subtests of writing was small. Swanson and Berninger (1996) also concluded that mastery of elementary writing processes, such as punctuation, spelling, and transcribing, allows greater working memory capacity for the higher level writing processes of generating, organizing, and revising.

WM and Overall L2 Proficiency

Compared to the number of studies carried out on the relationship between WMC and different language areas and skills; the number of studies on the relationship between WMC overall language proficiency is very few. The reason for this absence might be because of several reasons. As Bloomfield et. al. (2010) puts forward, one reason might be the lack of standardized tests for determining proficiency level across languages.

Gilabert and Muñoz (2010) investigated the role of WMC in L2 attainment and performance in their study, by asking the research questions whether differences in WMC can explain differences in general proficiency and whether differences in WMC can explain differences in performance (fluency, complexity and accuracy). To this aim, they worked with 59 undergraduate university students with L1 Catalan/Spanish who learnt English as a foreign language. The methods they used for data collection were various: a standardized Oxford Placement Test, two vocabulary tests, a phonetic categorization task, three aptitude-related tests (lexical access test, a non-word repetition task and a reading span task) and two standard tasks to elicit L2 performance (an oral interview and a film retelling task). The results suggested no correlation was found in the relationship between WM and overall proficiency. However, WMC and overall performance correlated in terms of fluency and lexical variety, whereas no correlation was found between them in terms of structural complexity of accuracy.

In their study, Kormos and Sáfár, (2008) addressed the question what the relationship between phonological short term memory capacity and performance in an end-of-year writing, listening, speaking and use of English test. To this end, they worked with 121 secondary school students aged 15–16 in the first intensive language training year of a bilingual education program in Hungary. The methods were a non-word repetition test and took a Cambridge First Certificate Exam. To measure their WMC, 50 of the students were also tested with a backward digit span test. The correlational analysis results showed that phonological short-term memory capacity plays a different role in the case of beginners and pre-intermediate students in intensive language learning. As regards the students who were beginners at the beginning of the school year, there was found no significant correlation between measures of phonological short term memory and achievement on various components of the language test. In case of pre-intermediate learners, however, the average non-word score moderately correlated with students' performance in the Writing and Use of English paper and with the total number of points students achieved in the test. In line with Gilbert and Muñoz's (2010) results, Kormos and Sáfár, (2008) also found correlation in terms of fluency and vocabulary. Among the components of the oral test, average non-word score was found to be significantly correlated with the number of points students received for their fluency and range of vocabulary. Lastly, as regards the backward digit span, it was found that the relationship of all the sub-tests and backward digit span is statistically significant with the exception of the writing component.

2.9. Working Memory and Mathematics

Mathematics is one of the most closely linked subjects to WM. According to Brainerd (1983), even the simplest mathematics calculations clearly require three working memory processes: temporary storage to hold problem information, retrieval that accesses relevant procedures and processing operations that convert the information into numerical output (as cited in Dehn, 2008). When explained in terms of the individual differences in mathematical problem solving, for example, Baddeley's WM model comprises of a central executive controlling system that interacts with a set of two subsidiary storage systems: the speech-based phonological loop and the visuo-spatial sketchpad. The phonological loop is responsible for the temporary storage of verbal information; items are held within a phonological store of limited duration, and the items are maintained within the store via the process of articulation. The visuo-spatial sketchpad is responsible for the storage of visual-spatial information over brief periods and plays a key role in the generation and manipulation of mental images. The central executive system is considered primarily responsible for coordinating the activities of the phonological and visual-spatial systems, but it also draws resources from LTM when the capacities of these subsidiary systems are exceeded (Baddeley, 1986; 1996).

To explain the relationship of these different components of working memory to mathematics, many studies are carried out comparing participants with normal mathematical abilities with participants who has problems in different areas of mathematics; such as mathematical difficulties (MD) (Anderson&Lyxell, 2007; Peng, Congying, Beilei&Tao Sha, 2012); mathematical and reading difficulties (MDRD) (Peng, et. al., 2012); Learning Difficulties (LD) (Swanson and Sachse-Lee, 2001); Fetal Alcohol Spectrum Disorders (FESD) (Rasmussen&Bisanz, 2005); Developmental Coordination Disorder (DCD) (Alloway, 2007); or instead, the participants are simply grouped as Poor Arithmeticians (PA) (Amico&Guarnera, 2005) or Low Arithmetic Group (LA) (Iuculano, Moro&Butterworth, 2011; McLean&Hitch, 1999) to be compared with their matched groups. In these studies, the phonological loop, the visuo-spatial sketchpad and central executive are measured independently so that the underlying reason of these mathematical deficits of participants could be better explained.

However, most studies investigating the relationship between Mathematics and WM are done with children. As Bull and Espy (2006) explains, the reason for this tendency could be that mathematics competence in young children is described by proficient counting, whereas in a college student, mathematics competence is marked by solving complex trigonometric problems and integrating equations. Thus, not surprisingly, because of the greater complexity of algebra and geometry, developmental models are lacking, more progress has been made in understanding the development of children's basic arithmetic skills (p. 63). Further, as Logie, Gilhooly and Winn (1994) agrees, since most adults know the answer to the sum 6+7 or the product 3x4, without having to follow any form of calculation algorithm, the answers to these problems are learned by association, thus allowing for direct memory access.

As for children's mathematics and WM, it could be said that approximately 3 to 6% of school-age children have mathematics disabilities and many more children struggle with mathematics (Dehn, 2008). Empirical investigations have consistently implicated working memory as a central deficit in children with mathematical disabilities. Compared to their same age peers, children with a specific mathematics disability have been found to be deficient in verbal working memory, visuo-spatial working memory, executive working memory, and working memory in general (Swanson & Sachse-Lee, 2001).

In their study, McLean and Hitch (1999), for instance, worked with 122 primary school children with specific arithmetic learning difficulties. To measure their arithmetic abilities, McLean and Hitch (1999) used the Graded Arithmetic-Mathematics Test, the Primary Reading Test, and six 1-min written tests of speeded calculation (single-plus single-digit addition, single-plus two-digit addition, two-plus two-digit addition, subtraction, multiplication, and division). As for WM measures, different tasks and tests were used to measure three components of working memory. The results showed that five of the working memory measures (i.e. the Missing Item task, Addition Span, Trails Verbal, Trails Color, and Corsi Span) correlated significantly with arithmetic ability. The Calculation Test also showed a high correlation with arithmetic ability. However, as McLean and Hitch (1999) also found interesting, the poor arithmetic group were impaired on Digit Span relative to the Age-Matched controls, though the difference just missed significance. They explained this result remarking that the deficit in digit span does not appear to reflect a problem associated with the phonological loop, as Non-word Repetition was unaffected.

This non-significant correlation between poor arithmetic children and their matched controls in terms of phonological loop is also present in D'Amicoa and Guarnera's (2005) study in which they also explored working memory in children (mean age 9 years) with low arithmetical achievement. As for data collection tools, all the children in their study completed a series of working memory tasks, involving the central executive functions (using both linguistic and numerical material), the phonological loop (using words, pseudo-words and digits) and the visual sketchpad (using both static visual-spatial patterns and visual-spatial sequences). The results indicated low performances in children with poor arithmetical skills, when compared to controls, in all the central executive tasks. However, the results of the analysis also showed that the phonological loop is not the major factor in explaining arithmetical difficulties. Indeed, poor arithmeticians demonstrated normal word span abilities, as already claimed by Passolunghi and Siegel (2001), as well as normal non-word repetition abilities, as reported in McLean and Hitch's study (1999).

Iuculano, Moro and Butterworth (2011) also concluded in their studies that phonological loop did not differ between their Low Arithmetic group and Typical Arithmetic group. After carrying out the data analysis; Iuculano et al. concluded that not only both span tasks forward, which are robust assessments of phonological loop, but also both span tasks backward, which also rely strongly on phonological loop, were performed at the same level in each group, suggesting that these WM processes were not critical for distinguishing typical from low attainment in arithmetic.

Contrary to aforementioned studies, which found no relationship between phonological loop and mathematical deficits, Peng, Congying, Beilei and Sha (2012) came up with just the opposite results. In their study in which they investigated phonological storage and executive function deficits in children with mathematics difficulties, Peng et al. worked with 68 children. Of these 68 children, 18 were classified as children with only mathematics difficulties (MD); 20 were classified as children with mathematics and reading difficulties (MDRD), and 30 were typically developing (TD) peers matched on age and general ability. The results showed that children with mathematics difficulties, both MD and MDRD sub-types, suffered from deficits in phonological storage and deficits in executive functions.

Andersson and Lyxell (2007) also found significant correlations between phonological loop, central executive and mathematical ability in their studies which they carried out with children with mathematical difficulties (MDs). They examined whether children with MDs or co-morbid mathematical and reading difficulties have a working memory deficit and to find out whether the hypothesized working memory deficit includes the whole working memory system (i.e., a general deficit) or only some specific components (i.e., a specific deficit). The results indicated that, when they are compared with the age-matched controls, both the MD group and the group with co-morbid mathematical and reading difficulties performed significantly worse on a number of tasks tapping central executive functions and the phonological loop. In contrast, no significant group effects emerged for the visuo-spatial sketchpad, or focused attention.

Besides mathematical deficits, Rasmussen and Bisanz (2005) worked with 21 children (aged 4 to 6 years) who had Fetal Alcohol Spectrum Disorders (FASD) which describes a continuum of permanent birth defects caused by maternal consumption of alcohol during pregnancy. They sought to examine to examine the performance of children with FASD on different types of mathematical achievement and on all three components of working memory, as well as to determine whether their math performance is related to working memory deficits. The results of the study revealed that children with FASD showed impairments in mathematics, with lower mean scores than the comparison group on both quantitative concepts and applied problems; and they also performed significantly lower than the comparison group on three of four measures of phonological working memory. However, group differences were not significant on visuo-spatial working memory central executive.

As for the participants with no specific difficulties in mathematical abilities, Holmes and Adams (2006) carried out a study to test the association between WM and children's mathematics using measures of WM ability that do not involve direct access to number or number knowledge. To this aim, they worked with 148 primary school children. The children completed Working Memory Test Battery for Children and age-appropriate mathematics tests designed to assess four mathematical skills defined by the National Curriculum for England. As for the results, Holmes and Adams found an overall significant association between children's WM ability and their mathematics attainment. However, again in-line with the results of McLean and Hitch (1999) and D'Amicoa and Guarnera's (2005), Holmes and Adams (2006) claimed that visuo-spatial sketchpad and central executive, but not phonological loop scores predicted variance in children's mathematical attainment.

In their studies, Zheng, Swanson and Marcoulides (2011) also found a positive relation between WM and mathematics. In their study, they sought to identify the components of WM that predict word problem solution accuracy in elementary school-age children To this aim, they worked with 310 second, third and fourth-graders, using a battery of tests to assess problem-solving accuracy, problem-solving processes, WM, reading, and math calculation. The study revealed that all three WM components significantly predicted problem-solving accuracy.

In their study, Miller and Bichsel (2004) investigated multiple relations between visual and verbal working memory; state, trait, and math anxiety; gender; and applied and basic math performance in 100 adults. Inter-correlations between the measures revealed that both basic and applied math performance were significantly related to both verbal and visual working memory. Therefore, it appears that both subsystems of working memory are utilized in math performance, suggesting that both applied and basic math performance have both verbal and visual components.

In their longitudinal study, Smedt et. al. (2009) examined the relationship between working memory and individual differences in mathematics. 106 first-graders participated in the study. Smedt et. al. (2009) measured all three components of WM – i.e. the phonological loop, the visuospatial-sketchpad, and the central executive – at the start of first grade. Mathematics achievement was assessed 4 months later (at the middle of first grade) and 1 year later (at the start of second grade). As regards the correlational results, working memory was significantly related to mathematics achievement in both grades, showing that working memory clearly predicts later mathematics achievement. As for the slave systems, Smedt et. al. concluded that although the central executive was a unique predictor of both first- and second-grade mathematics achievement; there were age-related differences with regard to the contribution of the slave systems to mathematics performance: the visuo-spatial sketchpad was a unique predictor of first-grade, but not second-grade, mathematics achievement; whereas the phonological loop emerged as a unique predictor of second-grade, but not first-grade, mathematics achievement.

There is also a relationship between WM and mathematics, in relation to language processing. As Swanson and Sachse-Lee (2001) argues, children with learning disabilities (LD) experience considerable difficulty on both WM and mathematical word-problem solving tasks; and deficits on these tasks can be linked to the phonological system (p. 295). Swanson and Sachse-Lee (2001) further explains that this is because mathematical word problems are a form of text and the decoding and comprehension of text draws upon the phonological system. In their studies, as well, they also found strong relationship between phonological processing and problem solving. Swanson and Sachse-Lee (2001) commented on this result by stating that, phonological processing is important to problem solving, since the phonological system plays an important part in accounting for individual differences in text processing (p. 316).

Taken all into consideration, several conclusions can be drawn from the reviewed literature. First of all, the role of the WM components (especially the phonological loop measured by simple span tasks) in mathematical achievement is not clear enough and there are fewer studies carried out with young adult participants than with children. Second of all, studies investigating the relationship between WMC and overall foreign language and overall native language achievement (verbal achievement) are relatively few and mostly carried out with children and with low proficiency level participants. Third of all, the role of the WMC (in terms of its phonological loop and the central executive components measured by simple and complex span tasks, respectively) is controversial both in verbal achievement and mathematical achievement. Finally, the relationship of foreign language achievement to native language and mathematical achievement needs further research in relation to WM or different components of WM.

CHAPTER 3

METHOD OF RESEARCH

3.0. Presentation

In this chapter, information about the participants, the setting, the data collection tools and procedures and the data analysis procedures are presented and discussed.

3.1. The Setting

This study was carried out at Hacettepe University School of Foreign Languages Department of Basic English, located in Beytepe Campus, Ankara.

At Hacettepe University, the medium of instruction vary depending on the department. It may be Turkish; partially (%30) English or completely (%100) English. The School of Foreign Languages Department of Basic English administers a Proficiency Exam at the beginning of the academic year for those students who are enrolled in departments in which the medium of instruction is partially or completely English. This Proficiency Exam has two steps. The first step is the Placement Exam. From this exam, a minimum of %50 success rate is necessary to be able to take the second step: the Proficiency Exam. The students have to get 65 points out of 100 in order to be exempt from the Preparatory School. For those students who fail to attain the required proficiency level in the Proficiency Exam; the Department of Basic English offers a compulsory course of one or two semester Basic English Program. Then, these students are placed into either a one or two semester program depending on their performance in the exam.

There are two different types of programs at the department. ING 160 Basic English Program is for students who have taken YDS (Yabancı Dil Sınavı: The Foreign Language Examination) to enter the university and have enrolled in departments where the medium of instruction is completely English (i.e. Departments of English

Language Teaching, American Culture and Literature, English Linguistics, etc.) The students who have failed in Proficiency Exam are placed in two groups: Intermediate Level I or Intermediate Level II, depending on their performance in the exam. The courses are held as 20 class hours for Intermediate Level I and Intermediate Level II in a week

ING 150 Basic English Program is for the students enrolled in departments where the medium of instruction is partially or completely English. The students who have failed in Placement Exam are placed in Elementary level and have 25 class hours per week. The ones who have failed in Proficiency Exam are placed in two groups: Intermediate Level or Upper Intermediate Level, depending on their performance in the exam. The courses are held as 20 class hours for Intermediate Level and Upper Intermediate Level in a week.

3.2. Participants

A total of 60 students (24 males and 36 females) participated in this study. The participants were selected by using convenient sampling procedure. Their ages range from 18 to 23 (M = 19.55; SD = 1.171). They are the students of Hacettepe University School of Foreign Languages Department of Basic English and they belong to 150 Elementary Language Groups (150-ELE).

150-ELE is a program is for learners with little or no previous experience in English language learning. This is a two-semester program, during which a variety of learning materials and assessments are implemented; and thus, the learners are assisted in gaining the required language and skills so that they can pursue their academic studies and use English effectively in work-related or social environments.
The sources used in 150-ELE Program are as follows:

- New English File Elementary (Oxford University Press)
- New English File Pre-Intermediate (Oxford University Press)
- New English File Intermediate (Oxford University Press)
- Interactions Listening & Speaking 2 (Silver Ed.) (Mc Grow Hill)

As for the assessment, 150-ELE groups are assessed and evaluated throughout each semester via various tests and exams, along with presentations and teacher assessments. The students in 150-ELE groups are required to fulfill the compulsory attendance and to show a %65 success rate at the end of two semesters, so that they can take the Proficiency Exam at the end of the year.

- *Achievement Exams*: These are exams which are done twice a term, on a previously announced date. These tests are comprised of reading, writing, listening and use of English parts.

- *Progress Tests:* These are exams which are done three times a term, on a previously announced date. These tests measure at least one of the skills (i.e. reading, writing, listening and use of English).

- *Story Book Exams:* These exams are done twice a term, based on 2 pre-decided story books given to the students at the beginning of the term.

- *Pop Quizzes*: These quizzes are small exams done to measure the learning process of the students. There are 8 to 10 quizzes in a term and they are unannounced.

- *Mock Exams*: These are practice exams for Achievement Exams. They are given to students with answer keys so that they can review and organize their studies for Achievement Exams.

- *Presentations*: These are assessments for evaluating the students' presentations skills. Students are required to prepare and present a topic of their interest in the classroom in groups and individually.

- *Teacher's Evaluation*: These are teachers' opinions on students' classroom performance and homework fulfillments. These are given by the teacher once a month.

Table 3.1 *150-ELE Groups 2 Semesters' Assessment Criteria*

Exam	**Points**
Achievement Exam I	100 pts.
Achievement Exam II	100 pts.
Achievement Exam III	100 pts.
Achievement Exam IV	100 pts.
6 Progress Tests (Total)	150 pts.
15 to 20 Quizzes (Total)	150 pts.
Story Exam I 30pts. (%50)	15 pts.
Story Exam II 30pts. (%50)	15 pts.
Story Exam III 30pts. (%50)	15 pts.
Story Exam IV 30pts. (%50)	15 pts.
Presentation	30 pts.
Teacher's Evaluation I	20 pts.
Teacher's Evaluation II	20 pts.
Total	830 pts.

3.3. Data Collection Tools

In order to collect data, various tools and exam results are used. In order to measure Working Memory Capacity, a revised and computerized version of the Reading Span Task by Daneman and Carpenter (1980) and computerized a forward digit span task were used. As for their verbal achievement, Turkish Part scores of the participants of the YGS (The Transition to Higher Education Examination) and English scores of the participants of 150-ELE Achievement I and II exams were used. As for mathematical achievement, Mathematic Part scores of the participants of the YGS were used.

3.3.1. Tools for measuring WMC

In order to measure the WMC of the participants, one simple span and one complex span measure was used. In order to measure the participants' simple spans, the "Digit Span Task"; and to measure their complex spans, a revised and computerized version of the original "Reading Span Task" by Daneman and Carpenter (1980) was used.

3.3.1.1. Digit Span Task (DSPAN)

In fact, the original version of the DSPAN classic digit span test goes back to the 1880s to John Jacobs, a London school master, who wanted to measure the mental capacities of his pupils (Dehn, 2008, p. 133). In the most basic sense, the participants are presented with a series of digits, beginning with three digits (e.g., '8, 3, 4') and then they are immediately required to recall the digits in the order they were presented. When they do this successfully, they are given a longer list (e.g., '9, 2, 4, 0'). The length of the longest list a person can remember is that person's digit span. In this study, a computerized version of the DSPAN was used. The version was implemented from Cambridge Brain Sciences web-page (www.cambridgebrainsciences.com).

3.3.1.2. Reading Span Task (RSPAN)

Different from the original RSPAN (see Chapter 2), as devised by Daneman and Carpenter (1980), a revised and computerized version of this RSPAN was used in this study.

To begin with, while the sentences in the original RSPAN were in English; in this study, the sentences were written in Turkish – not translated. As Noort et. al. (2008) explains, by using translations of the original RSPAN, one does not control for the specific language differences between the original English version and the translation of the RSPAN in word frequency, sentence length, etc. (p.36). When it comes to the reason for this choice derives from a study carried out by Sanches et. al. (2010) in which they examined the reliability and predictive validity of a set of English-language span tasks (RSPAN and OSPAN) with a population whose native language is not English. The results revealed that completing RSPAN in a non-native language does not permit an accurate assessment of WMC (p. 491). Further, as Sanches et. al. comments on this result they state that when bilinguals complete standardized tests in their non-native language, their performance tends to be lower, thus underestimating their true ability (p. 492). Therefore, the RSPAN sentences were written in Turkish.

Secondly, the original RSPAN involved 60 sentences, constructed with 13 to 16 words in length. However, as Noort et. al. (2008) exerts, rather than looking at the number of words, it would be better to control for the number of syllables and letters as well (p.36). Therefore, in this study, RSPAN again involved 60 sentences, but they were controlled for the number of words and the number of letters as well. The number of the words in sentences ranged from 14 to 17; and the number of letters in these sentences ranged from 91 to 98.

Third, in the original RSPAN, the participants were required to remember the last words of each sentence. However, related to this word-remembering issue, there are many problems agreed upon in literature. As Noort et. al. (2008, p. 36) states, in the original RSPAN, several issues were neglected about the to-be-remembered last words. First, no attention was paid to the *length* of the sentence-final words; yet there is an important difference between remembering a one syllable word or a four syllable word; since shorter words are better recalled in comparison with longer words. Next, the *frequency* of the sentence-final words was not controlled. This is important because frequent words are better recalled than infrequent words.

Furthermore, no special attention was paid to the *abstractness/concreteness* of the sentence-final words. Yet, this distinction can also be very important, because people can use two different memory sources. That is, to keep the abstract/concrete words in mind, they can use the phonological loop and remember the words by keeping the sound sequences active in their memory; or they can use the visuo-spatial sketchpad to create a visual imagery. The problems with using words are also explained from another point of view by Unsworth et. al. (2005) who explains that some of the shared variance between span tasks that use words and a measure of higher order cognition, such as reading comprehension could be due to word knowledge (p. 500). That is, as Sanches et. al. (2010) agrees, while the original RSPAN was found to correlate well with measures of reading comprehension and VSAT performance; that this correlation could be a result of domain-specific skills in verbal ability supporting better memory for the sentences that were read (p. 489). Therefore, in an effort to eliminate the potential influence of verbal proficiency, newer RSPAN tasks require that participants recall unrelated letters instead of the last words of the sentences (Conway et. al. 2005; Kane et. al, 2004; Sanchez et. al, 2010; Unsworth et. al., 2005). In this study also, instead of words, the participants were presented with a consonant (i.e. *F, G, T, Z,* etc.) for one second, after each sentence.

Additionally, from the total 60 sentences, half was written sensical and half was nonsensical. So, the participants had to determine whether the sentence was sensical or nonsensical. To give an example, whereas *"Yaşlı adam balkonda oturmuş çayını yudumlarken, birden karşı apartmandan bir çocuğun kendisine el salladığını farketti."* (As the old man was sitting on his balcony and sipping his tea, he realized a boy waving at him from the opposite house.) is a sensical sentence; *"Sabahları erken kalkıp evimizin karşısındaki yemyeşil tepside yürüyüş yaptığım zaman kendimi çok iyi hissediyorum."* (I feel myself very good when I get up early and take a walk in the very green tray opposite our house) is nonsensical. Nonsensical sentences were made by simply changing one word (e.g., "tray" from "park") from an otherwise normal sentence. There are many studies (Conway et. al. 2005; Kane et. al, 2004; Sanchez et. al, 2010; Unsworth et. al., 2005) using this sensicality judgement in their studies (see Appendix A for the list of sentences used in RSPAN).

Lastly, the original RSPAN was devised as a computerized RSPAN because of several reasons. First, as Noort et. al. (2008) argues, Daneman and Carpenter (1980) used cards to present the sentences and they did not use any time restrictions during sentence presentation. One problem with this method is that participants can read the sentences more slowly to improve their recall. When this type of strategy is used by participants, the RSPAN is no longer a strict working memory test (p. 36). In their study, therefore, Noort et. al. (2008) adjusted sentences in a way that they had a maximum presentation time of 6.5. Thus, in this study, the computerized version of the RSPAN showed the participants the sentences for maximum 7 seconds. Secondly, the computerized version of the RSPAN also provided the researcher with a standard in many senses in the data collection procedure (i.e. the presentation of the sentences, the letters, the presentation time of the sentences and letters, calculation, etc.).

3.3.2. Tools for measuring Verbal Achievement

Verbal achievements of the students are measured with two tests. For their first language (Turkish) verbal achievements, the Turkish part of the YGS exam; and for their foreign language (English) verbal achievements, the achievement exam at Department of Basic English was used.

3.3.2.1. Native Language Verbal Achievement

To measure their achievement in their first language (Turkish), the participants' YGS 2010 (Yükseköğretime Geçiş Sınavı: The Transition to Higher Education Examination) Scores were used.

YGS is the first-round of university entrance examination. Students take the Transition to Higher Education Examination (YGS) in April. Those who pass the YGS are then entitled to take the Undergraduate Placement Examination (LYS), the second-round exam in the new system taking place in June. In YGS, there are 4 subject areas, i.e. Turkish, Social Sciences, Mathematics and Physical Sciences; and 40 questions each. Thus students have to answer 160 questions in 160 minutes.

In this study, the participants' scores in the Turkish part of the exam were used (YGST). In this part, there are 40 questions, assessing the students' verbal ability in their first language. The content of the questions are usually based on sentence and lexical meanings, paragraph comprehension, parts of speech, word structure, elements of sentences, voice of verb, types of sentences, ambiguity, phonetics, spelling rules, punctuation, communication and the classification of culture-languages, etc.

3.3.2.2. Foreign Language Verbal Achievement

To measure their foreign language (English) verbal achievements, the participants' 150-ELE (Elementary) Achievement Exam I and II scores at Hacettepe University

School of Foreign Languages Department of Basic English were used. These are exams are done twice a term, on a previously announced date. These tests are comprised of reading, writing, listening and use of English parts and in total accounts for 100 points.

150-ELE Achievement Exam I (AE1) was the first achievement exam of the first term in which students were assessed in their Reading, Listening, Writing and Use of English achievements. It was done in one day, in two sessions, with 20 minutes break in between. The first session was for the Use of English and Writing parts; and the second session was for Listening and Reading parts.

In the Use of English part, the tasks involved a cloze-test (21 pts.) in which the students' vocabulary knowledge, along with tenses, prepositions, time markers, quantifiers, subject-object pronouns, comparatives, definite-indefinite articles were assessed. The Use of English part also involved a conversation fill-in task (9 pts.), in which the students are assessed in their knowledge of functional and practical English. The Writing part (15 pts.) asked students to write a paragraph in which they described a person in 120 to 150 words. For this, the students were given 2 topics to choose from and a writing checklist in which they could see how their writing would be assessed. The Listening part of the exam consisted of two parts, in which the students listened to an interview and a small talk, after which they answered true-false (12 pts.) and multiple choice questions (12 pts.). As for the Reading part (27 pts. in total), there were two reading passages and different question types, such as ordering events, multiple choice, reference, matching headings and true false questions (see Appendix B for the mock exam for the Achievement Test I).

150-ELE Achievement Exam II (AE2) was the second achievement exam of the first term in which students were assessed again in their Reading, Listening, Writing and Use of English achievements. It was done in one day, in two sessions, with 20 minutes break in between. The first session was for the Use of English and Writing parts; and the second session was for Listening and Reading parts.

In the Use of English part, the tasks involved a cloze-test (11 pts.) in which the students' vocabulary knowledge, along with tenses, tense markers, quantifiers, comparatives-superlatives, gerunds-infinitives and conjunctions were assessed. In the second part of the Use of English part, there was an open-cloze test (9 pts.), in which the students had to write one word in each gap, without any options. This part of the Use of English part again involved a conversation fill-in task (10 pts.), in which the students are assessed in their knowledge of functional and practical English. The Writing part (20 pts.) asked students to write a paragraph in which they described a picture in 200 to 250 words. For this, the students were given pictures to describe and linkers as prompts and a writing checklist in which they could see how their writing would be assessed. The Listening part of the exam consisted of two parts, in which the students listened to a radio program and an interview, after which they answered true-false (10.5 pts.) and multiple choice questions (9 pts.). As for the Reading part (30.5 pts. in total), there were two reading passages and different question types, such as multiple choice, reference, vocabulary and true false questions (see Appendix C for the mock exam for the Achievement Test II).

3.3.3. Tools for measuring Mathematical Achievement

To measure their achievement in their mathematical abilities, this time, the participants' YGS 2010 (Yükseköğretime Geçiş Sınavı: The Transition to Higher Education Examination) Mathematics part scores were used.

In this Mathematic part of the YGS (YGSM) exam there are 40 questions involving basic mathematics and geometry. The content of the basic mathematic questions are usually involve numbers, the concept of order, base arithmetic, partition-divisibility, GCD-LCM, rational numbers, rank-simple inequalities, absolute value, exponential expressions, roots ratio-proportion, equation problems, logic, clusters, correlation-function, process-modular arithmetic, permutation-combination-way, etc. The content of the geometry questions are usually involve basic concepts, direct angle, triangle angle, special triangles (upright triangle, equilateral triangle, isosceles triangle), triangle area, triangle similarity, bisector-median, triangle angle-border relations, polygons, circle-flat, solid, line analytics, point analytics, symmetry-rotation, etc.

3.4. Data Collection Procedures

For measuring WMC, data from RSPAN and DSPAN task was collected. For measuring Verbal Achievements, data from YGST and AE1 and AE2 scores were collected. For measuring Mathematical Achievement, the participants' YGSM scores were collected. A pilot study with 5 participants was carried out with RSPAN and DSPAN tasks, before the main data collection procedure took place. Necessary adjustments in both tasks were made according to the results of the pilot study.

3.4.1. RSPAN

The computerized version of the RSPAN was implemented in a computer lab at Hacettepe University School of Foreign Languages. In order there to be an absolute silence in the corridor where the computer lab was, the utmost attention was paid. The doors of the corridors were kept close and the task was done during lesson hours, so that there was no extra noise of the break times. Furthermore, since there were 18 computers in the lab, different sessions on different days were carried out, so that a total of 60 participants could take the RSPAN. The researcher personally and individually conducted the implementation of the task.

When the participants were placed in the lab, first of all, they signed a voluntary participation form. Then they were informed by the researcher about the task and what they were supposed to do via a short demo version of the computerized RSPAN.

First of all, the participants were informed that they have to turn off their cellular phones or anything that could distract their attention during the task. They were also required to put on the headsets, so that it could eliminate any possible outside noises.

Second, the researcher informed them that the task was computer based but they did not have to know any advance computer skills and that all they had to do is to click on the mouse and since it was computer based and time-limited, the task would take 15 minutes at most.

Before the participants began the RSPAN task, the researcher showed them a small demo of the task on the projector. The researcher explained that, in the most general sense, all they had to do is to read some sentences, decide if they are sensical or not, and while doing that, keep some letters in their minds. Then, the participants were told that, sentences of similar length will appear on the screen one after another; and after a sentence disappears from the screen, a question will appear, asking them if the sentence was sensical or not. Then, the participants were shown two examples of sensical and nonsensical sentences. Next, the participants were informed that after they answer the question, a consonant will flash on the screen for one second; and that they have to keep that letter in mind. The researcher told the participants that this process would begin with 3 sets of 2 sentences and end in 3 sets of 6 sentences. At the end of each set, a table with all the consonants would appear, and the participants had to recall and click on the letters they kept in their minds in the order they were presented. If the order was wrong, so would their answers be. The researcher also made participants aware that, they should be %85 correct on the sensicality questions so that their RSPAN scores can be taken into account (Figure 3.1 shows the demo version of the RSPAN presented to the participants). In the end, from a total 60 letters, the number of letters the participants correctly recalled was accepted as their RSPAN scores.

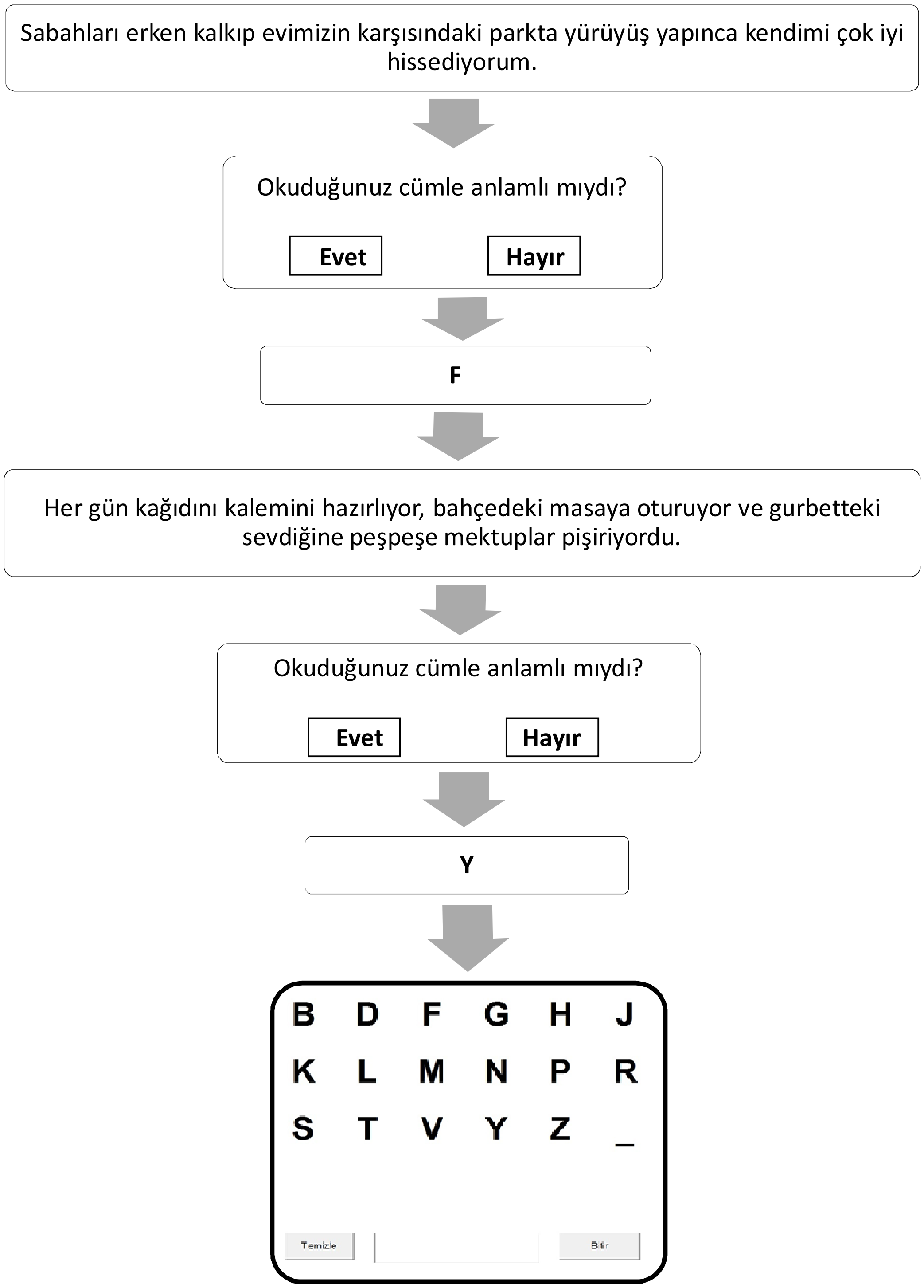

Figure 3.1 Demo version of the RSPAN

3.4.2. DSPAN

The DSPAN was done on a different day than RSPAN was done. Since the digit span task was also computer-based, the same conditions were arranged for the implementation of the task.

The DSPAN was done online on the website of Cambridge Brain Sciences (www.cambridgebrainsciences.com). The researcher again informed the student about the task and again showed a demo to the participants. Since this was a simple span task, the participants' job was also simple. In the task, the participants had to try to remember a sequence of numbers that would appear on the screen one after the other. When they heard the beep, they had to type all of the numbers into the keyboard in the sequence in which they occurred. If they correctly remembered all of the numbers then the next list of numbers would be one number longer. If they made a mistake then the next list of numbers will be one number shorter. After three errors, the test would end and would show the digit span of the participants as the result. However, in order for the results to be more reliable, the researcher made sure that the participants took the task three times and thus an average digit span score would be reached. In the end, the highest number of digits the participants could correctly recall was accepted as their DSPAN scores. The demo of the DSPAN is shown in Figure 3.2

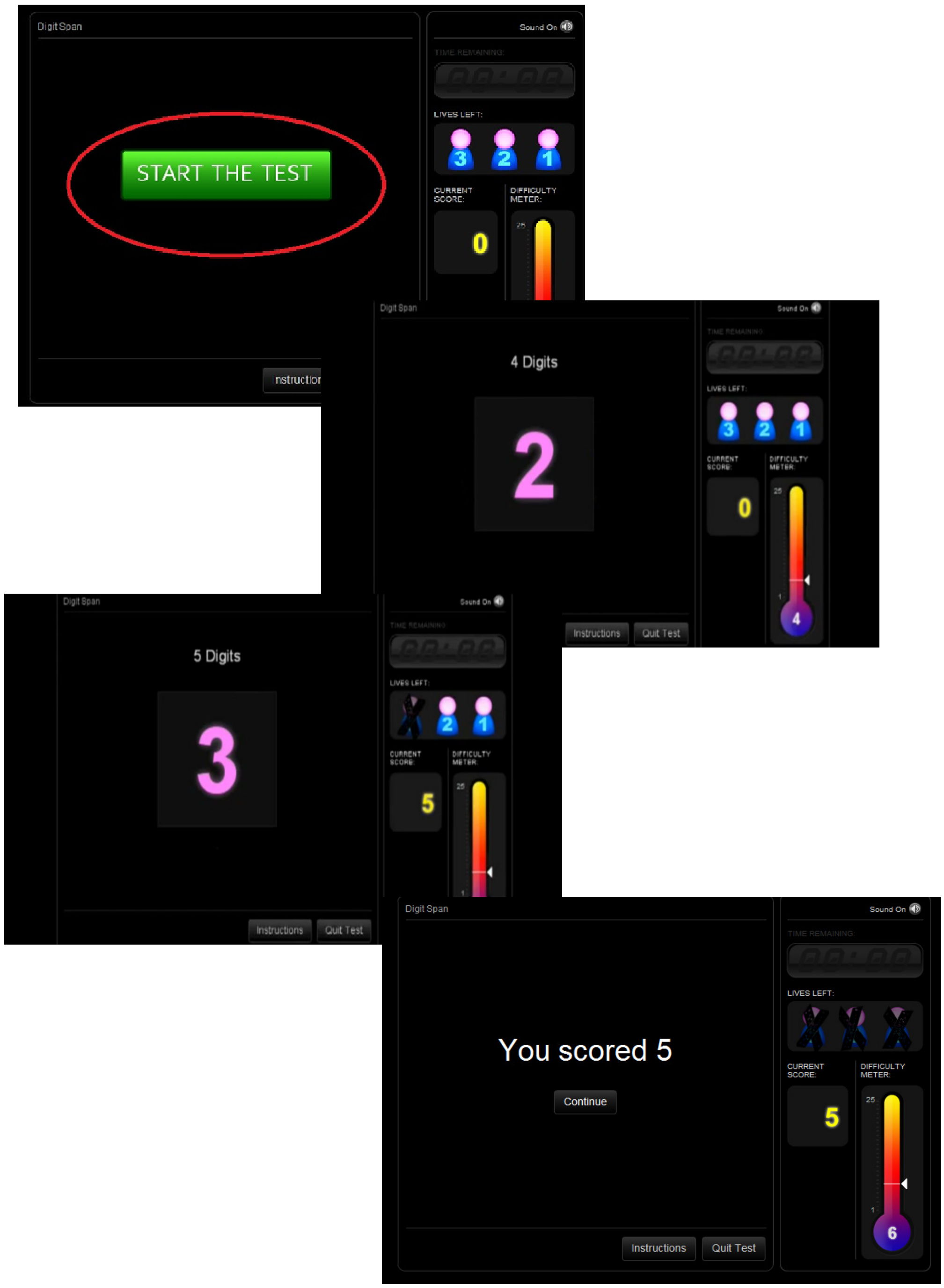

Figure 3.2 The demo version of the DSPAN

3.4.3. AE1 and AE2

Since the participants were already students at Hacettepe University School of Foreign Languages Department of Basic English 150- ELE Groups; and since they were all to take the AE1 and AE2 as a part of the assessment procedure, no additional data collection procedure was carried out for these exams. The students AE1 and AE2 scores were derived from Administrative Coordinators of the department. Since the exams were 100 points, the participants' scores out of 100 points were accepted as data. However, because of the nature of the YGST exam, only the total of the Use of English and Reading parts of both AE1 and AE2 exams were used in the data analysis procedure in order to be able to answer one of the research questions (i.e. "Is there a relationship between foreign language achievement and native language achievement in relation to working memory capacity?")

3.4.4. YGST and YGSM

Since YGS is the first stage of the university entrance examination; and since the participants were students at Hacettepe University, they all had taken this exam and they all had these YGST and YGSM scores. The participants were asked for their scores from this exam during the data collection procedure. Since there were 40 questions in Turkish part and 40 questions in the Mathematic part, the participants' number of their correct answers on each part of the test was accepted as data.

3.5. Data Analysis Procedures

In the present study, data was analyzed using SPSS version 18.0. Before conducting the analysis; the accuracy of data entry, missing values and the assumption of parametric test were investigated. Before the investigation process, assumptions were checked for each variable. In order to understand the characteristics of the sample, descriptive statistics (mean, SD, frequency and percentage) of the data were presented. After that, a series of correlation analyses were performed via Pearson product-moment correlation coefficients (r) to answer each research question.

CHAPTER 4

RESULTS

4.0. Presentation

In this chapter, descriptive and inferential statistics are carried out with the participant profile, WMC measures (RSPAN and DSPAN), along with verbal achievement measures (YGST, AE1 and AE2 scores) and mathematical achievement scores (YGSM).

4.1. General Descriptive Statistics

Participants: In this study, the participants were selected using the convenient sampling method at Hacettepe University School of Foreign Languages Department of Basic English 150-ELE Groups. The number of the participants is N=60 which is composed of 34 female students that is 56.7% of all the participants and 26 male students, which is 43.3% of all the students. Their ages ranged from 18 to 23 (*M* = 19.55; *SD* = 1.171).

Table 4.1 *Participant Characteristics*

	Gender		Age					
	Female	Male	18	19	20	21	22	23
No. of Participants	34	26	10	21	22	2	3	2

RSPAN Scores: Descriptive statistics for the RSPAN scores of the students (N = 60) were analyzed and the findings indicated that, the mean RSPAN score is *M* = 43.18 and standard deviation is *SD* = 10.09. The minimum and maximum RSPAN score among the all participants are 12 and 58 respectively. Descriptive statistics for the overall RSPAN score of the students are presented in Table 4.2.

Table 4.2 *Descriptive Statistics for RSPAN*

N						
Valid	Missing	Mean	Median	Std. Deviation	Minimum	Maximum
60	0	43,18	45,00	10,092	12	58

DSPAN Scores: Descriptive statistics for the DSPAN scores of the students (N = 50) were analyzed and the findings indicated that, the mean DSPAN score is M = 7.54 and standard deviation is SD = 1.50. The minimum and maximum DSPAN score among the all participants are 4 and 11 respectively. Descriptive statistics for the overall DSPAN score of the students are presented in Table 4.3.

Table 4.3 *Descriptive Statistics for DSPAN*

N						
Valid	Missing	Mean	Median	Std. Deviation	Minimum	Maximum
50	0	7,54	8,00	1,501	4	11

YGST Scores: As a measurement of native language verbal achievement, descriptive statistics for the YGS Turkish scores of the students (N = 42) were analyzed and the findings indicated that, the mean YGST score is M = 34.81 and standard deviation is SD = 2.94. The minimum and maximum YGST scores among the all participants are 25 and 40 respectively. Descriptive statistics for the overall YGST scores of the students are presented in Table 4.4.

Table 4.*4 Descriptive Statistics for YGST*

N						
Valid	Missing	Mean	Median	Std. Deviation	Minimum	Maximum
42	0	34,81	35,00	2,940	25	40

Achievement Exams I and II: As a measurement of foreign language verbal achievement, descriptive statistics for the AE1 and AE2 scores of the students (N = 60) were analyzed and the findings indicated that, the mean AE1 score is M = 75.00 and standard deviation is SD = 11.59. The minimum and maximum AE1 scores among the all participants are 51.50 and 97.50 respectively. Descriptive statistics for the overall AE1 scores of the students are presented in Table 4.5.

Table 4.5 *Descriptive Statistics for AE1*

N						
Valid	Missing	Mean	Median	Std. Deviation	Minimum	Maximum
60	0	75,00	74,50	11,591	51,50	97,50

Descriptive statistics for the AE2 scores of the students (N = 60) were analyzed and the findings indicated that, the mean AE2 score is $M = 58.42$ and standard deviation is $SD = 15.23$. The minimum and maximum AE2 scores among the all participants are 23 and 91 respectively. Descriptive statistics for the overall AE2 scores of the students are presented in Table 4.6.

Table 4.6 *Descriptive Statistics for AE2*

N						
Valid	Missing	Mean	Median	Std. Deviation	Minimum	Maximum
60	0	58,42	57,87	15,232	23,00	91,00

YGSM Scores: As a measurement of mathematical achievement, descriptive statistics for the YGSM scores of the students (N = 42) were analyzed and the findings indicated that, the mean YGSM score is $M = 29.52$ and standard deviation is $SD = 6.61$. The minimum and maximum YGSM scores among the all participants are 14 and 40 respectively. Descriptive statistics for the overall YGSM scores of the students are presented in Table 4.7.

Table 4.7 *Descriptive Statistics for YGSM*

N						
Valid	Missing	Mean	Median	Std. Deviation	Minimum	Maximum
42	0	29,52	31,00	6,616	14	40

4.1.1. Assumption Checks

Prior to doing the statistical analyses, assumption checks are carried out since it is important to check that any of the ‘assumptions’ made by the individual tests are not violated.

4.1.1.1. Normality

Skewness and Kurtosis values; along with Histograms and Q-Q plots of each variable were explored to examine the validity of normality assumption. All variables were negatively skewed, indicating a clustering of scores at the high end. Positive kurtosis values for RSPAN, DSPAN and YGST scores indicate that the distribution is rather peaked. Negative kurtosis values for AE1 and AE2 and YGSM scores indicate a distribution that is relatively flat. Table 4.8 shows skewness and kurtosis values for all variables.

Table 4.8 *Skewness and Kurtosis values of all variables*

	Skewness		Kurtosis	
	Statistic	Std. Error	Statistic	Std. Error
RSPAN	-,82	,31	,65	,61
DSPAN	-,06	,34	,33	,66
AE1	-,20	,31	-,63	,61
AE2	-,08	,31	-,45	,61
YGSM	-,79	,37	-,01	,72
YGST	-1,05	,37	1,64	,72

Kolmogorov-Smirnov statistics were also performed as another test of normality. As shown in Table 4.9, only AE1 and AE2 showed a non-significant result, which indicates normality.

Table 4.9 *Kolmogorov-Smirnov statistics as tests of normality*

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	Df	Sig.
RSPAN	,13	60	,02	,94	60	,01
DSPAN	,18	50	,00	,94	50	,01
AE1	,10	60	,19	,97	60	,10
AE2	,06	60	,20	,99	60	,88
YGSM	,15	42	,02	,93	42	,02
YGST	,19	42	,00	,93	42	,01

4.1.1.2. Homogeneity of variance

The Levene's test for equality of variance was conducted to test the homogeneity, the level of significance was selected as *alpha*=0.05, the findings supported the homogeneity assumption for all variables except YGST, the level of homogeneity was found greater than the significance level. The relevant values are presented in Table 4.10.

Table 4.10 Levene's Test for Equality of Variances

		Levene's Test for Equality of Variances	
		F	Sig.
RSPAN	Equal variances assumed	,95	,33
DSPA	Equal variances assumed	,12	,74
AE1	Equal variances assumed	,12	,73
AE2	Equal variances assumed	1,63	,21
YGSM	Equal variances assumed	,33	,58
YGST	Equal variances assumed	4,32	,04

In addition to the Levene's test; histograms, normal and detrended normal Q-Q plots proved no great deviation from normality (see Appendix D for histograms, normal and detrended normal Q-Q plots). Taking into account the performed tests of normality, it can be said that the variables used in this study satisfy the normality assumptions. Therefore, in order to answer the research questions; parametric techniques are used in further data analysis of the study.

4.2. Correlation Analyses

In order to describe the strength and direction of the linear relationship between the variables, Pearson product-moment correlation coefficients (r) were performed to answer each of the research questions.

4.2.1. Is there a relationship between working memory capacity and foreign language verbal achievement?

The relationship between WMC (as measured RSPAN and DSPAN) and foreign language achievement (as measured by AE1 and AE2) was investigated using Pearson product-moment correlation coefficient. Preliminary analyses were performed to ensure no violation of the assumptions of normality, linearity and homoscedasticity. There was a moderate, positive correlation between the RSPAN and AE1, $r = .39$, $n = 60$, $p < .01$, and AE2, $r = .27$, $n = 60$, $p < .05$. There was also a moderate, positive correlation between the DSPAN and AE1, $r = .37$, $n = 50$, $p < .05$, and AE2, $r = .32$, $n = 50$, $p < .05$. That is, high working memory capacity is associated with high achievement in foreign language. The summary of Pearson product-moment correlation coefficient is presented in Table 4.11.

Table 4.11 Correlation analysis of WMC and foreign language achievement

		AE1	AE2
RSPAN	Pearson Correlation	,39**	,27*
	Sig. (2-tailed)	,00	,03
	N	60	60
DSPAN	Pearson Correlation	,37*	,32*
	Sig. (2-tailed)	,02	,02
	N	50	50

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

4.2.2. Is there a relationship between working memory capacity and native language verbal achievement?

The relationship between WMC (as measured RSPAN and DSPAN) and native language achievement (as measured by YGST) was investigated using Pearson product-moment correlation coefficient. Preliminary analyses were performed to ensure no violation of the assumptions of normality, linearity and homoscedasticity. There was a moderate, positive correlation between the RSPAN and YGST, $r = .39$, $n = 42$, $p < .05$. No correlation was found between the DSPAN and YGST, $r = .25$, $n = 42$, $p > .05$. That is, high working memory capacity (as measured by RSPAN) is associated with high achievement in native language. The summary of Pearson product-moment correlation coefficient is presented in Table 4.12.

Table 4.12 *Correlation analysis of WMC and native language achievement*

		YGST
RSPAN	Pearson Correlation	,39*
	Sig. (2-tailed)	,03
	N	42
DSPAN	Pearson Correlation	,25
	Sig. (2-tailed)	,12
	N	42

* *p < .05.*

4.2.3. Is there a relationship between working memory capacity and mathematical achievement?

The relationship between WMC (as measured RSPAN and DSPAN) and native language achievement (as measured by YGSM) was investigated using Pearson product-moment correlation coefficient. Preliminary analyses were performed to ensure no violation of the assumptions of normality, linearity and homoscedasticity. There was a moderate, positive correlation between the DSPAN and YGSM, $r = .36$, $n = 42$, $p < .05$. No correlation was found between the RSPAN and YGSM, $r = .13$, $n = 42$, $p > .05$. That is, high working memory capacity (as measured by DSPAN) is associated with high achievement in mathematical achievement. The summary of Pearson product-moment correlation coefficient is presented in Table 4.13.

Table 4.13 *Correlation analysis of WMC and mathematical achievement*

		YGSM
DSPAN	Pearson Correlation	,36*
	Sig. (2-tailed)	,03
	N	42
RSPAN	Pearson Correlation	,13
	Sig. (2-tailed)	,42
	N	42

* *p < .05.*

4.2.4. Is there a relationship between foreign language achievement and mathematical achievement?

The relationship between foreign language achievement (as measured AE1 and AE2) and mathematical achievement (as measured by YGSM) was investigated using Pearson product-moment correlation coefficient. Preliminary analyses were performed to ensure no violation of the assumptions of normality, linearity and homoscedasticity. There was a large, positive correlation between the AE1 and YGSM, $r = .48$, $n = 42$, $p < .01$; and AE2 and YGSM, $r = .49$, $n = 42$, $p < .01$. That is, high foreign language achievement is associated with high achievement in mathematics. The summary of Pearson product-moment correlation coefficient is presented in Table 4.14.

Table 4.14 *Correlation analysis of foreign language achievement and mathematical achievement*

		YGSM
AE1	Pearson Correlation	,48*
	Sig. (2-tailed)	,00
	N	42
AE2	Pearson Correlation	,49*
	Sig. (2-tailed)	,00
	N	42

* *p < .01.*

4.2.5. Is there a relationship between foreign language achievement and native language achievement?

The relationship between foreign language achievement (as measured by the total of the Use of English and Reading Parts of AE1 and AE2) and native language achievement (as measured by YGST) was investigated using Pearson product-moment correlation coefficient. Preliminary analyses were performed to ensure no violation of the assumptions of normality, linearity and homoscedasticity. No correlation was found between AE1 and YGST $r = .19$, $n = 42$, $p > .05$. ; and AE2 and YGST, $r = .10$, $n = 42$, $p > .05$. That is, foreign language achievement seems not to be associated with achievement in native language. The summary of Pearson product-moment correlation coefficient is presented in Table 4.15.

Table 4.15 *Correlation analysis of foreign language achievement and native language achievement*

		YGST
AE1	Pearson Correlation	,19
	Sig. (2-tailed)	,22
	N	42
AE2	Pearson Correlation	,10
	Sig. (2-tailed)	,51
	N	42

CHAPTER 5

DISCUSSION

5.0. Presentation

This section is devoted to the discussion of major findings and conclusions elicited through the data analysis. Findings will be evaluated in three sections that refer to each research question: the relationship between WMC and foreign language achievement, the relationship between WMC and native language achievement; and the relationship between WMC and mathematical achievement.

5.1. The relationship between WMC and foreign language achievement

The correlation analysis in the present study revealed moderate correlations between WMC (as measured with RSPAN and DSPAN) and foreign language achievement (as measured with AE1 and AE2). Correlation analysis provides an indication that there is a relationship between two variables; that is, in this research, it was found that as participants' WMC increase, so does their foreign language achievement.

In this study, WMC was measured using one simple (DSPAN) and one complex (RSPAN) task. In literature, although RSPAN proves to correlate with most of second/foreign language achievement measures, DSPAN does not (see Chapter 2). In other words, the role of the DSPAN in foreign language achievement is controversial. The data analysis in this study, on the other hand, proves that both RSPAN and DSPAN are strong predictors of foreign language achievement.

5.1.1. The role of RSPAN in foreign language achievement

Baddeley's (1986, 2000b) theoretical model posits working-memory capacity as involving a multi-component system which consists of a supervisory attentional mechanism (the 'central executive') and three auxiliary domain-specific subsystems, each of which is responsible for processing phonological ('phonological loop'), visual ('visuospatial sketch pad'), and long-term memory-related data ('episodic buffer'). There seems to be a general consensus that Daneman and Carpenter's (1980) concept of working memory, operationalized through a complex span task (RSPAN) that requires the simultaneous processing and storage of items, maps onto Baddeley's construct of the *central executive* (CE) (Baddeley, 2003; Just and Carpenter, 1992; Turner and Engle, 1989). It follows from this that, the relationship found between RSPAN and AE1 and AE2 in this study, supports this claim that CE component of working memory plays an important role in foreign language achievement. As Daneman and Carpenter (1980) agrees, CE processes are probably one of the principal factors determining individual differences in working memory span. In his latest paper in 2012, Baddeley analyzed these CE processes by proposing four suggestions about the functions of the CE (p. 14):

- focusing attention
- dividing attention between two important targets or stimulus streams
- switching between tasks
- interfacing with LTM

These functions of CE clearly relates to foreign language processing in WM. To give an example, in reading comprehension, the reader must store pragmatic, semantic, and syntactic information from the preceding text and use it in disambiguating, parsing, and integrating the subsequent text (Daneman and Carpenter, 1980, p. 450). When the reader is going through all these storage and processing phases, the CE plays its roles in terms of focusing, dividing and switching attention between these phases and also interfacing with LTM. It is important to note that all these storage and processing functions taking place in reading also apply for other language skills (i.e. listening, speaking, and writing) and areas (i.e. grammar and vocabulary). In this study, all of these foreign language skills (except for speaking) and language areas were measured with Achievement Exams (AE1 and AE2); and the CE component of WMC was measured with RSPAN. Hence, it could be suggested that the correlations found between RSPAN and AE1 and AE2 clearly reflects the relationship between CE functions and foreign language processing in WM.

5.1.2. The role of DSPAN in foreign language achievement

As it was noted earlier, whereas the role of RSPAN in terms of its functions and its importance in foreign language is decidedly obvious, the same consensus does not apply for DSPAN. For instance, in a subsequent meta-analysis of 77 published studies, Daneman and Merikle (1996) showed that the estimated correlation between complex span measures (such as RSPAN) and standardized indices of reading and vocabulary knowledge was 0.42; compared with a value of 0.28 for simple span tasks (such as DSPAN) (cited from Jarrold&Towse, 2006, p. 41).

DSPAN task measures phonological component of WM, the phonological loop (PL). In Baddeley's WM model (1974), the PL is a slave system, assumed to comprise of two components: a temporary store and a rehearsal process based on a form of sub-vocal speech. According to Baddeley (1998), the mechanisms underlying phonological memory have evolved from earlier processes for speech perception (the phonological store), and speech production (the articulatory rehearsal component), hence it is likely that this aspect of working memory develops close links with the study of speech perception and production (p. 170). The clearest evidence for the role of PL in foreign language learning comes from the study of Baddeley, Papagno and Vallar (1988) in which, they worked with a patient, PV, who had a very pure phonological STM deficit (her auditory digit span was only two items). Baddeley, et. al. required her to attempt to learn eight items of Russian vocabulary (e.g., rose-svieti), comparing this with her capacity to learn to associate pairs of unrelated words in her native language, i.e. English (e.g., horse-castle). Baddeley et al. found that such native language pairs were learned as rapidly by PV as by normal control subjects, whereas she failed to learn any of the eight Russian items. It appears, then, that the PL can be a useful aid in learning new words in a foreign language. By this account, individuals with relatively poor phonological storage capacities will therefore encounter difficulties in learning the phonological forms of new words

(Gathercole, et al., 1999). When this association is taken into consideration, learning new words in a foreign language affects the success in all language skills (i.e. reading, listening, speaking and writing), thus in overall language achievement. In other words, the PL capacity (as measured with DSPAN), affects overall foreign language achievement (as measured with AE1 and AE2). This finding is supported with the significant moderate positive correlations found between DSPAN and AE1 and AE2 in this study.

The role of the PL in learning a foreign language is also related to the relationship between the PL and the CE. In Baddeley and Hitch's (1974) original model of WM, the PL was referred as a slave system. However, in his latest paper, Baddeley (2012) admits that it is becoming increasingly clear that the loop can also provide a means of action control – a role which is shared by the CE. Deriving from the aforementioned studies with PV, Baddeley (2012) attributes another role to the PL: new long-term phonological learning, a role which is again shared by the CE in a sense that the executive also interfaces with LTM (p. 14). In this study, a correlation between CE (as measured with RSPAN) was found between foreign language achievement (as measured with AE1 and AE2). Therefore, the correlations found between DSPAN and AE1 and AE2 in this study are reasonable, since the PL shares important functions with the CE.

5.2. The relationship between WMC and native language achievement

In this study, WMC was measured using one simple (DSPAN) and one complex (RSPAN) task; and native language achievement was measured with YGST. The correlation analysis in the present study revealed moderate correlations between RSPAN and YGST; but no correlation between DSPAN and YGST.

5.1.1. The role of RSPAN in native language achievement

As mentioned earlier, the RSPAN task, taps on the CE component of WM, which has four functions: (1) focusing attention (2) dividing attention between two important targets or stimulus streams (3) switching between tasks and (4) interfacing with LTM. The relationship found between WMC and foreign language achievement, thus, is also valid in the relationship found between WMC and native language achievement in this study. In the YGST exam, in which the participants' native language (i.e. Turkish) achievement was measured, the participants were required to demonstrate their knowledge in their native language in many senses, such as sentence and lexical meanings, paragraph comprehension, parts of speech, word structure, elements of sentences, voice of verb, types of sentences, ambiguity, phonetics, spelling rules, punctuation, communication and the classification of culture-languages, etc. It follows from this that, the participants had to focus, divide and switch their attentions between tasks and interface with their LTM, in order to be able to deal with these questions in their native language. That is, the cognitive processes carried out while answering comprehension questions in their L1 might not differ much from the cognitive processed carried out while answering comprehension questions in their L2. The correlations found between WMC (as measured with RSPAN) and native language achievement (as measured with YGST) clearly indicated this similar relationship. This finding is also supported by the studies in which strong correlations were found between complex span measures (such as RSPAN) and Verbal SAT Scholastic Aptitude Test (Daneman&Carpenter, 1980; Friedman&Miyake, 2004; Turner and Engle, 1989).

5.1.2. The role of DSPAN in foreign language achievement

In this study, no correlation was found between DSPAN and YGST. The reasons for this result were tracked to several issues regarding the PL (as measured with DSPAN) and the nature of the native language, which is different from the foreign language.

First of all, in this study, since RSPAN (as a measure of the CE) correlated moderately with YGST, one might also expect to find similar correlations between DSPAN (as a measure of phonological loop) and YGST as well; because as it was mentioned earlier, the PL shares an important function with the CE: *interfacing with*

LTM. The reason why no correlation was found between DSPAN and YGST – that is, between the PL and achievement in native language – could be explained by taking this viewpoint into consideration. Whereas the participants needed to interface more with their long-term memories while dealing with questions in a foreign language; they may not need to interface that much while they are dealing with questions in their native language. To explain it further, when they are answering a reading comprehension question in English, the students need to understand the grammar and vocabulary items in that question and in the related passage as well; thus they may need to consult more to their knowledge in LTM. However, when answering reading comprehension questions in Turkish, the participants only needed to rely on their working memories to in terms of storage and processing functions in order to conceptualize and make sense of the questions; thus provide an answer without consulting much to their long-term memories. Therefore, although a moderate correlation was found between RSPAN (as a measure of CE) and YGST; no correlation was found between DSPAN (as a measure of the PL) and YGST.

The second and the most important reason why PL and the native language were not found to be related in this study may be that, the PL is "a useful aid in learning *new* words" (Baddeley, 2003, p. 194). This finding derived from the idea that the PL might conceivably have evolved in order to facilitate the acquisition of language. Given that the patients studied were adult and had already acquired their native language, such a deficit would not be readily noticed clinically (Baddeley, 2003). Therefore, Baddeley, Papagno, & Vallar, (1988) carried out a study to test the capacity of patient PV, who had a very pure phonological STM deficit, to acquire the vocabulary of an unfamiliar foreign language, Russian. They required her to attempt to learn eight items of Russian vocabulary (e.g., rose-svieti), comparing this with her capacity to learn to associate pairs of unrelated words in her native language, i.e. English (e.g., horse-castle). Baddeley et. al. found that such native language pairs were learned as rapidly by PV as by normal control subjects, whereas she failed to learn any of the eight Russian items.

As Baddeley (2003) further explains, variables that impair the performance of the PL also disrupt foreign language learning, but not paired associate learning in one's native language, for which subjects typically rely on semantic coding. To give an example, requiring the subjects to suppress rehearsal by uttering an irrelevant sound disrupted their foreign language learning; but not native language learning (p. 194). It follows from this that, the PL may be fundamental only when *acquiring* native language vocabulary (Adams&Gathercole, 2000; Baddeley, Gathercole&Papagno, 1998; Gathercole, et. al., 1992; 1994; 1999) or when *learning* foreign language vocabulary (Gupta and MacWhinney, 1997; Masoura&Gathercole, 1999; 2005; Service, 1992).

In brief, the first reason why the PL (as measured with DSPAN) and overall achievement in native language (as measured with YGST) did not indicate any correlation in the data analysis of this study may be that when dealing with questions in native language, the participants do not need to consult to their LTM as much as they do when they deal with questions in their foreign language. Since they do not need to interface that much with their LTM, they tended to use their PL in a less efficient way, leading to a lack of correlation between DSPAN and YGST scores. Secondly, since the PL is a useful aid in *learning new words*, it was found to be effective in foreign language achievement in this study (as DSPAN and AE1 and AE2 showed positive moderate correlations). However, the PL remained passive in terms of native language achievement, because the participants were adults and they had already acquired their native language (Baddeley, 2003); thus there was no need for any function of the PL (DSPAN) in terms of native language achievement (YGST) in this study.

5.3. The relationship between WMC and mathematical achievement

Although it is supposed to measure the CE component of WM, RSPAN scores were not taken into account in the correlation analysis when investigating the relationship between WMC and mathematical achievement because as Holmes and Adams (2006) explains, it is generally accepted that number-based WM span measures are more strongly associated with mathematics than non-numerical span measures, such as those that use words (i.e. RSPAN in this study). One possibility for this explanation might be that WM and mathematics are linked because the assessments of both involve either number processing or direct access to numerical information Holmes and Adams (2006). Therefore, in this study, the relationship between WMC and mathematical achievement has been investigated only in terms of the PL (as measured with DSPAN) and overall mathematical achievement (as measured with YGSM). The correlation analysis indicated positive moderate correlations between DSPAN and YGSM.

As measured with DSPAN, the PL plays an important role in mathematics in many senses, as supported by the studies in reviewed literature. Amongst these studies, while the CE and the VSSP are generally found to be influential in mathematical achievement, the role of the PL remains unclear. While some studies support the role of the PL (Andersson&Lyxell, 2007; Peng, Congying, Beilei&Sha, 2012; Rasmussen&Bisanz, 2005; Zheng, Swanson&Marcoulides, 2011); others concluded that the PL is not the major factor in explaining arithmetical difficulties (D'Amicoa&Guarnera, 2005; Holmes&Adams, 2006; Iuculano, Moro and Butterworth, 2011; McLean&Hitch, 1999). In the present study, however, the PL was found to be a strong predictor of mathematical achievement.

The reason for the controversy regarding the PL derives from several factors. First of all, most studies investigating the relationship between Mathematics and WM are done with children. As Bull and Espy (2006) explains, the reason for this tendency could be that mathematics competence in young children is described by proficient counting, whereas in a college student, mathematics competence is marked by solving complex trigonometric problems and integrating equations. Thus, the role of the PL differs in children and in adults. At this point it is important to remember that the PL involves two components: a temporary store and a rehearsal process based on a form of sub-vocal speech. When children are doing simple calculations, such as "4+6=?", the data may be too little to be stored and even sub-vocally rehearsed in order to make the calculation. However, when adults are doing much more complex calculations, such as “(35x50)/2=?”, they need to rely more on their PLs since the data to be calculated needs a significant storage and sub-vocal rehearsal process. Therefore, some studies with children may not indicate a relationship between the PL and mathematical ability for this reason. However, since the participants in this study were adults and since the calculations they carried out were complex, they may have depended on their PLs more, as the correlation analysis showed so.

The second reason why the role of the PL is controversial might be deriving from the inter-relation between the PL and LTM. One of the most important functions of the PL is new vocabulary learning. Gathercole showed that existing language habits influence immediate non-word recall, making the non-words that have a similar letter structure to English, such as *contramponist*, easier than less familiar sounding non-words such as *loddenapish* (cited from Baddeley, 2012, p. 11). This clearly indicates a direct link from the PL to LTM. As Baddeley (2012) agrees, information flows from LTM to the PL, as well as the reverse.

From this inter-relationship between the loop and the LTM, it follows that since most adults readily know the answer to the sum 6+7 or the product 3x4, without having to follow any form of calculation algorithm, the answers to these problems are calculated and found by direct LTM access (Logie, Gilhooly&Winn, 1994, p. 395). In other words, as Passolunghi and Siegel (2001) agrees, the stronger long-term memory representation of numbers in the arithmetically gifted children may facilitate their item identification, and this in turn may enhance their digit span performance (as cited in D’Amico&Guarnera, 2005, p. 191). Logie, et. al. explains this issue further and gives an example about this inter-connection between the PL and LTM:

> From our earlier review of the literature, it was clear that subjects appear to have access to a vocabulary of sums and totals or arithmetic facts that they can access relatively automatically. Automated retrieval of arithmetic facts would allow accurate answers to a range of sums depending on the arithmetic vocabularies of the subjects involved. Moreover, access to such a knowledge base would allow approximations where the exact total was not immediately available. Thus, for example, given the sum of 28+19, most subjects would recognize that this was very close to 30+20, the answer to which would be readily available. Subjects might also notice that both numbers are a little less than 20 and 30, so that the correct answer would be a little bit less than 50. They could then guess 46, 47, or 48, and be assured of being very close to the correct total. Indeed, they have a reasonable chance of being correct (p. 407).

In brief, the correlation revealed by the data analysis between the PL (as measured with DSPAN) and mathematical achievement (as measured with YGSM) could be explained by deriving from two reasons. First, the reason why the PL sometimes is not found to correlate with mathematical achievement is that, those studies are mostly carried out with children; and since children's mathematics is too simple to be depending on PL's temporary storage and sub-vocal rehearsal processes; it is understandable why we found positive moderate correlations between DSPAN and YGSM, because in adult mathematics, the calculations are so complex that, the adults need to rely on their PLs to temporarily store the numbers and sub-vocalize the calculations so as to reach the solution of the question.

Secondly, since very basic calculations in children's mathematics such as 2x5 or 30x10 are readily stored in adults LTM, and since the PL allows information to flow from LTM to itself, as well as the reverse; it is again understandable that DSPAN correlated well with YGSM, since the PL allowed the participants to access the readily stored simple calculations so that they could deal with more complex mathematical calculations.

5.4. The relationship between foreign language achievement and mathematical achievement

In this study, foreign language achievement was measured with two Achievement Exams (AE1 and AE2) and mathematical achievement was measured with YGSM scores. The correlation analysis in the present study revealed large, positive correlations between foreign language achievement and mathematical achievement.

It is important to note that, in the data analyses of the present study, while foreign language achievement had shown relationship both with CE and PL measures of WM; mathematical achievement had shown relationship only with PL measures of WM. Taking the previous discussions about these relationships into consideration; the most important result to be drawn in terms of the relationship between foreign language achievement and mathematical achievement is the role of the PL in both foreign language and mathematical achievement. Since it has the function of being a useful aid in learning new words (for foreign language achievement) and the function of interfacing with LTM (for mathematical achievement); it can be stated that the role of the PL is more important than other components of WM (i.e. CE, in this study), regarding the achievement in foreign language and mathematics. This finding is in line with that of Swanson and Sachse-Lee's (2001) study, in which they concluded that, phonological processing is important to problem solving, since the phonological system plays an important part in accounting for individual differences in text processing (p. 316).

5.5. The relationship between foreign language achievement and native language achievement

Because of the nature of the YGST exam, only the total of the Use of English and Reading parts of both AE1 and AE2 exams were used in the data analysis procedure of the present study in order to be able to investigate the relationship between foreign language achievement and native language achievement. The data analysis, however, did not demonstrate any correlations between AE1, AE2 and YGSM scores; which means that the relationship between foreign language and native language is not as strong as the relationship between foreign language and mathematical achievement. This result can also be traced down to the role of the PL. That is, in the data analyses of the present study, while foreign language achievement had shown relationship both with CE and PL measures of WM; native language achievement had shown relationship only with CE measures of WM, not with PL. As mentioned before, this lack of correlation between native language and PL was thought to be deriving from two roles of PL: new vocabulary learning and interfacing with LTM. Since native language achievement (as measured with YGST) did not require participants to acquire new vocabulary items or interface with LTM, this lack of correlation was not found to be unexpected.

In brief, when foreign language achievement is investigated in terms of its relation to mathematical and native language achievements, by also taking into the roles of different components of WM into consideration; it could be tentatively suggested that; rather than the CE, the most important component of WM in terms of foreign language achievement is PL. The reason why the participants with high mathematical achievements also show high achievement in foreign language is probably the result of the efficient use of their PL.

CHAPTER 6

CONCLUSION

6.0. Presentation

In this chapter, the purpose, the data collection and analysis procedures and the findings of the study are summarized. Then some conclusions are drawn and the implications regarding the relationship between working memory capacity and verbal and mathematical achievement are discussed. Lastly, limitations and suggestions for further research about the concept of working memory are presented.

6.1. Summary

Although a similar concept was evident even in the writings of the seventeenth-century British philosopher John Locke in 1690; the term "working memory" was first coined by Miller, Galanter, and Pribram in their studies in 1960; and was later used by Atkinson and Shiffrin (1968) to describe their "short-term store" (p. 92). Even though hereafter many cognitive psychologists and memory experts viewed STM and WM as interchangeable or considered one to be a subtype of the other; what differentiates WM from STM in the most basic sense is that, whereas STM is the ability to remember information over a brief period of time (in the order of seconds), WM processes and manipulates the information instead of passive maintenance.

Because of its role of actively holding information in the mind and making it available for further processing, WM is considered as a system to carry out verbal and nonverbal tasks such as reasoning and comprehension. In the most general sense, *learning* is largely a function of the individual's working memory capacity (Dehn, 2008, p.3). The most important evidence for this comes from the studies which are carried out with children of different learning difficulties, such as specific language impairment (SLI) or mathematics difficulties (MD). In these studies, these children's performance in various WM measures was found to be significantly below than their matched groups (Baddeley, 2003; Andersson&Lyxell, 2007; Peng, Congying, Beilei&Sha, 2012).

Although a consensus about the role of the WM in academic learning is reached, the studies carried out in this field reveal some controversies, especially about the roles and functions of the different components of WM (i.e. PL, CE, VSSP, and EB). For instance, whereas some studies support the role of the PL in mathematics (Andersson&Lyxell, 2007; Peng, Congying, Beilei&Sha, 2012; Rasmussen&Bisanz, 2011; Zheng, Swanson&Marcoulides, 2011); others conclude that the PL is not the major factor in explaining arithmetical difficulties (D'Amicoa&Guarnera, 2005; Holmes&Adams, 2006; Iuculano, Moro and Butterworth, 2011; McLean&Hitch, 1999). As regards the language achievement, the role of the PL is again debatable. For example, in some studies, no correlation was found between PL and language measures (Daneman&Carpenter, 1980; Turner&Engle, 1989); while in other studies it was (Baddeley, Papagno&Vallar, 1988; Masoura&Gathercole, 1999, 2005). In some studies (Gilabert&Muñoz 2010), even the role of the overall WMC was doubted in terms of language achievement.

Taking the importance of WMC in academic learning; and the reviewed literature into consideration; the relationship between working memory capacity, verbal and mathematical achievement was investigated in this study. To this aim, a total of 60 (34 female, 26 male) volunteering students from 150-Elementary groups at Hacettepe University School of Foreign Languages Department of Basic English participated in this study. Their ages ranged from 18 to 23 (M = 19.55; SD = 1.171). In order to measure their WMC, one simple (DSPAN) and one complex (RSPAN) measures were used. The participants' verbal achievements were measured twofold: their native language achievements were measured with YGS Turkish scores; whereas their foreign language achievements were measured with the Prep School's Achievement I and II Exams. Finally, their mathematical achievement was measured with YGS Mathematical scores.

In order to answer the five proposed research questions, both descriptive and inferential statistics were carried out using the statistical program, SPSS version 18. Since the data was normally distributed, the Pearson product-moment correlation coefficients *(r)* were performed to answer each of the research questions so that the strength and direction of the linear relationship between the variables could be described.

The correlation analyses showed positive moderate correlations between measures of WMC and verbal and mathematical achievements. As a measure of WMC and foreign language achievement, RSPAN and DSPAN moderately correlated with both AE1 and AE2. As a measure of WMC and native language achievement, RSPAN also correlated moderately with YGST scores. Next, as a measure of WMC and mathematical achievement, DSPAN correlated moderately with YGSM scores. Finally, foreign language achievement and mathematical achievement (as measured with AE1, AE2 and YGSM, respectively) correlated largely; whereas foreign language achievement (only AE1) correlated to some extent with native language achievement.

Apart from these positive, moderate correlations, no correlation was found between RSPAN and YGSM scores. Normally, RSPAN is considered to be a measure of the CE component of WM; and many studies reveal strong correlations between measures of CE and mathematical achievement (Andersson&Lyxell, 2007; Peng, Congying, Beilei&Sha, 2012; Rasmussen&Bisanz, 2011; Zheng, Swanson&Marcoulides, 2011). The reasons for this lack of correlation between RSPAN and YGSM scores in this study might be that in the RSPAN task in this study, the participants read a series of sentences and then remember a series of letters. As Holmes and Adams (2006) explains, it is generally accepted that number-based WM span measures are more strongly associated with mathematics than non-numerical span measures, such as those that use words (i.e. RSPAN in this study). One further possibility for this explanation might be that WM and mathematics are linked because the assessments of both involve either number processing or direct access to numerical information (Holmes and Adams, 2006).

In addition, no correlation was found between DSPAN and YGST scores. The reasons for this lack of correlation were tracked down to two issues: First of all, since DSPAN is a measure of PL component of WM; and since one of the functions of PL is interfering with LTM; it was concluded that whereas the participants needed to interface more with their long-term memories while dealing with questions in a foreign language; they may not have needed to interface that much while they are dealing with questions in their native language. The second reason might be that, another important function of the PL is being "a useful aid in learning *new* words" (Baddeley, 2003, p. 194). That is, the PL may be fundamental only when *acquiring* native language vocabulary (Adams&Gathercole, 2000; Baddeley, Gathercole&Papagno, 1998; Gathercole, et. al., 1992; 1994; 1999) or when *learning* foreign language vocabulary (Gupta and MacWhinney, 1997; Masoura&Gathercole, 1999; 2005; Service, 1992). Thus, it is conceivable that no correlation was found between DSPAN and YGST measures, because the participants were adults and they had already acquired their native language (Baddeley, 2003); thus there was no need for any function of the PL in terms of native language achievement.

Data analysis also revealed no meaningful correlations between foreign language and native language. The reason for this lack of correlation was track down to the role of PL. Since there were also found no correlation between native language and PL, the lack of correlation between foreign language and native language was considered unsurprising. Because of the fact that the PL has two important functions of being a useful aid in learning new vocabulary and interfacing with long term memory; these functions are considered to be necessary in foreign language achievement; but not in native language achievement. Therefore, the role of PL was less evident than CE in terms of native language; and the relationship between foreign and native language achievement was thus only mediated by the role of PL.

6.2. Conclusions and Implications

In the present study, a significant relationship between working memory capacity and verbal and mathematical achievement was found. It is important to note that correlation does not mean causation. Rather, it only provides an indication that there is a *relationship* between two variables (Pallant, 2011, p. 128); that is, in this research, it was found that as participants' WMC increase, so does their verbal and mathematical achievements.

When the achievement in foreign language was investigated in terms of its relationship with mathematical and native language achievement, by also taking the components of WM (PL and CE) into consideration; it was seen that the role of PL was much more evident than CE when it comes to foreign language achievement. The reason for this tendency could be that PL is a useful aid in learning new words in a foreign language (Gupta&MacWhinney, 1997; Masoura&Gathercole, 1999; 2005; Service, 1992); and it has the role of interfacing with LTM, a function which is crucial in adults in foreign language and mathematical achievement (Andersson&Lyxell, 2007; Peng, Congying, Beilei&Sha, 2012; Rasmussen&Bisanz, 2005; Zheng, Swanson&Marcoulides, 2011); but not that much in native language achievement (Baddeley, 2003)

These results have several implications in terms of working memory and academic achievement in general. First, it can be tentatively said that, if WMC and the efficiency of its components (especially the PL in line with the results of the present study) can be improved, so can the verbal and mathematical achievements; and achievements in other school subjects; or even all other cognitive skills which require the functions of WM. Second, as Shipstead, Hicks and Engle (2012) agrees, the implication here is that, if performance in all of these domains is somehow limited by WM capacity, then a training program that increases WM capacity should result in improvements in all of these areas (p. 6).

The first published research on working memory training was actually done by Klingberg, Forssberg and Westerberg in 2002. In their study, Klingberg et. al. (2002) worked with children with ADHD (attention-deficit/hyperactivity disorder) and healthy adults. They investigated whether WM capacity could be improved by training; and if impairment of WM is a core deficit in ADHD; this would imply that improvement of WM would decrease the symptoms in ADHD. A randomized-controlled design was used. Results indicated improvements on non-trained tasks of working memory as well as on several other neuropsychological tests. The study can be considered to be important in that it is the first indication that working memory capacity can be increased with training.

Since their study in 2002 had several limitations such as the small sample size, the lack of behavioral measures, and no longer-term follow-up; Klingberg, et. al. (2005), replicated their previous studies with 53 children again with ADHD, between the ages of 7-12. They investigated if whether systematic training of WM tasks during a 5-week period would improve WM, improve other executive functions, and reduce the ADHD symptoms. Results indicated significant gains in non-trained measures of working memory, non-verbal reasoning, and response inhibition. In addition, significant reductions in parent ratings of ADHD symptoms were found, although comparable reductions in teacher ratings were not evident. Gains evident immediately after the training ended were largely intact 3-months later.

Although they found these early findings look promising; Holmes, Gathercole and Dunning (2009) stated that the educational significance of this training program is yet untested. In particular, as they suggested, it is not known (1) whether the training benefits extend to children with low WM who do not have ADHD, (2) what components of WM are trained, or (3) whether the enhancement of WM function is of a sufficient degree to ameliorate or overcome the learning difficulties associated with low WM (p. F2). In their study, therefore, Holmes et. al. (2009) aimed to answer these three questions by evaluating the extent to which the training program boosts performance of children with low WM on a standardized battery of untrained and well-validated WM tasks and on measures of academic ability, both immediately following completion of training and 6 months later. 42 children screened for working memory deficits were randomly assigned to high or low intensity training conditions. Children receiving high intensity working memory training showed significant gains on several non-trained measures of working memory that remained evident at 6 months. They also showed improved on a 'real world' measure of listening skills. Furthermore, 6 months after training ended significant gains in a measure of math achievement had emerged.

These findings did not go unchallenged. WM training programs, which are sold as tools for improving cognitive abilities, such as attention and reasoning; and which are marketed to schools as a means of improving underperforming students' scholastic performance; and which are also available at clinical practices as a treatment for ADHD were challenged by Shipstead, Hicks and Engle (2012). In their paper, Shipstead et. al. reviewed research conducted with a WM training software and highlighted several concerns regarding methodology and replicability of findings. In general they concluded that these kinds of WM training programs will improve performance on tasks that *resemble* these programs; however, for people seeking increased intelligence, improved focus and attentional control, or relief from ADHD; current research suggests that these training programs do not provide the desired result (p. 20).

Jaušovec and Jaušovec (2012) agrees that it is easy to increase test performance by simply practicing the tests themselves, or by practicing similar tasks. They also provide the example of highly controversial Mozart effect to explain this debatable issue:

> Interventions aiming to improve intelligence resulted in only very little if any success at all, only sporadic attempts have been made to investigate interventions that could increase ability. To mention just one, the highly controversial Mozart effect. College students after 10 min of listening to Mozart's Sonata (K. 448) had Stanford–Binet spatial subtest IQ scores 8–9 points higher than students who had listened to a relaxation tape or listened to nothing. The IQ effects did not persist beyond the 10–15 min testing session. (p. 98)

It follows from here that the main problem with WM training and the programs which claim to train WM is that, the effects of training transfer to untrained tasks are bound to be demonstrated. In other words, improved performance on the training task may not signal an increase in WM capacity. Shipstead, Redick, and Engle (2012) gives an example to further explain this relationship:

> Chase and Ericsson (1982) reported a participant (S.F.) who, after several months of training on an adaptive span task, was able to recall sequences of more than 80 digits. However, when the digits were presented at a faster rate, his scores returned to normal levels. The reason for this decline was that S.F. had developed a strategy of mapping short sequences of numbers onto preexisting knowledge (i.e., cross-country running times, historical dates). When the testing conditions were changed, his strategy could not be employed.

The training of WM is also investigated in terms of brain's plasticity. Westerberg and Klingberg (2007), for example, worked with three young, healthy adults in their study. The results showed that practice of WM tasks over several weeks induced a gradual improvement in performance and the training-induced significant increased in WM-related activity in the prefrontal cortex. Nevertheless, this change of activity in the brain's related areas is also controversial. For instance, Jaušovec and Jaušovec (2012) agrees that even the amount of five days practicing a five-finger piano exercise may enlarge areas of the brain responsible for finger movements. On the other hand, as Jaušovec and Jaušovec (2012) further explains, when practicing stops, the brain tends to return to its normal size, which was shown by a study where people learned to juggle for 3 months. After training, an increase in size in the mid-temporal area and the left posterior intra-parietal sulcus (areas responsible for visual motion information) was observed. Nonetheless, after 3 months of no practice, these areas returned to their previous size (p. 97).

It goes without saying that, although the WM training and its effects on general cognitive abilities is debatable (see Shipstead, Redick, and Engle, 2012; and Shipstead, Hicks, and Engle, 2012 for reviews); this controversy is no surprise, since the concept of WM training is a relatively recent issue in literature. The largest issue seems to be that, as Shipstead, Hicks, and Engle (2012) agrees, while there is logic to

WM training (increase WM and improve related abilities), this literature is still struggling to find a theory (p. 22). In brief, the main implication that could be drawn from the present study is that, WM training could be used as a remediating intervention for individuals for whom low WM capacity is a limiting factor for academic performance or everyday life.

6.3. Limitations and Further Research

This study is carried out with the students of Hacettepe University School of Foreign Languages Department of Basic English as participants. For that reason, the results are specific to this sample and cannot be generalized for all the language learners in different foreign language learning contexts. Another limitation of the study is that there is no manipulation and randomization of the variables in this study (i.e. gender, language background, anxiety levels of the participants, etc.). For that reason, there might be other factors that might have influenced the WM measure scores or verbal and mathematical achievement scores of the participants. The limitations are expected to be overcome with further research and the suggestions for further research.

This study, therefore, can be carried out again by controlling other variables and taking into account the controversies surrounding the WM, WMC and WM training in literature. WMC, for example, could be measured with various other simple and complex span measures, measuring all or different components of WM (CE, PL, VSSP, EB). Moreover, verbal, mathematical or other academic subject achievements of the students could also be measured with different data collection tools. The participants could also be diversified by working with different age groups, with different language backgrounds; or with different educational backgrounds, etc.

More importantly, the issue of WM training could be further researched. Even though there are opposing views regarding methodology and replicability of findings (Shipstead, Hicks&Engle, 2012); the studies recently carried investigating the effects of WM training and improvement in cognitive areas are promising (Holmes, Gathercole&Dunning, 2009; Klingberg, Forssberg&Westerberg, 2002; Klingberg, et. al., 2005; Westerberg&Klingberg, 2007). In futher studies, experimental studies with a longitudinal training of WM could be implemented, thus by investigating its effects on various cognitive skills and academic success.

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APPENDIX A

The List of Sentences Used in RSPAN

2 SENTENCE SETS

SET 1:

Şoför, camları kırılmış, çatısı uçmuş, terası paramparça olmuş eski bir villanın önünde arabayı okudu.

İki arkadaş oturmuşlar beraberce yemeklerini yemişler, aynı kaptan su içmişler ve hoş bir muhabbet etmişler.

SET 2

Eve gelip de mutfaktaki dolapları karıştırdığında, bulabildiği şey sadece birkaç parça kuru ekmek oldu.

Tam kutusundan çıkarıyordu ki babaannesinin hediye ettiği elmas taşlı kolye birden düşüverdi elinden.

SET 3:

Kadın mutfağa geçti, bardaklardaki huzursuzluğu dağıtmak için hemen neşeli müzikler çalan bir radyoyu açtı.

Genç adam dükkânda koşturup ona buna talimat yağdırırken aslında beklemekte olan müşterileri ihmal ediyordu.

3 SENTENCE SETS

SET 1:

Okuldan eve döndüğünde, her gün yaptığı gibi büyük bir sevinçle televizyon izlemeye koyuldu küçük çanta.

Rüzgâr öylesine hızlı yağıyordu ki, sokaklarda ne sağlam bir direk kalmıştı, ne de arabalarda kırılmadık cam.

Eşinin kendisine hediye ettiği büyük porselen vazoyu masanın üzerine kendi fotoğrafının yanına koydu.

SET 2:

Bal yapabilmek için minik arılar sürekli gezerek milyonlarca çiçekten bitki özü toplamak zorundaydılar.

Küçük çocuk günlerdir beklediği oyuncak ayıyı alınca öyle sevindi ki, birden dedesinin boynuna atlayıverdi.

Akşam yemeğinde sofrada tabağıma lambaları koyarken, bendeki üzüntünün sebebini bir tek yengem anlamıştı.

SET 3:

Yaşlı nine sandığı açtı, gözündeki yaşları sildi ve en üstteki oyalı mendillerden bir tanesini torununa uzattı.

Sabanın erken saatinde tren garına giderken vapurdan arabaya, arabadan vapura binmek beni hayli yormuştu.

Kadıncağız saatine bakıp da hiç zamanının kalmadığını görünce otobüse doğru aceleyle koşmaya başladı.

4 SENTENCE SETS

SET 1:

Elmalar o günden sonra karar vererek, her okul çıkışı bir yerde toplanıp birlikte ders çalışmaya başladılar.

Her yılbaşında ailece toplanır, çanta içinde yemek yer, sohbet eder, gülüp eğlenir, hasret giderirlerdi.

Komşular gidince ortalığı şöyle bir toparlayıp akşamki misafirlere yemek yapmak için mutfağa koşturdu.

Çocukluğunun geçtiği iki katlı evin bahçesine bahar geldiğinde, menekşeler mor mor acar, mis gibi kokarlardı.

SET 2:

Hayatının en karanlık günlerinden birinde kardeşinin hastalık haberini aldı ve hemen hastaneye koştu

Çöp bahçesinde bir başına oturan yaşlı adam, yanına gelen aynı yaşlardaki arkadaşına öfkeyle söyleniyordu.

Öğle yemeğinden sonra bir rehavet çökünce, ufak bir uyku dövüşmek için salondaki eski divana uzanıverdi.

Mahkûm, hücredeki ilk gününde biraz korktuysa da, şimdi yavaş yavaş bu yalnızlığa alışmaya başlıyordu.

SET 3:

Adamcağız ilk defa geldiği bu eski kasabada epeyce gezindikten sonra küçük bir lokantanın önünde durdu.

Genç adam açlıktan ve soğuktan bitkin bir şekilde bankta otururken, kocaman bir araba yanaştı kaldırıma.

Yokuştan aşağı koşar adım esen sert takvim, genç adamın ceketini savuruyor, adeta dengesini bozuyordu.

Annesinin tüm ısrarlarına rağmen gece geç yattığından, sabahları erken bayılmak onun için çok zor oluyordu.

5 SENTENCE SETS

SET 1:

Kırk elli adım uzaklaşmıştı ki, iki kanadın havada çarpışmasından çıkan boğuk bir gürültü gözünde tütüverdi.

Yaşlı çiftçi bulutlara saplanmış küçük çocuğu bir çırpıda çekip çıkardı ve onu acılı bir ölümden kurtardı.

Aydınlanma çağından sonra dünyada çıkan savaşların çoğu, doğal çorapları ele geçirme amacı güdüyordu.

Çocukluğumda o kadar az oyun oynamıştım ki, bu yaşımda bile şaka yapmayı, gülmeyi, eğlenmeyi pek seviyordum.

Sağanak yağmurun altında atını dörtnala süren jokey, omzunun üzerinden rakibine doğru bir keman fırlattı.

SET 2:

Ormanlar kralı yaşlı aslan dinlenmiş ve birkaç gün sonra kendini toparlayıp eski kuvvetine kavuşmuştu.

Akşama doğru eve gelince çantasını açtı ve o an gözlüğünü mağazadaki sevinçlerin üstünde unuttuğunu hatırladı.

Soluk ve yıpranmış giysiler içindeki yaşlı çift, kapıyı çaldılar ve utangaç bir tavırla içeri girdiler.

Bir ay sonra, askerlerin savaşta topladıkları ganimeti tencerenin huzuruna götürecekleri gün gelip çatmıştı.

Cam kenarında oturan yaşlı bebek her gün pencereden bakıyor, dışarıda uğuldayan rüzgârın sesini dinliyordu

SET 3:

Sıcak yaz aylarını geçirmek için uçak kenarlarına kaçanlar şimdi birer birer kışlıklarına dönüyorlar.

Kötü haberi alınca bir koltuğa çökmüş, bütün gün aynı koltukta adeta bir heykel gibi hareketsiz durmuştu.

Ustasının bu sonu gelmez nasihatlerinden sıkılan çırak, artık dayanamadı ve gidip kendine ait bir dükkân açtı.

Yeni görünümüyle ruh sağlığı da iyileşen genç, hem okulda hem sosyal hayatında büyük başarılar yıkadı.

Dünyaca ünlü kravat turnuvayı kazandıktan sonra, alkışlar arasında ödülünü alıp kameralara poz verdi.

6 SENTENCE SETS

SET 1:

Zengin olduğu her halinden belli olan ihtiyar, birkaç adım attıktan sonra kaldırımda bir gökyüzü gördü.

Yaşlı adam çayını yudumlayıp kurabiyesini yerken, bir taraftan da duvardaki eski saate bakıp duruyordu.

Onun bu sözlerinin mavi olduğundan hiç şüphe etmediler ve yaptığı konuşmayı ses çıkarmadan dinlediler.

Şövalye, atıyla kulenin içinden güney surlarına geçti ve dolambaçlı taş merdivenlerde düşmanla karşılaştı.

Profesör, yapacağı konuşmayı önceden hazırlamış ve söyleyeceklerini bir yığın ırmağa teker teker yazmıştı.

Heyecanından yol o kadar uzamaya başlamıştı ki, bitkin kalorifer bir an evini hiç bulamayacağını zannetti.

SET 2:

Genç kız fincanına yeni bir etek doldururken birden karşısındaki sandalyeye asılı çantaya ilişti gözü.

Eldivenlerin kenarında arkadaşlarıyla oynayan çocuk, bir an duraksayarak babasına oltayla ne yaptığı sordu

Öğretmeni, küçük çocuğun diğer çocuklarla oynamadığını ve ders notlarının hep düşük olduğunu gözlemişti.

Biraz ileride, yolun kenarında, iki kedinin koyun koyuna sokulmuş, birlikte uyumakta olduklarını gördüler.

Yaşlı adam emekli ikramiyesiyle göl kıyısında kendine küçük bir ev satın almış, içini dayayıp döşemişti.

Çocuklar o günden sonra ne boş işlerle uğraştılar ne de tüm vakitlerini televizyon izleyerek geçirdiler.

SET 3:

Evde kendisini sığıntı gibi hisseden, artık hiçbir maddi katkısı olmayan balkon, gittikçe içine kapanıyordu.

Kıvırcık sarı saçları, masmavi gözleri ve kalkık burnuyla adeta bir kartpostalı andırıyordu minik bebek.

Öğrenciler, eğitimden sonra yeteneklerinin farkına varıp, kendileri için en doğru mesleğe karar vermişlerdi.

Genç adam hapisten yeni çıkmış olmasaydı, şehirdeki birçok şirkette ona belki bir kartopu verebilirlerdi.

Bütün hafta ziyadesiyle yorulmuş olan adam, tüm Pazar gününü miskinlik yaparak yaralayacağını düşündü.

Mutlu anne, acı dolu geçen onca aydan sonra bebeğinin minik yüzünü görünce sevincinden adeta nutku tutuldu.

APPENDIX B

Mock Exam for Achievement Exam I

USE OF ENGLISH - PART A

Circle the correct alternative.

Teo Stone, 35, and Sally Swan, 20, are both experienced climbers. Sally is Teo's niece. Last weekend, they were on a climbing holiday in Switzerland. They (1) ________ the whole Saturday morning climbing.

1. a) wasted b) spent c) made

In the afternoon, they were very tired and hungry. They needed a break and they (2) _______ a great place to relax. They stayed there for a very long time and when they were 3.000 meters up, there was a terrible storm. They got tired and wanted to sleep. The wind was horrible and the snow was two meters deep. They couldn't move. Teo had his mobile with him so he sent a text message to his friend (3) ________ the center of Switzerland and he asked for help. About four hours later, Teo's friend replied with a text message. He said, 'I can't afford to come there. I don't have (4) _________ money but I called the police.'

2. a) find b) are finding c) found
3. a) on b) in c) off
4. a) much b) some c) many

The police contacted the mountain rescue team. They asked (5) ________ is it to the center?' Immediately, the rescue team prepared the helicopter. They tried to take them off the mountain but the weather was awful so the helicopter couldn't reach the climbers. They sent this text message to (6) _________: 'So sorry. We tried. Wind is too strong. It's two hours walk. Have to wait till morning. Take care. Be strong'.

5. a) How far b) How much c) How long
6. a) their b) theirs c) them

Next morning, the storm (7) _________. The helicopter arrived at the mountain to rescue them. One of the men in the rescue team asked, 'Have you ever experienced something like this before? They could only say 'NO' because they were very hungry and looking forward to having something (8) _________ dinner.

7. a) is going to pass b) passed c) is passing

8. a) in b) on c) for

Later, in the interview, Teo said to the reporters, we were not afraid (9) _________ we knew the rescue team was the best. We were too cold – freezing -15◦C – and we felt bad. We spent the night eating (10) ________ chocolate biscuits and planning a holiday in the sun'.

9. a) because b) so c) but

10. a) a lot b) some c) any

PART B

Fill in the blanks with only ONE WORD. Don't use 'not' and 'contractions' (eg. they're, it's …).

Tony always gives (0) ___his___ wife roses on her birthday.
It (1) _______ her birthday today and Tony is in a flower-shop.
Shop Assistant: How can I (2) ________ you?
Tony: I (3) _______ like some roses for my wife, please.
Shop Assistant: These pink roses (4) _________ beautiful, sir.
Tony: No, no. I prefer red roses.They are (5) ________ than the pink ones.
Shop Assistant: But they are much (6) _________ expensive.
Tony: It doesn't matter.
Shop Assistant: All right. How many roses do you want?
Tony: Eleven,please. How much do they cost ?
Shop Assistant: £10.
Tony: Oh, no! I don't have (7) _________ money with me. I think I left it all at home in the morning.
Shop Assistant: Never mind! You (8) _________ give it later, sir.
Tony: Thanks a lot, but (9) _________ there a bank near here? I'd like (10) ________ pay right now.
Shop Assistant: Well, there is one (11) _________ to the supermarket.
Tony: OK. Thank you very much, see you.
Shop Assistant: Good bye,sir.

PART C

Read the conversation below. Choose the best word(s) or phrases from the box below, and write down the letter in the blank. Use each of them once. There are three extras in the box. The first one is an example.

A: Sorry Jane, I'm late.
B: That's OK. _____E______(1)
A: Where are we going to go?
B: _____________(2) you saw a film in the cinema?
A: Three months ago.
B: ____________ (3) the cinema then
A: What's on?
B: There's a romantic Italian film.
A: Really? I love romantic films. ___________(4) you?

Do you like romantic films?
B: Quite a lot. I __________ (5) see it.
A: How can we get to the cinema?
B: ___________ bus.(6)
A: It's 14:00 now. __________ (7) does the film start?
B: At 14:30.
A: All right. Come on. ____________(8)

A. how often B. what about C. with D. it's time to go E. don't worry F. would like to G. when was the last time H. by I. like J. let's go to K. what time

READING

TEXT I

Part A: Read the text and put the paragraph headings in the correct place.

There is one extra.

A. What is dyslexia?
B. Typical problems for children with dyslexia at school
C. How to help people with dyslexia
D. What some talented people had in common
E. Other famous people who had dyslexia
F. A person who had hidden talents

HIDDEN TALENTS

1. ____

They often didn't learn to read and write until they were older. Their parents often thought they were stupid and their friends laughed at them. Some of them hated their schooldays and decided to drop out of school as soon as possible. In short, they wanted to leave it early because they needed to get rid of the tension.

2. ____

Some of the world's greatest composers, writers and inventors had an unpleasant time at school like this. Later, when they became successful, nobody was more amazed than their old classmates. Were these people stupid? No, of course not! Some people believe that they shared something similar – dyslexia.

3. ____

Dyslexia is a learning disability which means that people have problems with reading and remembering written words. It is often difficult for them to memorize things. Studies show that people with dyslexia use a different part of their brain to read and remember. Experts think that the cause of dyslexia is genetic: probably somebody else in the family also had dyslexia. Statistically, about 15 percent of people are dyslexic, but not everybody who has dyslexia knows about it.

4. ____

Some people with dyslexia discover they have extraordinary, hidden talents, but only when they are older. A good example is Agatha Christie, one of the most successful writers in history – two billion books published in 44 languages! At school she had problems with writing and often got bad marks for essays. Her parents were discontented with this situation. Her parents' not being pleased with the poor results in the school made Agatha leave school early. She only started writing because her older sister said she couldn't do it! And even when she was already a famous writer, she sometimes felt embarrassed because she still couldn't spell.

5. ____

There are many more examples of people like Agatha: Christian Andersen, Albert Einstein, Leonardo da Vinci, Pablo Picasso and Thomas Edison; important and creative people who had problems with reading and writing when they were young. Of course, that doesn't mean that everybody with dyslexia is a genius who is known as a brilliant person. However, it shows that sometimes people can be a lot more intelligent than they seem.

Part B: Choose the correct answer

The passage is mainly about _________________.

a) different talents

b) a learning disability

c) the life of creative people

d) functions of our brain

Part C: Find the words in the text which mean the following.

1) leave (paragraph 1) __________________

2) not pleased, unhappy (paragraph 4) __________________

3) very clever person (paragraph 5) __________________

Part D:

1. 'it' in paragraph 3 refers to: _______________

Part E: *Are the sentences True or False? Circle the correct answer. Do not correct the false sentences.*

1. Their success worried the friends of some famous writers, composers and inventors. T / F
2. People with dyslexia were probably born with the disability. T / F
3. Special and hidden talents of dyslexic people are discovered at their early ages.T/F
4. Agatha Christie started writing because she wanted to show her parents that she could write. T / F

Part F: Answer the questions

1. Why didn't dyslexic people like their school?

2. What is the cause of dyslexia according to the experts?

TEXT II

WAS FRED FLINTSTONE A VEGETERIAN?

Some anthropologists now think that for millions of years man's diet was more than 80 percent vegetarian. Alan Vega investigates…

Twenty-four million years ago, when our ancestors lived in the tropical forests of central Africa, they ate plants and fruit, and from time to time a few insects. When these prehistoric people started to travel north into the desert and couldn't find enough food, their diet changed and they began to eat a lot of seeds and other plant material. And this is how man lived for the next twenty-two million years, eating roots, seeds, fruit, nuts, vegetables and occasionally a little meat.

How do we know? One important clue is our teeth. Just like animals which eat plants, humans have teeth called molars (these are the large flat teeth at the back of our mouths) which we need to break down hard food such as seeds. Archeologists can also tell us about diets of the past. In fact, we know a lot about the human diet over the last 7.000 years.

The Aztecs and Incas ate a lot of cereals, beans and fruit and not much meat at all. In classical India most people didn't eat meat and the Japanese were mainly vegetarian until a few years ago. The main food of the slaves who built the Pyramids was boiled onions! Even today, some societies whose lifestyles are unchanged (like the Aborigines of Western Australia) are still mostly vegetarian.

During the nineteenth century people in western countries suddenly began to eat a lot more meat. New methods of keeping and killing animals, better transport and new inventions like fridges and freezers helped to reduce the price of meat for ordinary people. It was probably at this time that the typical western meal that millions of people eat every day - meat, potatoes and vegetables – was born.

Also during the nineteenth century, the vegetarian movement started in Europe and the USA. But it was only in the 1960s that more and more people in the west resolved to give up meat in their diets. So why do people choose to be vegetarian? Many people decide to become vegetarian for personal reasons. First of all, some people think that it is healthier not to eat meat. Others believe that it is barbarous to eat animals. For instance, the Irish writer George Bernard Shaw also found it cruel and once said, 'Animals are my friends - and I don't eat my friends. Imagine having your friend as a hamburger for lunch.' Finally there are some people who think that growing food for cows and pigs to eat is not very economical. Today vegetarianism is more and more popular in Europe and the USA. But in most countries people who never eat meat are still a very small minority.

A) Circle the best answer according to the text. (1.5x6=9 pts.)

1. When our ancestors changed locations, they ______________.

   a) lived longer than others
   b) changed their foods
   c) found enough plants and fruit
   d) hunted for animals to eat

2. We know that people in the past were mostly vegetarians because ________.
   a) their teeth were like animals' teeth that eat plants
   b) it was very difficult to eat hard foods such as seeds
   c) 7.000 years ago it was against the rules to eat meat
   d) It was easier to find plants to eat

3. The Japanese ___________________________________.
   a) were not very interested in vegetables
   b) had always eaten boiled onions
   c) have started eating meat only recently
   d) still eat only vegetables

4. Ordinary people started to eat more meat in the 19th century because ______.

   a) it was cheaper than the past
   b) they thought it was healthier
   c) they found new methods to cook meat
   d) it tastes good with potatoes and vegetables

5. Which of the following is NOT a reason to become a vegetarian?

   a) personal reasons
   b) health issues
   c) economical reasons
   d) being popular

6. Vegetarianism today _________________________.

a) is more economical than it was before
b) makes people who eat cows and pigs annoyed
c) is becoming more common in Europe and the USA
d) means eating very small amount of meat

B) Circle the best answer according to the text. (0.75x2=1.5pts.)

1. The word "resolved" in paragraph 5, means ____________.
a) decided b) forgot c) hated d) changed

2. The word "cruel" in paragraph 5, means ____________.
a) easy b) typical c) unkind d) difficult

ANSWER KEY FOR MOCK EXAM I

USE OF ENGLISH

Part A

1. b 2. c 3. b 4. a 5. a 6. c 7. b 8. c 9. a 10. b

Part B

1.is 2.help 3.would 4.are 5.beter 6.more
7.any 8.can 9.is 10.to 11.next

Part C

1. E 2. G 3. J 4. B 5. F 6. H
7. K 8. D

READING - TEXT I

Part A

1. B 2. D 3. A 4. F 5. E

Part B

b) a learning disability

Part C

1. drop out of 2. Discontented 3. genius

Part D

1. dyslexia / that they are dyslexic

Part E

1. F 2. T 3. F 4. F

Part F

1. Because they were not successful / their parents thought they were stupid / their friends laughed at them
2. It is genetic

TEXT II

Part A

1. b 2. A 3. C 4. A 5. D 6. c

Part B

1. a 2. C

APPENDIX C

Mock Exam for Achievement Exam II

USE OF ENGLISH - PART I

A) Read the text and circle the best answer.

J.K. Rowling, ____________(1) is the writer of the Harry Potter series, was born___________(2) July 31st 1965. She has sold 103 million books in print. Her publisher did not want the readers to know she was a woman. He thought boys would not want to read books written by a woman. ___________(3) she has no middle name, she added K for Kathleen to her name and she writes under the pen-name "J.K. Rowling". Kathleen was her grandmother's name. She loved her grandmother very much. Her grandmother always tried to make her happy.

1.	a) who	b) where	c) which	d) what
2.	a) in	b) of	c) at	d) on
3.	a) Although	b) So	c) But	d) Then

J.K. Rowling has a very interesting life with many ups and downs. Her success did not come very easily. In 1990, she ____________(4) from the University of Exeter. She could not find a good job. She had to work as a secretary during the day and _____________(5) night she wrote stories. It was difficult because she was mostly very tired, but she wrote anyway because it made her relaxed and happy.

4. a) has graduated b) was graduating
   c) graduate d) graduated
5. a) in b) on c) at d) for

One day, something changed her life completely. When she ______________(6) by train, she met her boy-friend from university. They talked _____________(7) the past. He asked her if she still wrote stories and she said "YES". She did not know that he was a succesful publisher in England. "Look! I have a great idea! Work for me! You __________ (8) be rich when you start publishing your stories." he said and she accepted. This was the beginning of her successful career.

6. a) has travelled b) was travelling
   c) travels d) is going to travel
7. a) from b) about c) to d) of
8. a) don't b) won't c) will d) can't

B) Fill in the blanks with only ONE WORD. Don't use 'not' and 'contractions' (eg. they're, it's …). Be careful with the correct use of negatives and questions, correct tense and pay attention to subject verb agreement and spelling.

Student Environmental Projects

Twenty-one students from Cumberland High School, 200 km west of Southampton, started __________(1) take part in some landcare projects at the beginning of 2005 semester, and they have won the Environmental Project Award twice.
In their last project, the students researched several environmental problems in their local area and thought __________ (2) ways to solve the problems. They _________(3) a long time discussing the environmental issues with their teachers. After a long discussion, the students decided on one project. They decided ________(4) grow vegetables without chemicals at a garden __________(5) is very cloze to school. Next year they are __________(6) to plant winter vegetables and sell them to the local community. The school will use the money for other environmental projects in the local area.
'We still have to think what to do with the money we ________(7) from selling the vegetables,' said Peter Smith, one of the students involved in the project. 'We want to spend _________(8) very carefully. We'll certainly need ________(9) money to prepare posters and inform the community about our activities. We can all do something – recycle newspapers, save water or energy. When we do our part of the work _________(10),we can all help to save our planet.'

USE OF ENGLISH - PART II

Two friends, Emma and Mary, are speaking on the phone. Read their conversation below and complete it with the expressions in the box. Use each one only once. There are two extras.

Mary: Hello!
Emma: Hello! Is that Mary Jason ?
Mary: Speaking.
Emma: Hi Mary . It's Emma. How are you ?
Mary: Not bad, (1) _______________?
Emma: Fine. (2) ______________? Shall we do something together ?
Mary: (3) ______________. I have some guests in the evening and I have to go shopping and cook something.(4) ___________?
Emma: Sorry, I'm busy this evening. Maybe another time.
Mary: Emma! You don't know anybody here. You should come Melissa Brown is coming too. She is the most important person in this town and she can help you to find a job.
Emma: (5) _____________. When you know somebody important it is easier to get a job. What's she like?
Mary: Well, I think she's great, very friendly.
Emma: Ok then I'll come to meet her. Is there anything I can do for you for the evening?
Mary: Oh, actually yes! Can you please do some shopping?

Emma: Yes, of course but we have a problem. I don't know anything about the supermarkets here. I only know Wegmen's.
Mary: Wegmen's ? (6)__________________ .
Emma: Why?
Mary: It is too expensive and (7) _________________ is the shop assistants. They are so unkind. Can you go to Shaw's?
Emma: Sure. How can I go there?
Mary: Er.. Let me think. (8) ________________?
Emma: Yes, twice.
Mary: Then you can find your way easily. Shaw's is very close to it.
Emma: That's OK. I remember it. What do you need? Give me the shopping list……

A. Would you like to join us
B. What are you doing this afternoon
C. I think that's true
D. and you?
E. I'd love to but I can't
F. the worst thing about it
G. How is she
H. It is a horrible place to shop
I. Have you ever been to Harrold's Bookstore
J. Where is it

READING I

MARIA PREPARES TO CELEBRATE HER 110th BIRTHDAY

Maria Pettigrew says the odd drop of sherry in the evening has helped her live so long.

Scotland's oldest woman, who has lived in three centuries, is today celebrating her 110th birthday. Maria Pettigrew explains that her recipe for a long life is a simple diet, not smoking and the odd drop of sherry in the evenings.

Her friends and family have been preparing a special party for her at the hospital where she lives. She wants to look good for her birthday and she has been putting together a special outfit for the occasion. Speaking from the hospital, she said: 'My nurse has taken me out shopping a couple of times, once to buy shoes and once to order a new wedding ring, because this one is getting too big for me'.

Maria was born one of four children in Liberton, Edinburgh, to policeman Andrew Scougall and mother Helen. She left school at fourteen to work on her family farm to support her family, where she met the two loves of her life. At nineteen, she married one of them, farm worker William Mc Cardle. Her secret admirer, Tom Pettigrew, was heartbroken and he left for Australia to set up a new business.

Shortly after the First World War, William died of an asthma attack. Maria brought up their three children on her own until thirteen years later when Tom returned from Melbourne. He confessed his secret love to Maria and the couple were married for 42 years.

Maria says: ‘I’ve only had two boyfriends and they were both decent men. Two happy marriages, and three children - what more could a woman ask for?’

Maria keeps in good health, although her eyesight is beginning to fail. She lived in her own home, doing her own cooking and housework until five years ago, when she moved to the hospital.

Maria was born before telephones, televisions and washing machines. Of all the changes she has lived through she says that ‘the most extraordinary thing I ever saw was a motor car. I had never seen one before. I was so shocked I fell in a ditch.’

Maria has six grandchildren and fourteen great-grandchildren and they have all been helping with the preparations for the party. Maria is sure she will enjoy sharing her birthday cake with her children, grandchildren and the rest of her family and friends today. Though no doubt they’ll have to help her blow out all those candles.

Read the article and circle the correct answer. Do not correct the false ones.

1. Maria has bought a new wedding ring because she has lost her old one.
   a. True   b. False   c. Doesn’t Say
2. When she was a teenager, she had to work to help her parents.
   a. True   b. False   c. Doesn’t Say
3. Her first husband died in the war.
   a. True   b. False   c. Doesn’t Say
4. Tom Pettigrew’s marriage to Maria was his first one.
   a. True   b. False   c. Doesn’t Say
5. She had no children from her second husband.
   a. True   b. False   c. Doesn’t Say
6. She still cooks for herself.
   a. True   b. False   c. Doesn’t Say
7. The invention which surprised her the most was a motor car.
   a. True   b. False   c. Doesn’t Say
8. Her children and grandchildren have bought her a surprise present for her birthday.
   a. True   b. False   c. Doesn’t Say

READING II

BRAIN, THE SLEEPING GIANT

A. Read the paragraphs and put them in order. Number them 1-4.

A._____ Another example is a young man called Dario Donatelli. He recently graduated from a university in Pittsburgh, where he specialized in techniques for remembering numbers. He describes himself as quite normal, stating, ‘My memory is just like anyone else’s. There are probably hundreds of thousands of people whose memories could work more precipitately than mine if they had the same interest in numbers as I have.’ He has become one of the greatest memorizers of all time, and has broken the world record for memorizing the largest amount of numbers. He recently memorized a number of seventy-three numerals (numbers). When asked how he did this, he replied, ‘I group the numbers into pairs, or threes or fours, and I link them with something I am familiar with, for example, my brother’s age, a date of birth, a month of the year, etc.’ He can now remember almost 100 numbers at any other time.

B. _____ Your brain is like a sleeping giant. During recent years, research has shown that the brain is much more intelligent than we ever imagined. Even the commonly-heard statement that, on average, we use only one percent of our brain may well be wrong. It now seems that we use even less than one percent, which means that the rest of it, a colossal amount of our brain can still be developed. It is still impossible for people to know what the human brain is capable of doing.

C. ____ However, realistically, could we all do the same? The important thing to remember is that our brain actually improves with time and practice. If we force our brain to learn, if we do things to make it work more, then we will be triumphant. So, perhaps the best advice to achieve good results from our brain might be to take a trip to the local library or bookshop, buy a book about something that has always interested us but which we know very little about, remember to read it regularly and see how quickly we can teach our minds to learn something completely new and different. We may be surprised by what we can accomplish.

D. _____ A good example of what the brain is capable of is a man called Smith. He was famous for having a perfect memory. If you asked him what happened to him on a particular day fifteen years before, he could tell you but would pause for a moment and then ask, ‘At what time?’ His extraordinary ability was studied for many years by a psychologist who finally concluded that, at a very early age, Smith’s brain had the power to remember every detail about his life. Apart from that, Smith was like any other human being.

B. Circle the best answer according to the text.

1. The human brain __________.
   a) and its limits are still unknown to people
   b) cannot develop by sleeping a lot
   c) makes it impossible to work at full capacity
   d) can only be used one percent on average

2. Smith __________.
   a) had physical powers different from others
   b) was known for his great memory
   c) had a life-changing experience when he was young
   d) studied with scientists to discover his own ability

3. Dario Donatelli _________.
   a) broke a record for his ability to memorize
   b) describes his memory as different from others
   c) can memorize three groups of numbers
   d) is interested in the memories of other people

4. To improve our brain we need __________.
   a) young brain   b) good genes
   c) a lot of practice   d) the best advice

5. We can train our minds by __________.
   a) going on trips to different countries
   b) getting the best advice from friends
   c) learning new things by reading
   d) remembering frequently about the past

6. "colossal", in paragraph B, means __________.
   a) large   b) equal   c) moderate   d) tiny
7. "more precipitately", in paragraph A, means a lot __________.
   a) faster   b) quieter   c) later   d) relaxing
8. "triumphant", in paragraph C, means__________.
   a) easy going   b) successful   c) interesting   d) introvert

ANSWER KEY FOR MOCK EXAM II

USE OF ENGLISH

PART I

A.

1.	a	2.	d	3.	a	4.	d	5.	c	6.	b
7.	b	8.	c								

B.

1. to	2. of / about	3. spent	4. to	5. which / that
6. going	7. earn / get	8. it	9. some / more	10. well

PART II

1.	D	2.	B	3.	E	4.	A	5.	C	6.	H
7.	F	8.	I								

READING I

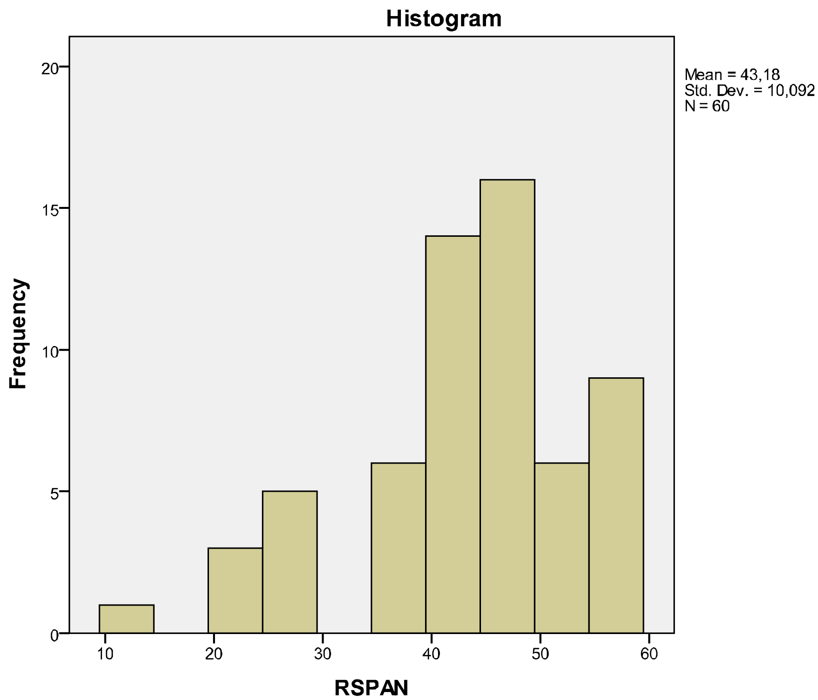
1.	b	2.	a	3.	b	4.	c	5.	a	6.	b
7.	a	8.	c								

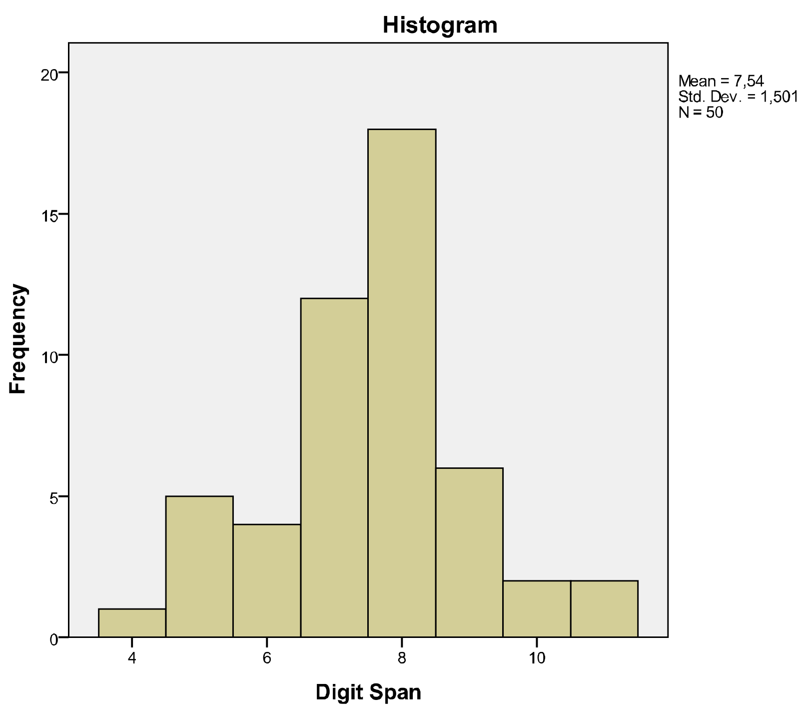
READING II

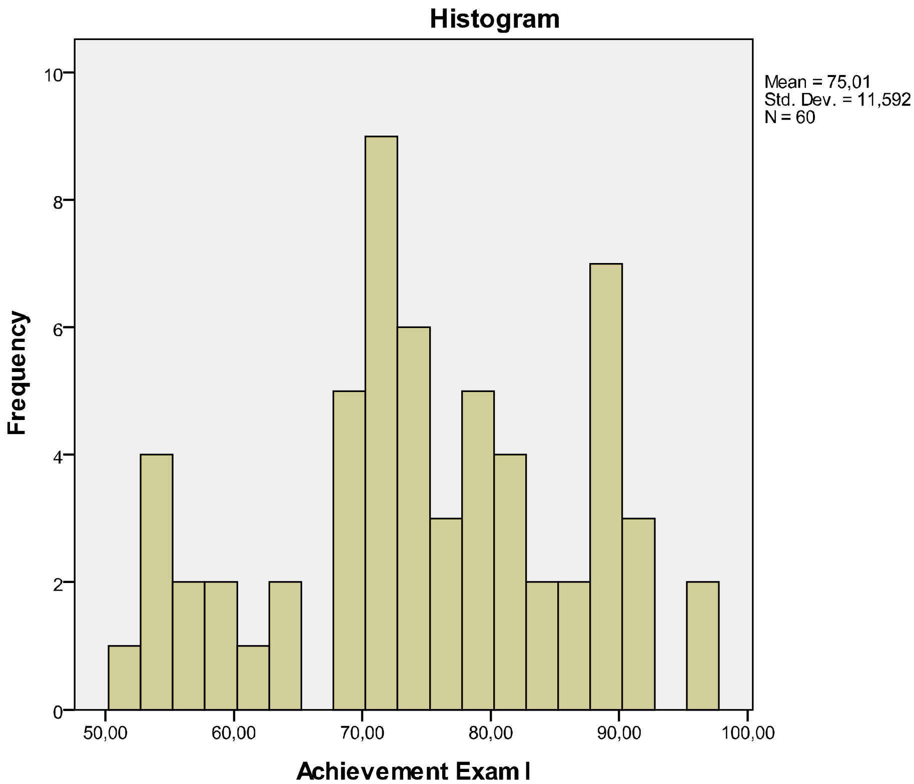
A. 3	1. a	6. a
B. 1	2. b	7. a
C. 4	3. a	8. b
D. 2	4. c	
	5. c	

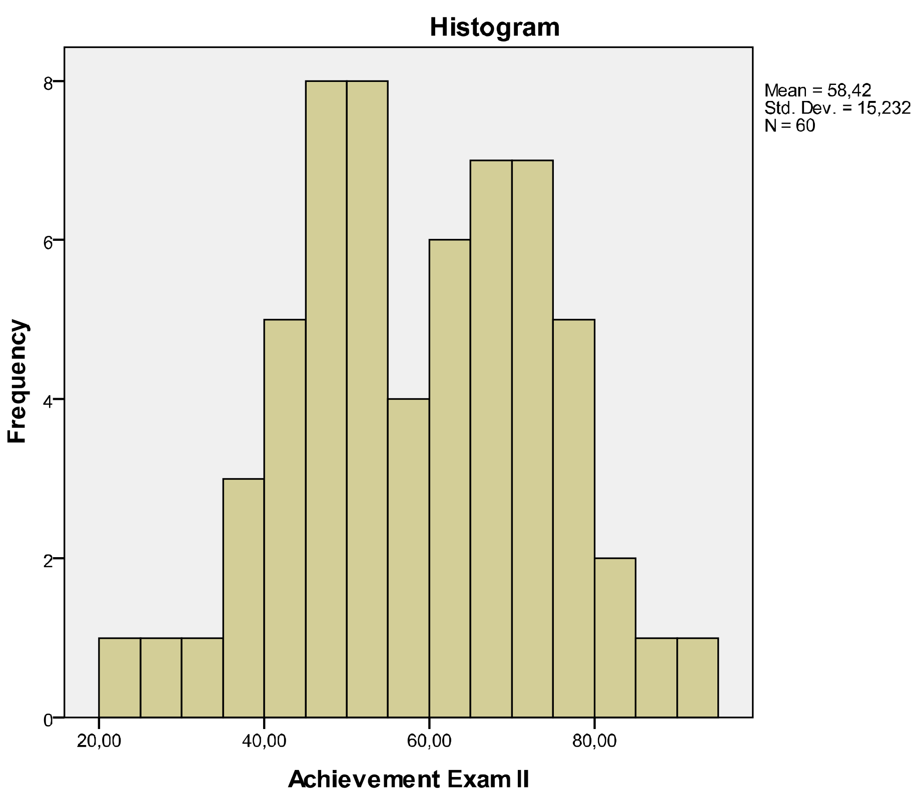
APPENDIX D

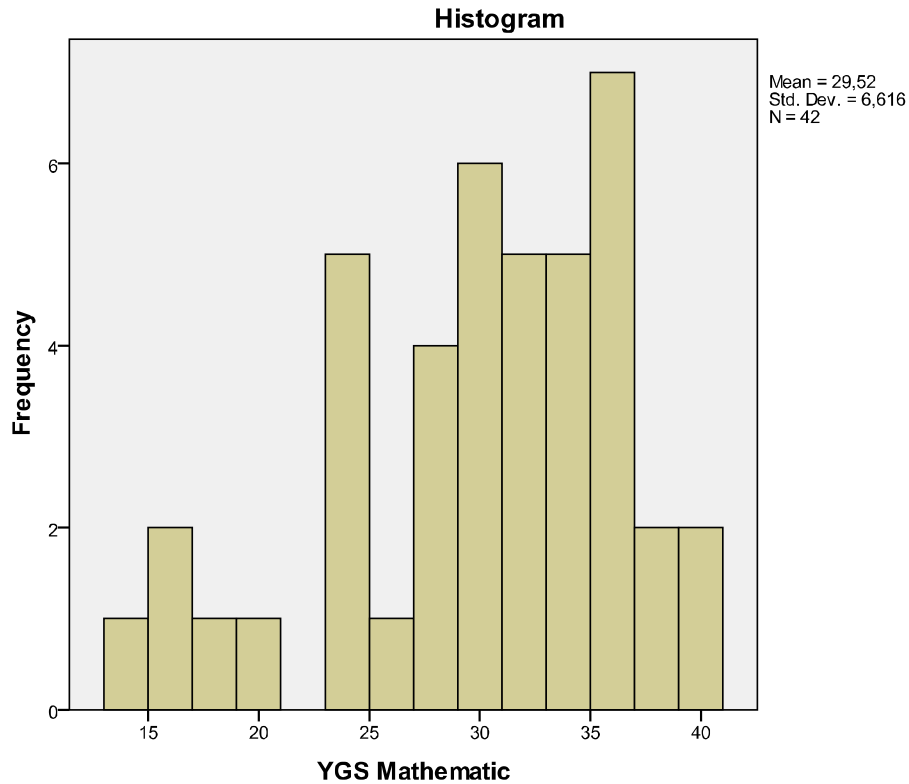
Histograms, Normal and Detrended Normal Q-Q plots

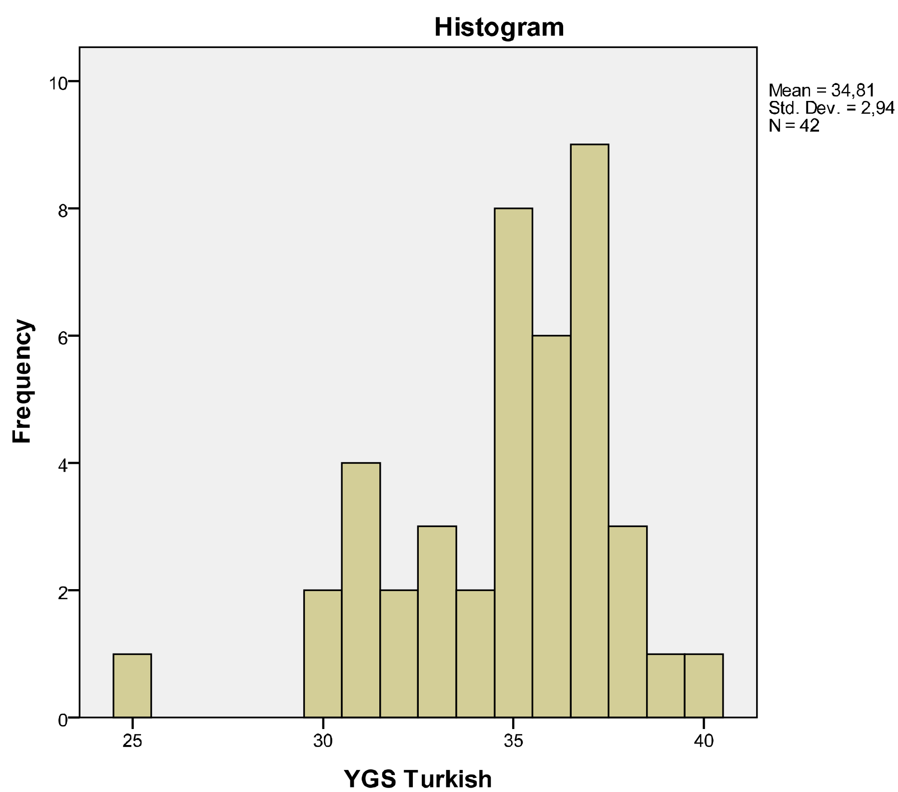


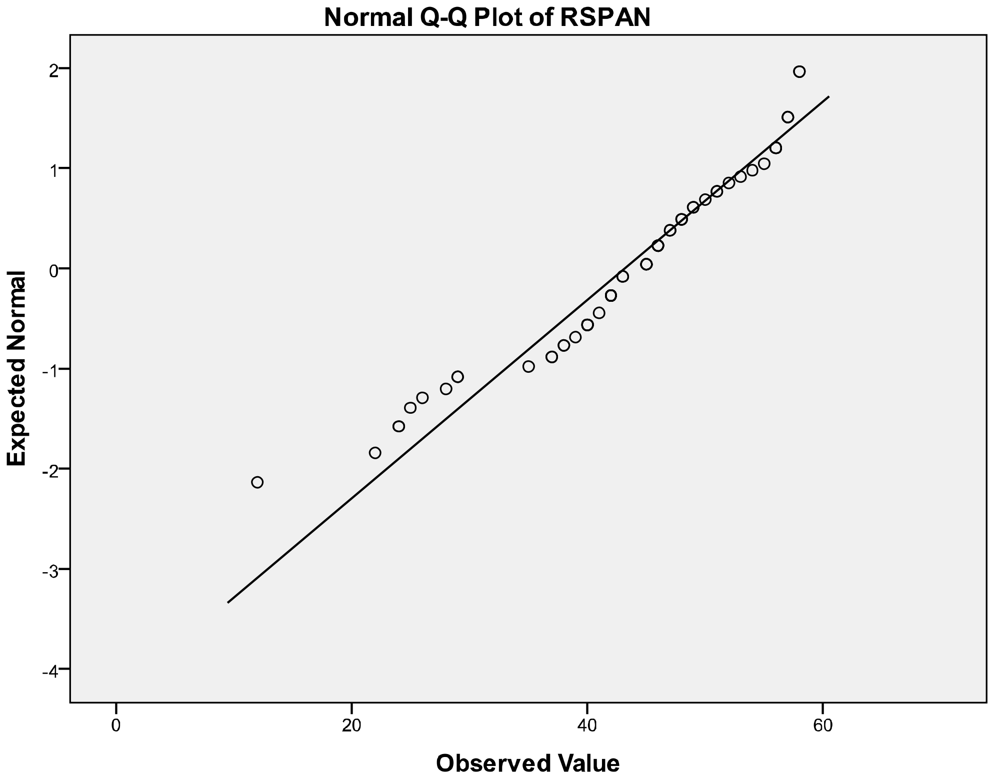


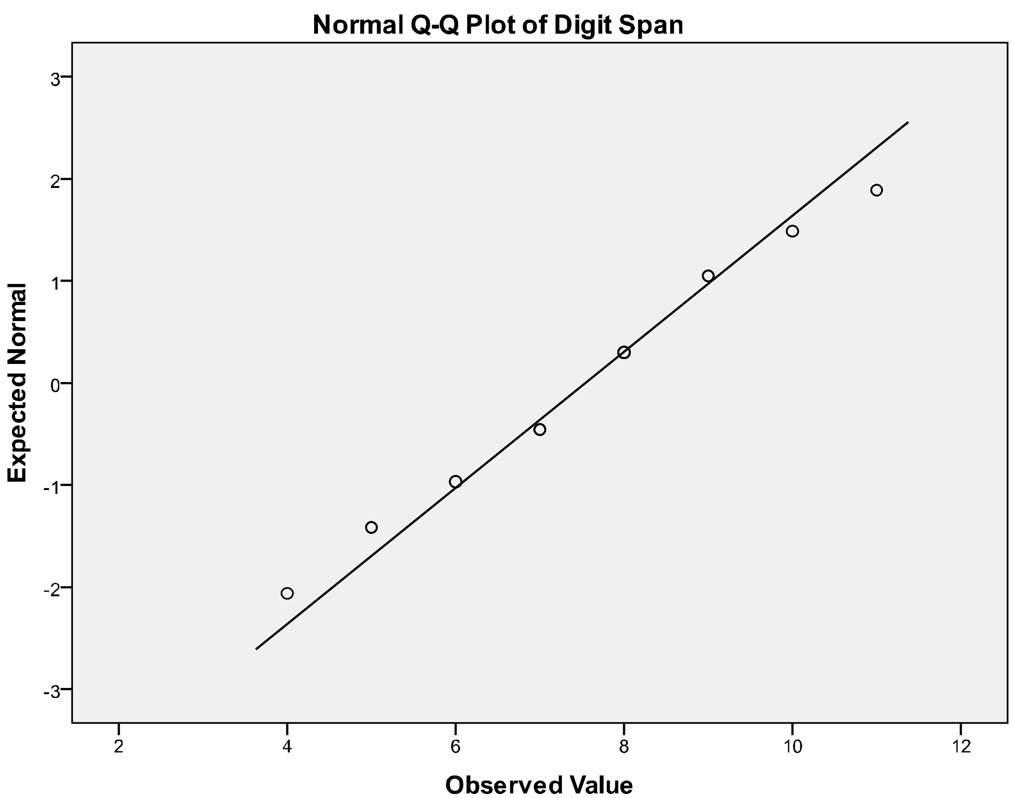

Histogram
Mean = 75,01
Std. Dev. = 11,592
N = 60
Frequency
0
2
4
6
8
10
50,00
60,00
70,00
80,00
90,00
100,00
Achievement Exam I

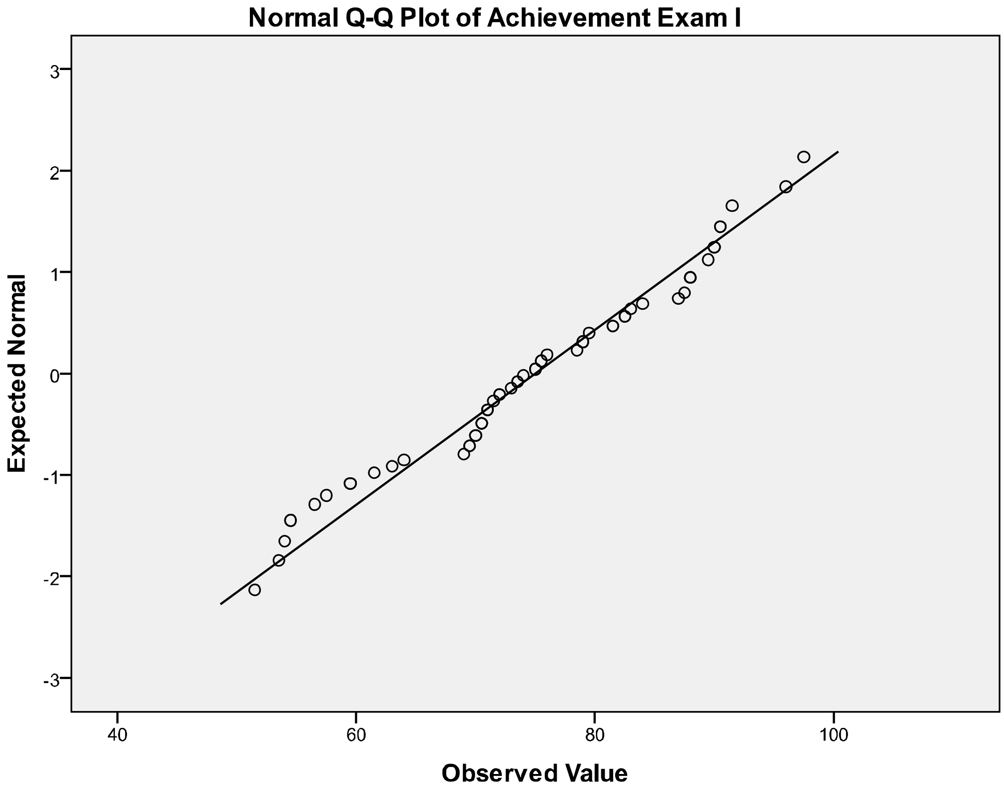

Histogram
Mean = 58,42
Std. Dev. = 15,232
N = 60
Frequency
0
2
4
6
8
20,00
40,00
60,00
80,00
Achievement Exam II

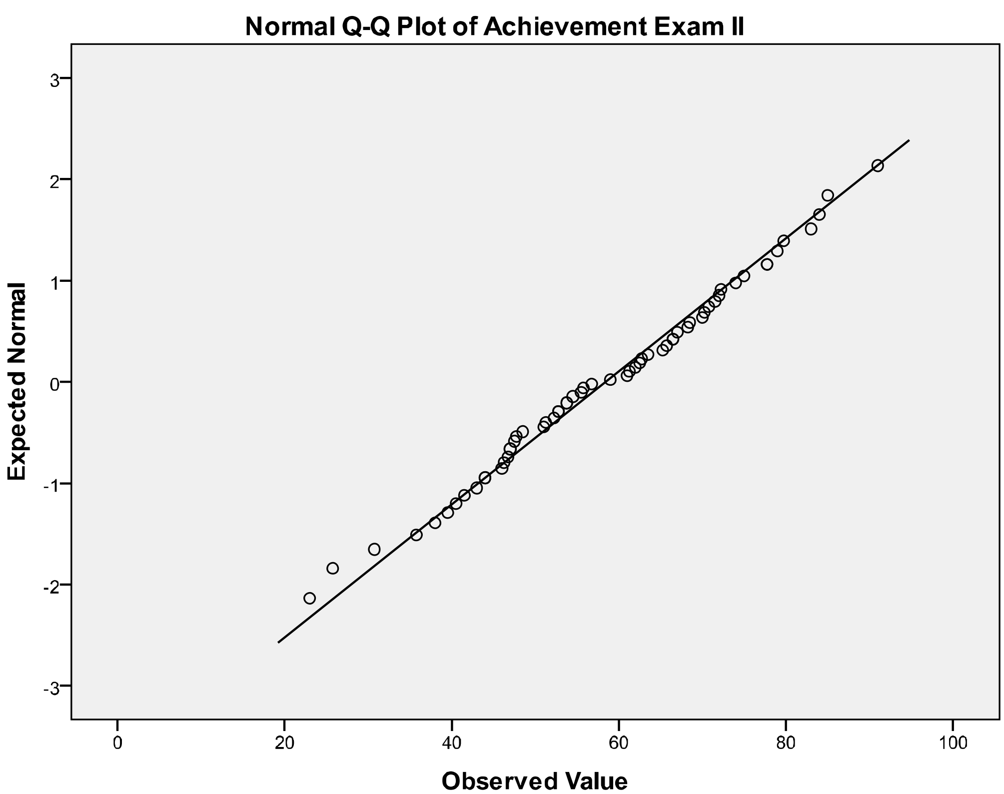

Histogram
Mean = 29,52
Std. Dev. = 6,616
N = 42
Frequency
0
2
4
6
15
20
25
30
35
40
YGS Mathematic

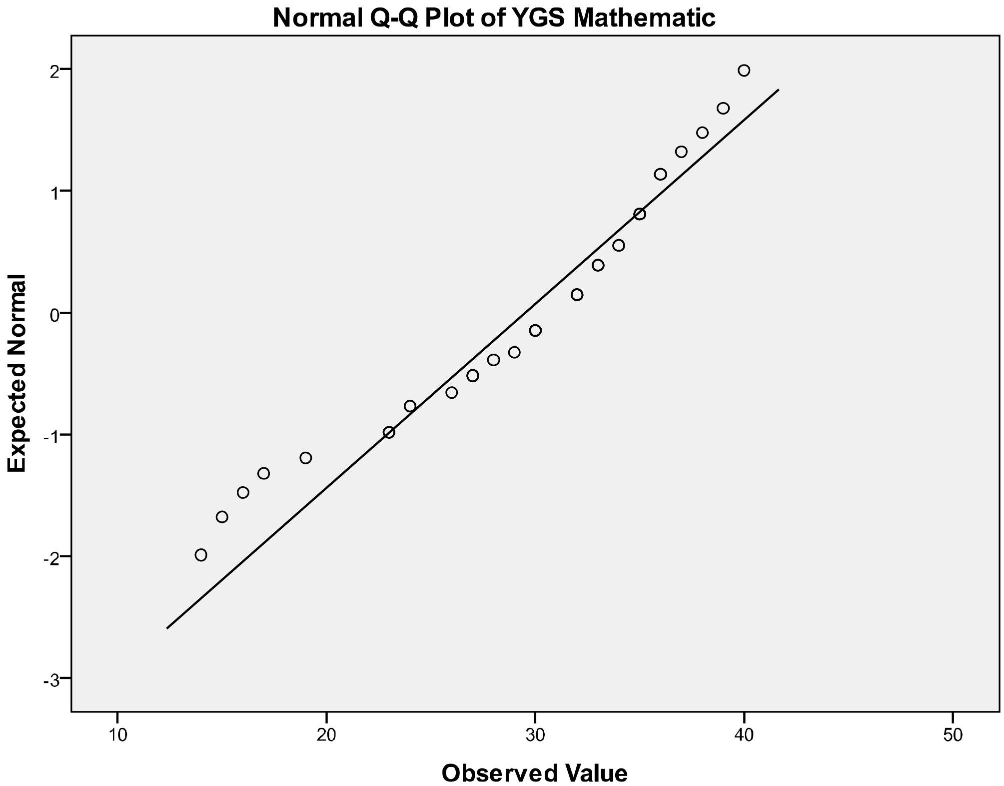

Histogram
Mean = 34,81
Std. Dev. = 2,94
N = 42
Frequency
0
2
4
6
8
10
25
30
35
40
YGS Turkish

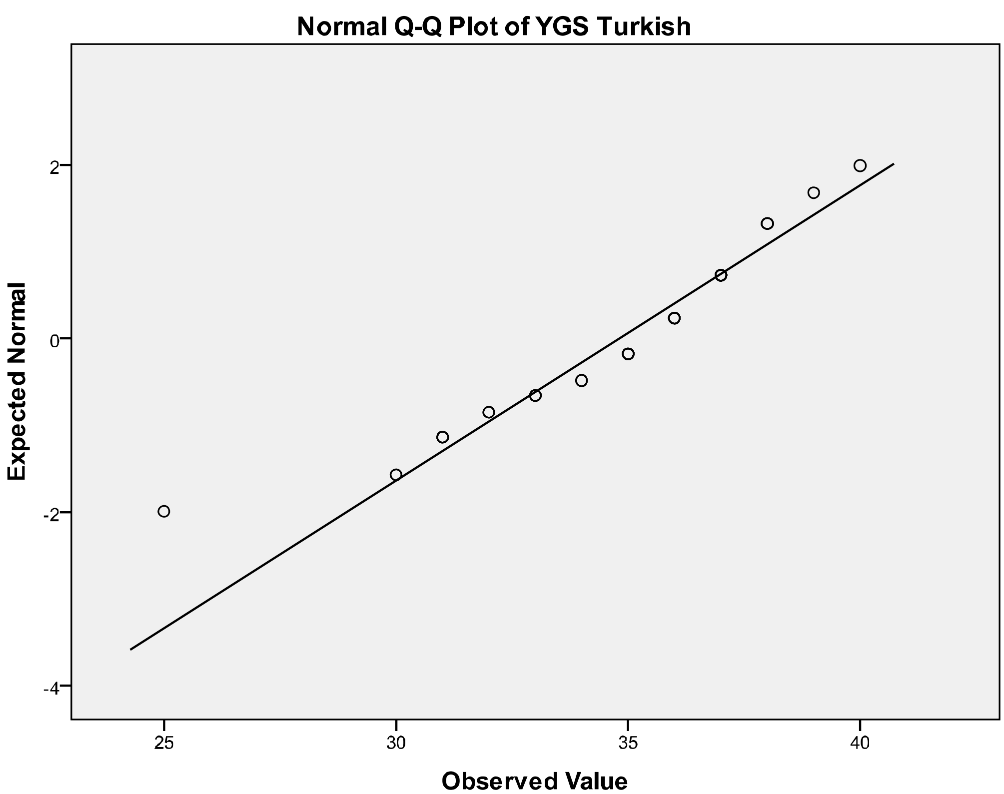

Normal Q-Q Plot of RSPAN
Expected Normal
Observed Value
2
1
0
-1
-2
-3
-4
0
20
40
60

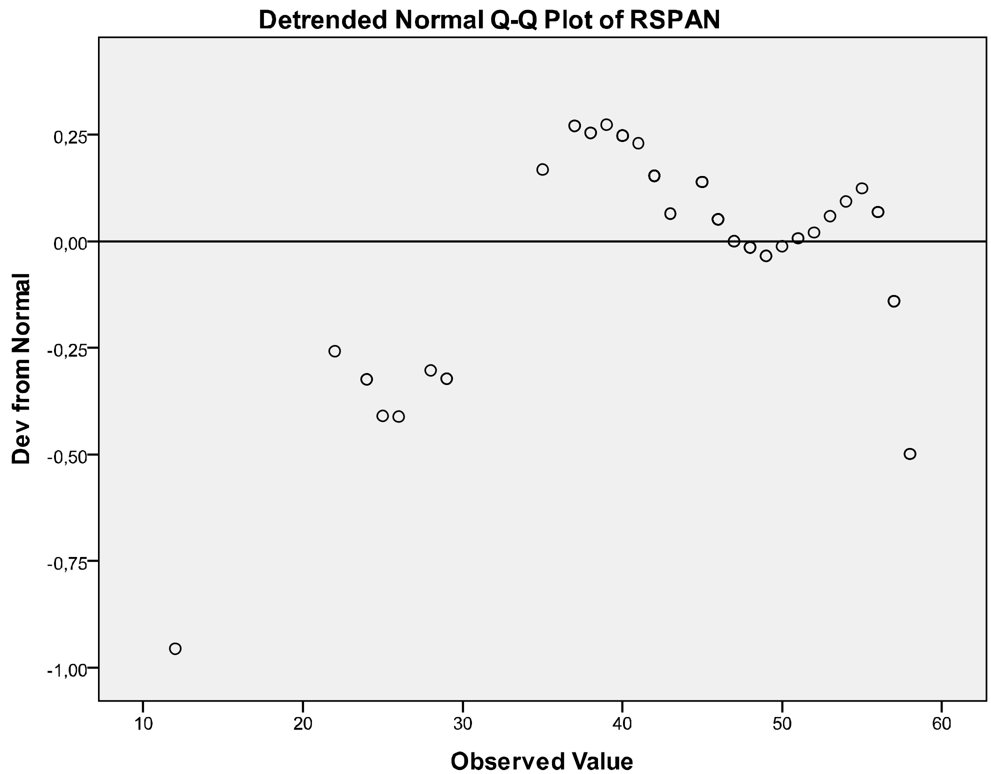

Normal Q-Q Plot of Digit Span
Expected Normal
Observed Value
3
2
1
0
-1
-2
-3
2
4
6
8
10
12

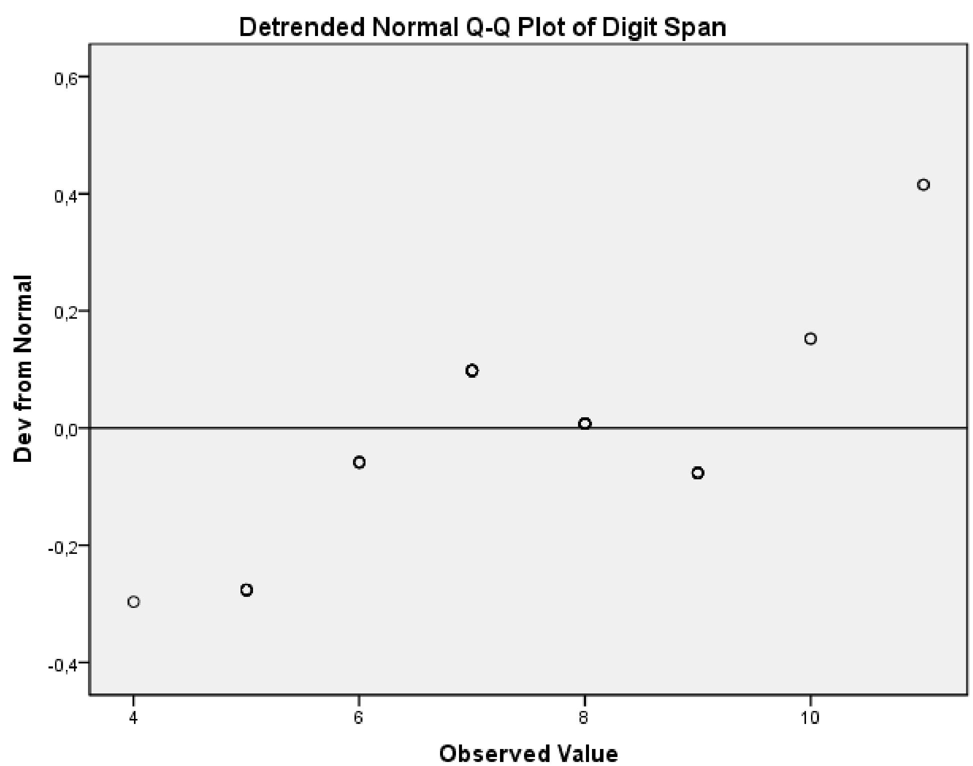

Normal Q-Q Plot of Achievement Exam I
Expected Normal
Observed Value
3
2
1
0
-1
-2
-3
40
60
80
100


Normal Q-Q Plot of Achievement Exam II
Expected Normal
Observed Value
3
2
1
0
-1
-2
-3
0
20
40
60
80
100

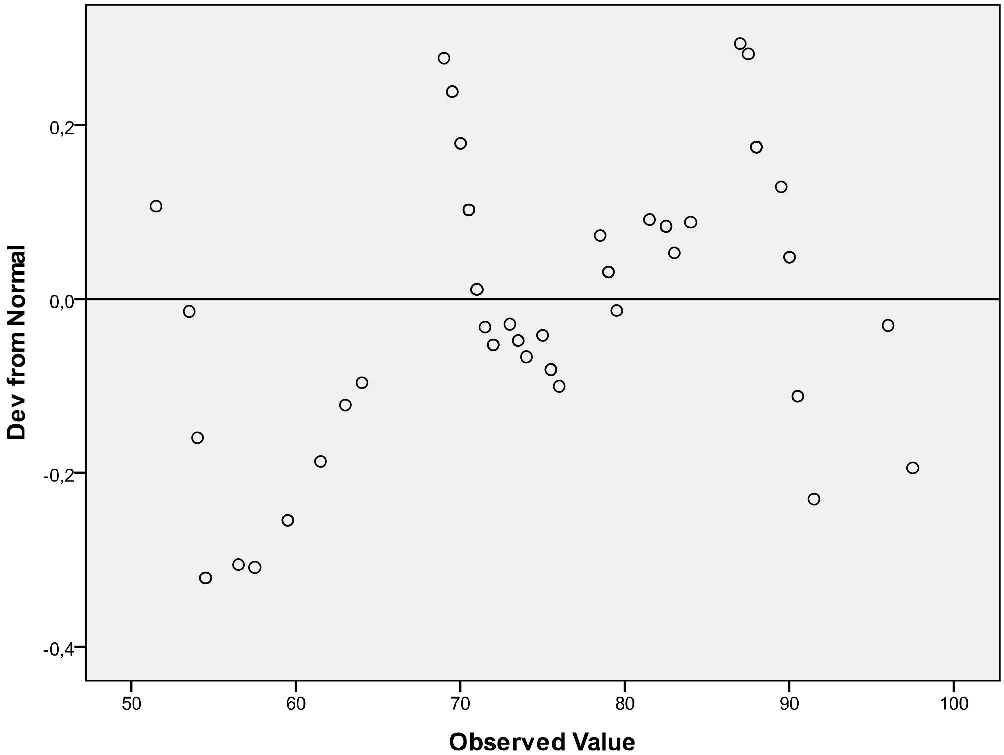

Normal Q-Q Plot of YGS Mathematic
Expected Normal
Observed Value
2
1
0
-1
-2
-3
10
20
30
40
50


Normal Q-Q Plot of YGS Turkish
Expected Normal
Observed Value
2
0
-2
-4
25
30
35
40

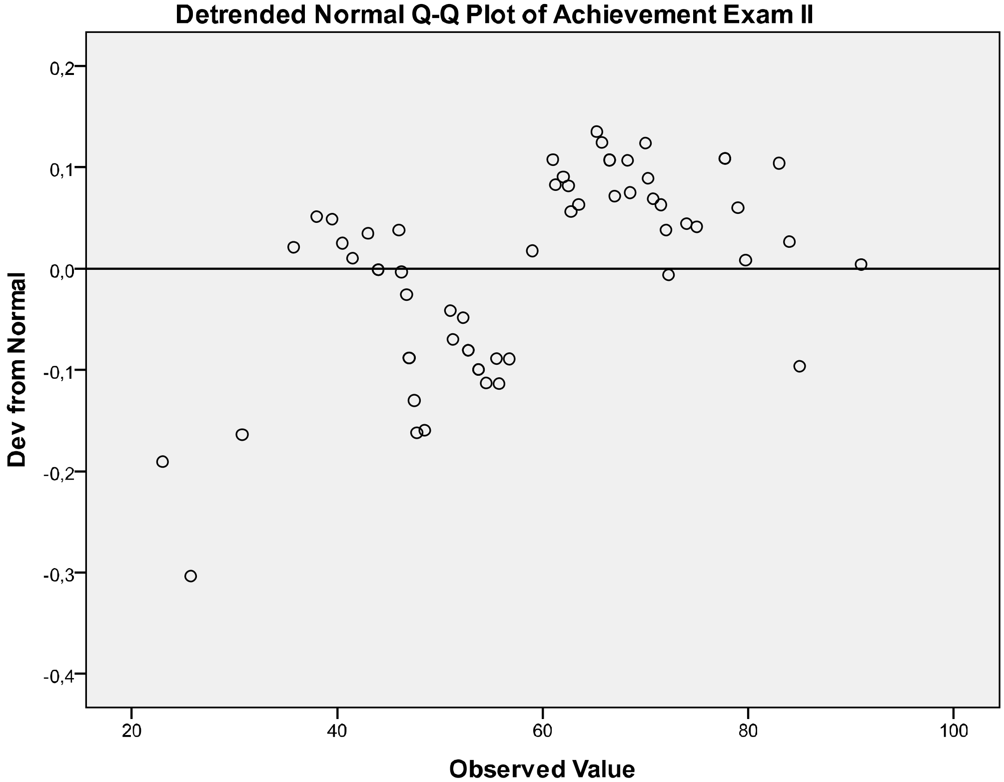

Detrended Normal Q-Q Plot of RSPAN
Dev from Normal
0,25
0,00
-0,25
-0,50
-0,75
-1,00
10
20
30
40
50
60
Observed Value

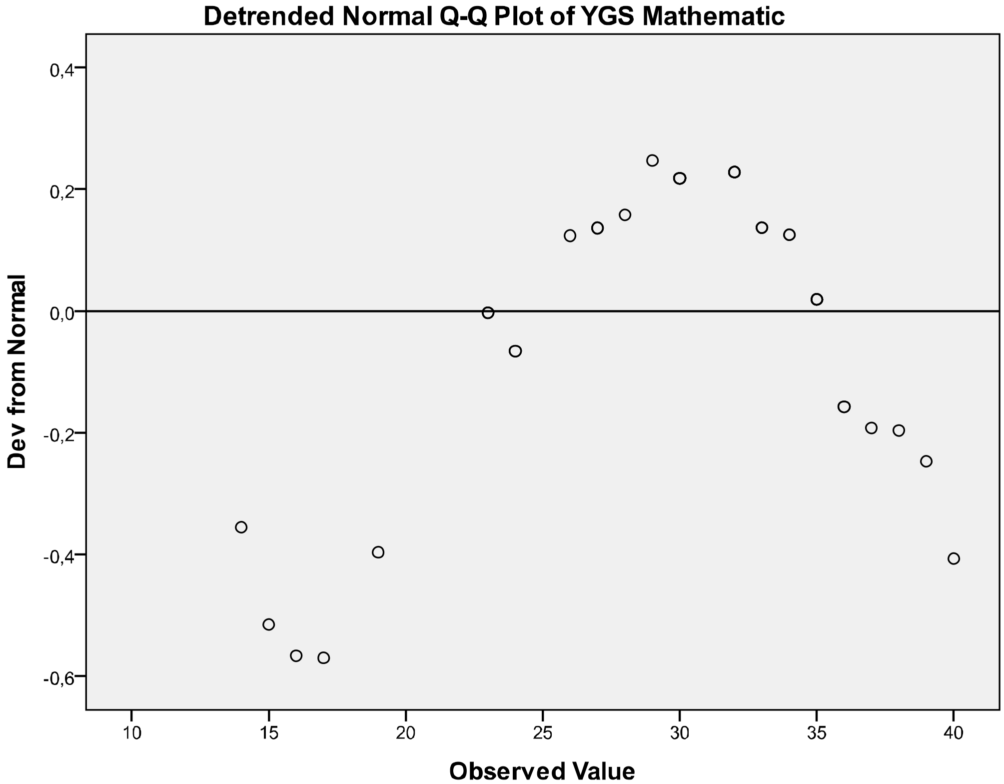

Detrended Normal Q-Q Plot of Digit Span
Dev from Normal
0,6
0,4
0,2
0,0
-0,2
-0,4
4
6
8
10
Observed Value

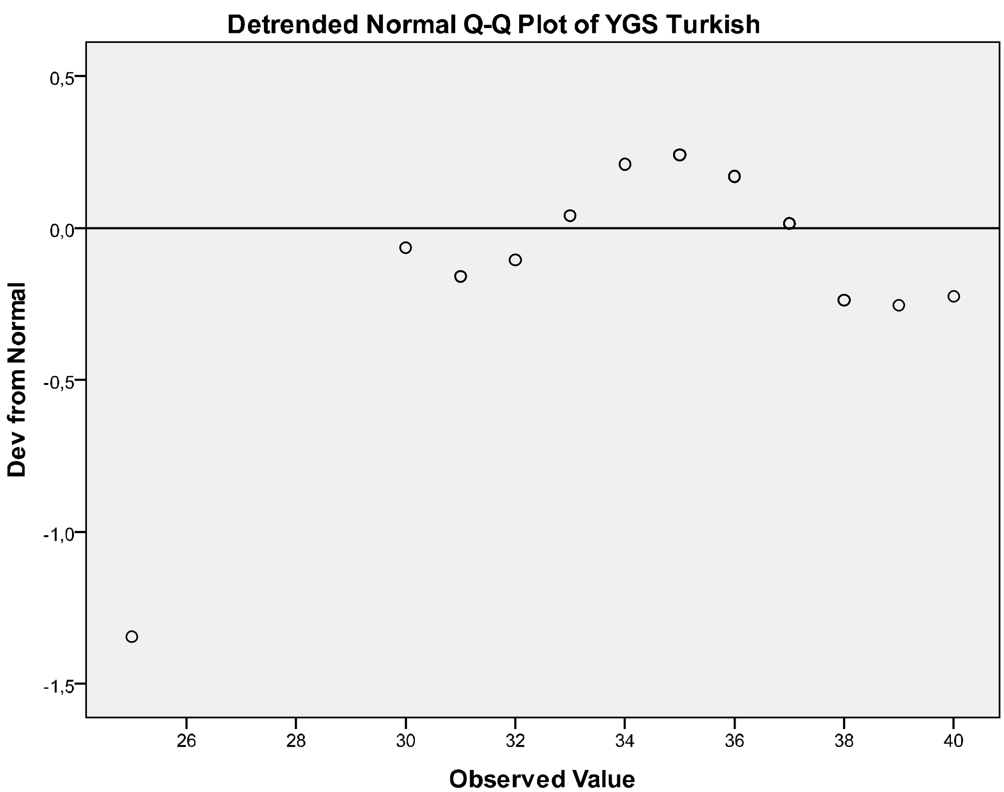
Detrended Normal Q-Q Plot of Achievement Exam I



Detrended Normal Q-Q Plot of Achievement Exam II




Detrended Normal Q-Q Plot of YGS Mathematic
Dev from Normal
0,4
0,2
0,0
-0,2
-0,4
-0,6
10
15
20
25
30
35
40
Observed Value


Detrended Normal Q-Q Plot of YGS Turkish
Dev from Normal
0,5
0,0
-0,5
-1,0
-1,5
26
28
30
32
34
36
38
40
Observed Value

TEZ FOTOKOPİ İZİN FORMU

ENSTİTÜ

Fen Bilimleri Enstitüsü ☐

Sosyal Bilimler Enstitüsü ☐

Uygulamalı Matematik Enstitüsü ☐

Enformatik Enstitüsü ☐

Deniz Bilimleri Enstitüsü ☐

YAZARIN

Soyadı : LEBLEBİCİOĞLU
Adı : AYŞEGÜL
Bölümü : İNGİLİZ DİLİ ÖĞRETİMİ

TEZİN ADI (İngilizce) : AN INVESTIGATION OF THE RELATIONSHIP BETWEEN WORKING MEMORY CAPACITY AND VERBAL AND MATHEMATICAL ACHIEVEMENT

TEZİN TÜRÜ : Yüksek Lisans ☐ Doktora ☐

1. Tezimin tamamı dünya çapında erişime açılsın ve kaynak gösterilmek şartıyla tezimin bir kısmı veya tamamının fotokopisi alınsın. ☐
2. Tezimin tamamı yalnızca Orta Doğu Teknik Üniversitesi kullanıcılarının erişimine açılsın. (Bu seçenekle tezinizin fotokopisi ya da elektronik kopyası Kütüphane aracılığı ile ODTÜ dışına dağıtılmayacaktır.) ☐
3. Tezim bir (1) yıl süreyle erişime kapalı olsun. (Bu seçenekle tezinizin fotokopisi ya da elektronik kopyası Kütüphane aracılığı ile ODTÜ dışına dağıtılmayacaktır.) ☐

Yazarın imzası .... Tarih ....