A PSYCHOLINGUISTIC STUDY OF L1 TURKISH AND L2 ENGLISH WRITING: THE ROLE OF WORKING MEMORY

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for Asuman Canbay and Alp Canbay…

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RESEARCH INTERESTS

- Writing Skill in Language Learning
- Feedback on Writing
- Memory Systems
- Second Language Acquisition
- Bilingual Education
- Writing Process
- Psycholinguistics

TECHNOLOGY EXPERTISE

- Research Tools: SPSS (Advanced)
- Writing Analysis: InputLog Keystroke Program
- Web Design: Adobe Dreamweaver, Filezilla, Wordpress,

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ABSTRACT

A Psycholinguistic Study of Writing: The Role of Working Memory

by

Mehmet Orkun Canbay

The purpose of this study is to develop a production span test to be used in L1 Turkish and L2 English and to see the role of working memory in the L1 and L2 writing process and quality. In addition to the role of working memory in writing, the study examines if working memory training leads to any increase in working memory capacity and subsequently leads to any change in the writing process and quality due to the improvement in working memory capacity. Twenty-eight freshman students from Department of English Language Teaching (ELT) who are native speakers of Turkish participated in the study. The study consisted of two parts: a) developing a production span test in L1 Turkish and L2 English and b) examining the relationship between working memory and writing process and quality in L1 and L2, as well as the impact of working memory training on working memory capacity and the writing process in addition to writing quality in L1 and L2. Data comes from reading span test, production span tests which were used for the working memory capacity, and also Inputlog. The writing process was quantified through Inputlog and online working memory training was given to the experimental group for eight weeks through Lumosity. Statistical analyses of factor analyses of Varimax rotation, Spearman's rank order correlation and Mann-Whitney U test were used. Argumentative essays in in L1 Turkish and L2 English were used for the writing quality and the writing process components. The findings of the study revealed implications with respect to the working memory and writing relationship and the impact of the working memory training on the working memory capacity.

Key Words: working memory, production span test, writing skill, working memory training.

KISA OZET

Yazma üzerine Psikolinguistik bir çalışma: İşler belleğin rolü

Mehmet Orkun Canbay

Bu calismanin amaci Turkce ve Ingilizce'de kullanilmak amaciyla uretim araligi testi uretmektir ve isler bellegin birinci dil ve ikinci dilde yazma sureci ve yazma kalitesi uzerinde etkisini incelemektir. Isler bellegin yazma becerisindeki rolune ilaveten, calisma isler bellek egitiminin isler bellek kapasitesine etkisi olup olmayacagini ve sonrasinda isler bellek kapasitesindeki gelisimden dolayi yazma surecinde ve yazma kalitesinde herhangi bir degisiklige sebep olup olamayacagini incelemektedir. Anadili Turkce olan yirmi sekiz Ingilizce ogretmenligi bolumu ogrencileri calismaya katilmistir. Calisma iki bolumden olusmaktadir: a) Ingilizce ve Turkce uretim araligi testinin gelistirilmesi, b) isler bellegin birinci dil ve ikinci dilde yazma becerisi sureci ve kalitesi ile iliskisi ve isler bellek egitiminin isler bellek kapasitesine, ve birinci dil ve ikinci dilde yazma becerisi sureci ve kalitesine etkisini incelemek. Veriler okuma aralik testi, uretim aralik testi ve Inputlog programindan alinmistir. Yazma becerisi sureci ve yazma becerisi kalitesi icin birinci dil Turkce ve ikinci dil Ingilizce'de tartismaci kompozisyonlar kullanilmistir. Yazma becerisi sureci Inputlog programi ile nicelendirilmistir ve deney grubuna sekiz hafta suresince internet uzerinde isler bellek egitimi Lumosity araciligiyla verilmistir. Varimax rotasyon factor analizleri, Spearman's rank order korelasyonu, Mann-Whitney U testleri istatistiksel analizler icin kullanilmistir. Calismanin bulgulari isler bellek ve yazma becerisi iliskisine ve isler bellek egitiminin isler bellek kapasitesi uzerine etkilerine dair sonuclari aciklamaktadir.

Anahtar kelime: isler bellek, uretim araligi testi, yazma becerisi, isler bellek egitimi.

CHAPTER 1

INTRODUCTION

1.1. Background of the Study

Understanding the nature of learning has been one of the main concerns of researchers throughout history. While asking the very crucial questions to understand how we learn, the answers were bound to the limited knowledge and understanding of human psychology.

Early attempts in search of better ways of learning were mainly based on the assumption that any learning process is not quite different from each other. That is to say; the way any individual learns how to act in a functional and physical situation, such as opening the door would not be much different from the way the same individual learns how to act on a highly cognitive process which requires problem solving and attention. These early attempts to define learning can be considered within the framework of the behavioristic approach. Behaviorism, being one of the fundamental approaches in defining the learning process, reflects this assumption by claiming that learning happens as habit formation only when required conditions are provided, such as reinforcement or conditioning (Skinner,1938).

The later periods have indicated a fundamental shift from behaviorist to cognitive, constructivist, and social constructivist approaches. While Piaget was discussing the difference between assimilation and accommodation and the importance of equilibrium in the process of learning so as to clarify the constructivist way of learning, Vygotsky was proposing the need for understanding the difference between actual level and potential level of learning (Vygotsky,1978). These approaches have served as the offshoots of further research, leading to newer theories.

Beginning initially as a response to the behavioristic models of learning, cognitive theories emphasized mental sources as the primary systems actively involved in learning. Going beyond observable behaviors, the mental aspects of information processing was stressed with a number of maps and metaphors. Cognitive approaches defining the mental systems proposed a number of components which were credited to learning, such as attribution (Weiner, 1986), memory (Atkinson and Shiffrin, 1968; Baddeley, 1974), and cognitive load (Sweller, 1988).

Memory, which is among the components and/or factors contributing to cognitively defined process of learning, was considered to function for multiple purposes to store and retrieve any knowledge. The earliest attempts at elucidating memory as the storage of knowledge date back to the times when the philosophers were deep in search of the relation between mind and body and also the relation between body and soul. Moreover, the very early publications discussing memory can be traced back to the times when St. Augustine (AD 397) implied that the human kind has different types of memory linked with senses, skills, ideas, and emotions (pg X.12-26 in Confessions).

Later hypotheses on memory proposed through the cognitivist approaches emphasized the significant reliance of mental systems on memory. This awareness was due to cognitive research, the results of which highlighted the memory as a component functioning in mental processes (Broadbent, 1958; Atkinson and Shiffrin, 1968; Baddeley and Hitch, 1974). Accepting that individuals have a number of differences either coming from birth or acquired in life, researchers consider cognitive skills and sources among those differences (Bandura, 1997; Bruner, 1990; Gardner, 1983, 1993). From the same perspective, accepting that people do not have the same cognitive capacities and skills, the

impact of these capacities are examined in a controlled setting through which we can see how each of them contributes to the success and failure of learning.

Although it is still not quite possible to illuminate clearly how and what happens within the memory, it is already accepted that the impact of memory capacity is highly significant in any action requiring the use of any mental source. Defined in various ways nowadays, memory, in a broad sense, stands for either the storage of knowledge or the capacity of carrying out tasks while at the same time storing the knowledge required (Atkinson and Shiffrin, 1968; Baddeley and Hitch, 1974; Broadbent, 1958).

Researchers reported that memory is an essential component of language learning and is considered as a mental source contributing to language learning subskills. While it is not possible to ignore the importance of storing knowledge on both short and long term basis during a mental process, memory, on its own, is considered to have a function among the individual differences contributing to the success and failure in language learning (Ellis and Sinclair, 1996; Masoura and Gathercole, 2005; Noort, Bosch and Hugdahl, 2006; Kormos and Safar, 2008; Abreu, Gathercole and Martin, 2011; Tagarelli, Mota and Rebuschat, 2011). In the light of the research precisely on working memory, it is already clear that any linguistic process, either receptive or productive, within a low working memory capacity would not be the same as a process completed within a high working memory capacity.

In the field studies have been conducted on the relationship between working memory and reading, listening, speaking and writing regarding the direct and indirect impact of working memory on these language skills. Reading is one of the most investigated skill regarding the impact of working memory (Baddeley and Wilson,1988; Abu Rabia, 2001; Friedman and Miyake, 2004; Chun and Payne, 2004; Walter , 2004; Naumann, Richter, Christmann, and Groeben, 2008, Alptekin and Ercetin, 2009; Payne, Kalibatseva, and

Jungers, 2009; Fontanini and Tomitch , 2009; Pae and Sevcik, 2011;Rai, Loschky, Harris and Peck, 2011; Dyke, Johns and Kukona, 2014; James, Krishnan and Aydelott, 2014). Although not much has been investigated as in the case of reading, studies have been conducted on a)listening (Waters and Caplan ,2004; Gu and Wang, 2007; Tsuchihira, 2007; Was and Woltz , 2007), and c) writing (Tetroe, 1984; Bereiter and Scardamalia , 1987; Fayol, Largy, and Lemaire, 1994; Swanson and Berninger, 1994; McCutchen, Covill, Hoyne, and Mildes, 1994; Lehto, 1996; Swanson and Berninger, 1996; Ransdell, Arecco, and Levy, 2001; Kellogg, 2001; Hoskyn and Swanson, 2003; Kellogg, Olive, and Piolat, 2007; Vandenberg and Swanson, 2007; Olive, Kellogg, and Piolat, 2008; Lu ,2010).

Writing, being one of the productive skills, requires the interaction of a number of cognitive sub-processes. Memory is one of these sub-processes which is a highly interactive cognitive mechanism that feeds the text production with retrieved knowledge from short term (working) memory, and long term memory.

As Hayes and Flower (1980a) pointed out, writing is 'a set of hierarchical and recursive thinking processes' which comprises various cognitive components. There are only rare studies focusing on the L2 writing ability and working memory capacity. The earliest study was conducted by Ransdell *et al.* (2001) in which they compared bilinguals and multilinguals in terms of the long-term working memory use while writing in the presence of unattended irrelevant speech and a concurrent memory load. The overall study showed the bilingual advantage in suppressing irrelevant information, which, as a conclusion, proposed that fluency in another language would provide advantages on long-term working memory for multilinguals and bilinguals in dual task language conditions.

Second, Vandenberg and Swanson (2007) examined the connection between working memory and the macrostructure (e.g., planning, writing, and revision) and

microstructure (e.g., grammar, punctuation) of writing with high-school students from different ethnic groups. The results showed that there is a relationship between the macrostructure and the executive component of working memory but not between the phonological and visuospatial components of working memory. Similar relation was also found between the central executive component of working memory and microstructure components of writing.

Finally, Lu (2010) carried out a study examining the cognitive factors influencing the writing process in L2 with Chinese L2 learners of English. The factors examined in the study were language proficiency in L2 English, writing ability in L1 Chinese, knowledge on genre, writing strategy use, and working memory capacity in L1 and L2. The study showed that proficiency in L2 language predicts L2 writing; however, genre knowledge and L2 writing strategies come after L2 proficiency in determining L2 skill. Surprisingly, the results did not reveal any correlation between working memory and writing ability in L1 and L2.

As can be seen, none of these studies compared working memory and writing relationship precisely in L1 and L2 writing.

1.2. Significance of the Study

To the knowledge of the researcher, a close survey of studies on working memory and writing indicates that, with the exception of studies conducted by Noort, Bosch and Hugdahl (2006) on foreign language proficiency, the existing studies focused either on L1 (Tetroe, 1984; Bereiter and Scardamalia, 1987; Fayol, Largy, and Lemaire, 1994; Swanson and Berninger, 1994; McCutchen, Covill, Hoyne, and Mildes, 1994; Lehto, 1996; Swanson and Berninger, 1996; Kellogg, 2001; Hoskyn and Swanson, 2003; Kellogg *et*

al.,2007; Olive *et al*., 2008) or on L2 (Ransdell *et al.*, 2001; Lu, 2010; Vandenberg and Swanson, 2007).

The present study contributes to the field by a) a production span test which was precisely designed and developed for the present study, and b) by clarifying the relationship between working memory, writing process and quality. Within this framework, a comparison of the L1 Turkish and L2 English writing process regarding their respective relationship with working memory will be examined. Accepting that working memory capacity is one of the individual differences, the study aims to highlight if working memory capacity can be improved through online training within a limited time. The study also aims to investigate if any improvement in the working memory capacity will lead to any significant change in the writing process and quality in L1 and L2.

1.3. Aim of the Study

The present study has two dimensions. The first part of the research includes statistical examination of the production span test developed specifically for this study. The second part of the study investigates: a) the relationship between working memory and L1 and L2 writing process and quality b) if there is an effect of working memory training on working memory capacity c) if eight weeks training period effects L1 and L2 writing process and quality. Specifically speaking, the following research questions were asked:

First part of the study

1. To what extent does production span test measure working memory capacity compared to reading span tests?

As for the second part of the study,

1. Is there a relationship between working memory capacity and Turkish and English online writing processes of EFL students?

2. Is there a relationship between working memory capacity and Turkish and English online writing quality of EFL students?

3. Does working memory training lead to any effect on working memory capacity of EFL students taking working memory training?

4. Is there a difference in L1 Turkish and L2 English writing processes and quality of EFL students after the eight weeks training period?

1.4. Overview of Methodology

1.4.1. Participants

Twenty-eight freshman ELT (English Language Teaching) students participated in the study on the basis of convenience sampling. They were all native speakers of Turkish (ten males, eighteen females) with 14 in control and 14 in experimental group. Their proficiency level ranged between B1 and Pass A level considering Cambridge FCE test.

1.4.2. Setting

The present study was conducted in an undergraduate program of an English Medium University in Izmir, Turkey. The students register in the program according to their scores of the national exam. They study in prep school if they do not comply with the required level of proficiency in English. The graduates of the program receive the diploma of English language teaching to serve as teachers at both public and private schools.

1.4.3. Data Collection Instruments

The study was a quasi-experimental study with a control and experimental group utilizing a pre and posttest design. Because of the multitask nature of the data collection process, the current study included seven separate instruments for data collection: a) level

tests in FCE b) topic familiarity test c) reading span test d) production span tests e) writing task on Inputlog.

1.4.4. Procedures

To see the level of the participants and precisely if their level of proficiency falls with in the scope of the study, the Cambridge English: First (FCE) test was given at the beginning of the study. The FCE which is a standardized test includes five sections; reading, writing, listening, language use, and speaking. However, the current study used the listening, reading and language use sections so as to lower the test overload on the participants.

As the general perspective of the study included writing in L1 and L2, a familiarity test was used to determine the topics to be used in writing tasks. The topics on the familiarity test were compiled through discussions with four experienced writing instructors in the same institution.

As three of the research questions ask for the quality and the comparison of the writing process in L1 and L2, the study included InputLog (Leijten and van Waes, 2006), a highly developed online keystroke program. Inputlog provided a number of valid quantified data so as to answer the research questions comparing the subcomponents of the writing process in L1 and L2. The writing components included twelve items regarding the writing process. Moreover, the editing and revision done during the writing process were quantified with the help of the recording feature of Inputlog. The writing process was quantified in L1 Turkish and L2 English individually by two researchers who were trained to distinguish between the difference between editing and revision. The quantification of the writing process helped compare the two languages and see the impact of the treatment on the writing process.

Since one of the aims of the study was to see if it is possible to improve the working memory, a treatment on the working memory capacity enhancement was given through an online cognitive training program (Lumosity). In order to have further comparisons and correlation analysis and also to see if the treatment led to any increase on the working memory capacity of the participants, the two span tests (reading span test and production span tests) in L1 and L2 were conducted before and after the treatment. The reading span tests and production span tests in English and Turkish were used to measure the working memory capacity in the study. The reading span tests included the general nature of the working memory tests with a grammatical judgement question and the retrieval of the final word of a sentence. As the study focuses on the writing and working memory relationship, the production span tests which tap the productive aspect of a working memory capacity were used as another data collection instrument.

The treatment, which aimed at enhancing the working memory capacity, was given through an online program. It lasted for twenty-eight hours in total and was followed daily for eight weeks by the participants. The treatment included online games developed specifically for the cognitive training on working memory.

1.4.5. Scoring the Data

The initial phase included the scoring of FCE in the light of the official answer key and also the official scoring band of the FCE. As the writing and speaking sections were excluded, the test included tree sections each of which contributed to the overall grade with 3.3 out of 10. Regarding the individual score of the questions, each question in reading had 1.33 and listening sections had a value of 1.14, whereas each question in use of English section had 0.92 value.

The writings were scored by two raters for English and by two raters for Turkish with at least five years of teaching experience and with an MA in the field of teaching. Individual informative sessions with each pair of raters were set and the raters were informed about the tasks and the global scoring perspective. Ten samples from the pilot study were used for the moderation session. Each writing was scored by the raters and the scores were compared within the group of raters. After having five practices for each language, the raters were given time for scoring the other five sample essays. The scores included both the content and the grammar scores given for each individual writing. The average score of content and grammar was considered as the ultimate score for the writing. After the completion of the scoring of essays in a limited time, the final scores were compared within the group of raters to be included as a final writing quality score into the study. The existing discrepancies in scores were solved with agreement on the justifications of the raters to each other.

The reading span tests measured the process and also storage of the input and therefore they yield two scores for the further analysis. Grammatical judgement of the sentences was the first score, and the second score included the retrieval of the last word of the sentence. That is to say; the scoring of the production tests covered the storage and process scores of any sentence produced. The test takers who produced a sentence in line with the rules given were considered to have accomplished the procedural aspect of the test item, which includes the use of memory sources while at the same time dealing with a piece of knowledge. However, the tests takers who produced a sentence but broke the rules were considered to have accomplished only the retrieval aspect of the production span test, which is based on remembering. Through the production span tests, the participants had two scores: one for the procedural aspect and one for the retrieval aspect.

The study also had a keystroke program InputLog regarding the data collection on writing process. InputLog (Leijten and van Waes, 2006) was used as the keylog program and it provided a detailed quantification of the writing process up to the preferred subcomponents. The data provided through Inputlog included the individual quantified scores on eleven subcomponents of the writing process. The revisions and editing by the participants were quantified after the individual analysis of the writing process by the help of the recording function in InputLog.

1.4.6. Data Analysis

This study included a quantitative data analysis of the data collected through the proficiency test in English, reading span tests in English and Turkish, production span tests in English and Turkish, and writing tasks in English and Turkish.

All quantitative data were analyzed through SPSS 22.00 with the exact tests needed to answer the three research questions in the study. The first step of the analyses was to see if the data collected was normally distributed or not. For this purpose, the data was analyzed using the Kolmogorov-Smirnov tests in SPSS 22. The results of Kolmogorov-Smirnov tests determined types of further analyses.

For the first part of the study, in order to see to what extent production span test measures working memory capacity compared to reading span tests, factor analyses of Varimax rotation were carried out with the data collected through reading span and production span tests.

For the second part of the study, in order to determine if there is a relationship between working memory capacity and L1 and L2 writing processes, the data collected through reading span and production span tests in L1 and L2 and also through writing tasks in L1 and L2 were examined with Spearman's rank order correlation. The correlation

analysis helped to see the relationship between working memory capacity and L1 and L2 writing processes subcomponents. The first research question asked if the operation, the reading and the production span tests scores correlate with the L1 and L2 writing process subcomponents which were previously quantified with Inputlog.

For the second research question asking if there is a relationship between working memory capacity and L1 and L2 writing quality, Spearman's rank order correlation analysis was carried out. The quantitative scores collected through the writing tests on the text quality were examined to see if they correlate with the operation, the reading and the production span tests scores.

The third question tried to answer a folded aspect of the working memory capacity. The primary aim was to see if working memory training leads to any effect on working memory capacity of EFL students. Depending on the affirmative results of the primary question that working memory training leads to any effect on the working memory capacity of EFL learners, the secondary aim was to see if this effect leads to any change in L1 and L2 writing processes and subsequent writing quality of EFL students. The data analyzed within this research question came through the operation, reading and the production span tests, global scoring of the writing texts, and the writing process subcomponents quantified by InputLog.

1.6. Limitations of the Study

The present study had several limitations. First of all, the study had limited number of the participants. Due to this limitation in findings, statistical findings of the study cannot be generalized.

Moreover, only eight weeks could be devoted to the treatment although longer period of time was necessary for this kind of study. Presumably, the findings could have been different if the treatment had been longer.

In addition, since there were some deficiencies of the Inputlog program, such as determining whether the pause time stands planning, revision or editing, it is difficult to precisely claim all pauses may be linked to planning. Therefore, close observation of the participants during the process of the writing was necessary through think aloud protocols. However, due to the limited scope of the study, this could not be done. As a result, this may have affected the findings in relation to writing process.

Moreover, since the study was conducted in a specific EFL context (L1 Turkish), the results cannot be generalized to other setting, and this may be considered as another limitation of the study.

In addition to these, attention could not be measured or controlled in the study. As a result, the comparative findings could not be linked directly to the impact of attention training.

Furthermore, the process of multitask data collection might have been considered as a time-consuming process by the participants; as a result, this might have demotivated the participants during the study.

1.7. Recommendation for Further Study

The present study has some recommendations for further research. First of all, another study can be conducted on the issues investigated in the study in a different context with a larger number of participants. Such a study could include observation of the participants during the writing process to overcome the deficiency of the online programs, such as Inputlog. Moreover, while investigating the relationship between working memory

and writing process and quality, factors other than proficiency could be controlled, such as attention as a cognitive confounding factor. Furthermore, a comparative study can be conducted by using two different span tests; reading span test and production span test, to measure working memory capacity and to see which span test has the higher predictive power for reading skill, writing skill, listening skill and speaking skill. In addition to these, a comparative study examining the impact of individually working memory training and attention training may be conducted so that any reliable impact of these can be determined on writing process, writing quality and other cognitive sources, such as attention and working memory.

1.8. Organization of the Study

The present study includes five main chapters. Chapter one covers the background of the study, the statement of the problem, the aim of the study with the research questions, overview of the methodology (the participants, setting, data collection instruments, treatment, data analysis), contribution of the study and the limitations of the study. Chapter two includes the literature review on mainly working memory and language learning. The section comprises sub-sections with a detailed literature review on both theories and studies regarding working memory with language skills with a special focus on writing. The chapter also describes the span test types and working memory enhancement programs. Chapter three gives the comprehensive information on the methodology with the participants, setting, data collection instruments, treatment and data analysis. Chapter four provides the findings with the statistical analysis done so as to answer the research questions in the study. Chapter five presents the discussions and chapter six presents the conclusions in the light of the findings and limitations of the study and the recommendations for further studies. Finally, references and the appendices are found at the very end of the dissertation.

1.9. Definition of the Significant Terms

Cognition: refers to information processing related to perception, attention, categorization, learning and memory, thinking, decision making, problem solving, and language use (Bender and Beller, 2013)

Cognitive Approach: focuses on how we think and understanding the mind (Skehan,1998)

Span Test: measures the working memory capacity through the tasks tapping both storage and the process of the knowldge (Daneman and Carpenter, 1980)

Editing: refers to the surface level changes and local rearrangements regarding the grammar, spelling errors, punctuation mistakes, incorrect words, sentence fragments, and other mechanical problems in writing (Horning and Becker, 2006).

InputLog: is a keystroke program that has been specifically developed for the assessment of writing process (Leijten and van Waes, 2006).

Production Span Test: measures working memory in which test takers are asked to remember as many words as they could in order to write a sentence around each word (Alamargot, Lambert, Thebault, and Dansac, 2007; Chuy, Alamargot and Passerault, 2012).

Reading Span Test: measures the working memory capacity through the retrieval of either the final or the first word of a sentence and also another task, such as grammatical judgement (Friedman and Miyake, 2005)

Revision: refers to the global changes in terms of the content, purpose, flow of the ideas, organization, and focus (Haar, 2006)

Working Memory: refers to the system that is responsible for storing and processing of new and already stored knowledge within or by the help of its subcomponents (Baddeley, 2000)

CHAPTER 2

REVIEW OF LITERATURE

2.1. Introduction

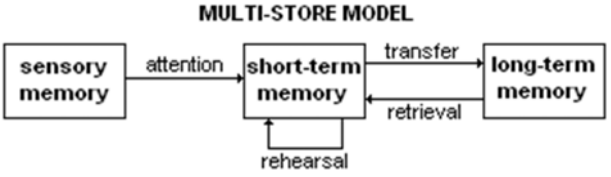
2.2. Memory Types

Memory, which is one of the ultimate sources of human cognition, is generally considered as the source where the knowledge is stored and partially processed. A number of proposals have been made in literature so as to define how the memory functions and depict what the sub-components it includes.

Among those proposals, two of them were discussed and attracted the attention in literature. One of them is Atkinson-Shiffrin memory model and the other one is Baddeley's model of working memory. In a sense, these models attempted to define the memory and its function with multi-components.

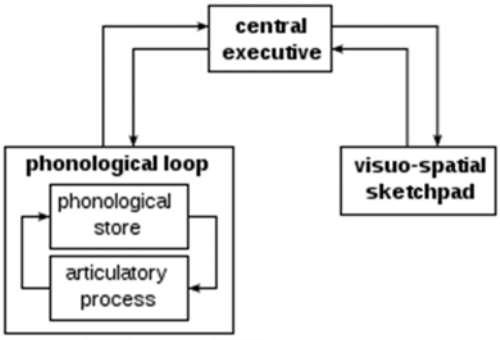
Richard Atkinson and Richard Shiffrin proposed the Atkinson–Shiffrin model which is also named as the the multi-store model or modal model. The model, dating to 1960s, puts forward that human memory has three individual components: a sensory register, a short term store, and a long term store (Atkinson and Shiffrin, 1968). According to the Atkinson–Shiffrin model, any type of input enter into the short-term memory after is detected by the sensory motor through attention. As long as it rehearsed, the knowledge would be transferred into the long term memory. The process is explicitly defined in figure 2.1. below.

Figure 2.1. Atkinson- Shiffrin Multi-store model of memory (Atkinson and Shiffrin,1968)



Baddeley and Hitch (1974) offered a different model of memory. Although the later proposals have changed quite a lot regarding the sub-components, the earlier versions stressed the function of short-term memory and its slave systems. The model is depicted in figure 2.2 below.

Figure 2.2. The working memory model (Baddeley and Hitch, 1974)



Regarding the scope of the current study, the memory types, the changes in depicting the multitask nature of memory, the sub-components involved in memory are discussed in depth and thoroughly. The subsequent sections on long term, short term and working memory, which are the basic memory types discussed in the literature, give a detailed aspect of the memory.

2.2.1. Long Term Memory

Functioning as a cognitive source for multiple purposes, long term memory is defined as a large capacity which stores knowledge to be retrieved. In any immediate action requiring any previously stored knowledge, the connection between the working memory and long term memory is established. Andrade (2001) discusses that retrieval of the relevant sensory

information from long-term memory is highly automated, being rapid, complete and resistant to interference. Long term memory is commonly divided into explicit memory (declarative) and implicit memory (procedural memory). However, explicit memory (declarative) is reported to have three sub-components: which are episodic memory, semantic memory, and autobiographical memory. Explicit memory, the contribution of which to formal language learning has been discussed, is proposed to function for conscious way of learning and storing the declarative knowledge. Implicit memory, which is claimed to contribute to acquisition, stores procedural knowledge (Ullman, 2001). Long term memory is reported to be one of the sub-components of different models defining the detailed functioning of working memory. Cowan (1995) proposes that working memory is a sub-component of long term memory in the Embedded Process Model; however, long term memory is defined to be a different component according to the working memory model proposed by Baddeley (2000). The common assumption in the proposed models is that the information in the long term memory store is stored and readily accessible but needs to be activated when needed. One of the strengths of long term memory is proposed to be that long term has an unlimited space and does not decay over periods of time (Oberauer, 2002; Oberauer, 2005).

2.2.2. Short Term Memory

Short term memory, which is defined as another type of memory, functions for storing any input or knowledge for a limited time. The function of storing any knowledge cognitively for a limited period of time was first defined as primary memory by James (1890). Short term memory serves as a temporary storage. The ultimate agreement is that the knowledge stored in short term memory is limited and vulnerable to decay over the time. The limited capacity and duration determine the major cut between long term and short term memory. That is to say: the duration and the capacity of the long term is different from short

term memory. Capacity refers to the amount of any knowledge to be stored, whereas duration explains the time that any knowledge is kept before it decays in the memory. The functional aspect of the short term memory is more precisely and well defined in the Atkinson- Shiffrin Multi-store model of memory. As is discussed above, the Atkinson- Shiffrin Multi-store model proposes that short term memory serves as a passage where any knowledge or any input is stored before going into the long term memory (Atkinson and Shiffrin,1968).

2.2.3. Working Memory

Memory, broadly defined as one of the major subjects among the cognitive studies concerning with storage and manipulation of information, has been categorized into different components referring to different functions. As discussed above, long-term memory, one of the basic components of memory, is assumed to be a durable storage for information and to function primarily for associating and relating the knowledge stored to the new situations. Short-term memory, another basic component of memory, is assumed to have a limited capacity functioning for a short period of time and limited knowledge (Cowan, 2008). The need for defining how working memory functions led to a number of models proposed by different researchers. Theoretical comparisons show that the models proposed claim that working memory has different subcomponents which interact with each other during the working memory functions. While reviewing models of working memory, Miyake and Shah (1999) compiled ten models which have been proposed so far. The list of models is given in table 1. below with the names of contributors who worked on them.

Table 1. Working Memory Models

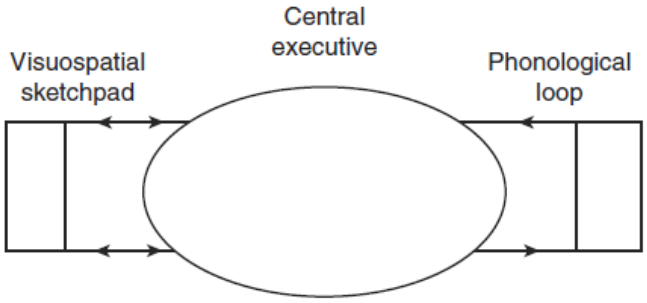
	Working Memory Model	**Contributor**
1)	The Multiple Component Model	Baddeley, Alan D.; Logie, Robert H.
2)	Embedded-Processes Model	Cowan, Nelson

3)	Controlled Attention Framework	Engle, Randall W.; Kane, Michael J.; Tuholski, Stephen W.
4)	Modeling working memory in a unified architecture: ACT-R Model	Lovett, Marsha C.; Reder, Lynne M.; Lebiere, Christian.
5)	Executive-Process/Interactive Control (EPIC) Model	Kieras, David E.; Meyer, David E.; Mueller, Shane; Seymour, Travis.
6)	Soar Architecture	Young, Richard M.; Lewis, Richard L.
7)	Long-Term Working Memory (LT-WM) Framework	Ericsson, K. Anders; Delaney, Peter F.
8)	Interacting Cognitive Subsystems (ICS) Model	Barnard, Philip J.
9)	Controlled and Automatic Processing (CAP2) Archiecture	Schneider, Walter.
10)	Biologically Based Computational Model	O'Reilly, Randall C.; Braver, Todd S.; Cohen, Jonathan D.

When the list of the working memory models is examined meticulously, it is seen that there has been a significant shift in the last fifty years. This shift is a long expedition from core unitary short term memory to a multi component working memory. One of the earliest attempts to define the functional aspect of the working memory arises from Broadbent when it was realized that there are two separate systems responsible for individual. Broadbent (1958) was one of the earliest researchers who claimed that short term memory and long term memory rely on separate systems. The filter theory of Broadbent (1958) covered two subcomponents named as the S system and the P system. Strikingly, S system was reported to be responsible for and capable of storing sensory information but S system was reported to convey the information into the P system. Moreover, the two systems differed in terms of the duration and the capacity. Broadbent's Filter Theory was one of the cornerstones that shaped the understanding and the interpretation of the working memory as the following models stressed the existance of separate components. In addition to these, Richard Atkinson and Richard Shiffrin proposed in 1968 that the memory had three sub-components a) sensory register, b) short-term store and c) long term memory. The Atkinson-Shiffrin model was the earliest attempt to propose the sequential nature of information processing in memory. The model put forward that short-term memory functions as a

passage by the help of which the information can access to long-term memory. The Atkinson-Shiffrin model which is also known as the multi-store model (Atkinson and Shiffrin, 1968) led to further expansions regarding the functional subcomponents of the working memory. Being one of the most highlighted and accepted models, The Working Memory Model was depicted by Baddeley and Hitch (1974). As it is seen in figure 2.2, above the subcomponents of phonological loop and visualspatial sketchpad is the central executive. The model had two subcomponents functioning either as a unitary system or individual single subcomponents. In other words, the function of working memory was classified into three components: a) *phonological loop* refers to the storage and manipulation of phonological/auditory information; b) *visual-spatial sketchpad* functions for generating and storing non-verbal visual images; c) *the central executive system* controls the strategy selection, attention and use in information processing.

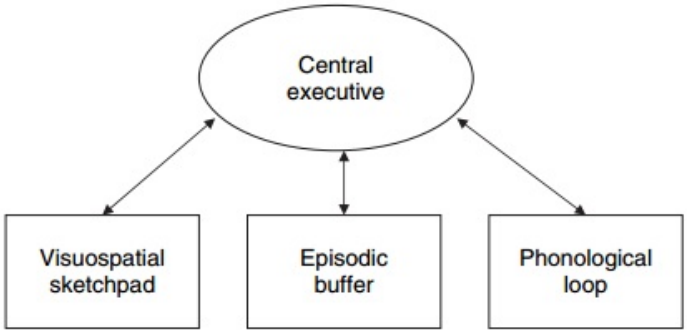
Figure 2. 3. The original conceptualization of working memory model (Baddeley and Hitch, 1974)



After various attempts to define the functional aspects of working memory, the model was finally shaped with the inclusion of episodic buffer, which is another component of working memory proposed and defined by Baddeley (2000). The final version of the multimodel system is depicted in the figure 2.4. The new component, episodic buffer, is

claimed to function as a temporary storage system for integrating information from long-term memory and the sub-components of working memory. The logical explanation for the separate functional components of working memory was highlighted through the dual-task methodology in which two separate tasks could be performed without tapping each other and inhibiting the performance (Baddeley, 2000). In other words, each component in WM functioning for a different purpose could function individually while also serving together at the same time to accomplish a task. Another functional categorization of working memory came from Ericsson and Kintsch (1995) who claimed that working memory has two functional components. Short-term working memory (ST-WM) functions for updating and using representations, regulating attention among tasks, and sorting relevant information and limiting irrelevant information. Long-term working memory (LT-WM) functions in accessing to relevant information from long-term memory to retrieve. The function of each subcomponent in Multi Modal is discussed in the next section.

Figure 2.4. Baddeley's model of working memory (2000)

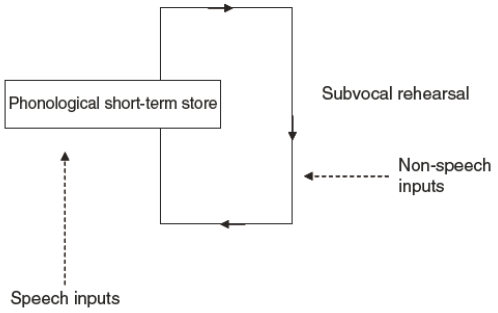


2.2.3.1. Phonological Loop

The earliest attempt to define the storage and processing of verbal and acoustic information was made by Baddeley and Hitch in 1974 when they termed this system as 'articulatory loop'. The advanced system defined in Figure 5 was proposed by Baddeley in 1986 with the representation of the two-component model in which auditory speech input

reaches to the phonological short-term store where it is stored for a short period of time. The representation of verbal and acoustic information is subject to a rapid decay demonstrating that auditory speech information unconditionally reaches phonological store (Baddeley, 1986, Gathercole, 2007). The rapid time-based decay refers to the inhibition and deterioration of knowledge unless it is conveyed from the phonological short-term store to subvocal rehearsal, all of which explains why long items take longer to activate than short items.

Figure 2.5. The Phonological Loop Model (Baddeley, 1986)



2.2.3.2. The Visuospatial Sketchpad

Visual sketchpad, the second component of WM, is responsible for the storage and manipulation of the visual and spatial form of information (Baddeley, 2003). With the evidence from neuroscience, it is already known that the right hemisphere regions of the inferior prefrontal cortex, anterior occipital cortex, and posterior parietal cortex are responsible for the functions related to visuospatial information (Gathercole, 2007). Moreover, the individual functions of either visual or spatial were proved by the neuropsychological patients with the brain lesions causing impairments of visual storage but intact spatial memory and the opposite impairments in spatial memory but intact visual memory (Hanley *et al*., 1991; Della Sala *et al*., 1999; Della Sala and Logie, 2003) In other words, it has been proved that the sketchpad has two distinct components functioning

interrelated (Gathercole, S. E., 2007). Broadly defined for its function in daily life, visual sketchpad serves as the reflection of visual knowledge on any image or text onto the right hemisphere where this knowledge is stored for a short period of time and is manipulated for both individual and concurrent activities, such as reading, writing, and tracking an object (Baddeley, 2003).

2.2.3.3. Episodic Buffer

Among the all components of working memory, episodic buffer is the most recent component proposed by Baddeley (2000). Defined also as a 'multimodal' temporary store, episodic buffer serves for binding the information in different modalities. In other words, the nature of the knowledge to be retained may differ as either visual or phonological, but the episodic buffer binds the information in different modalities. It is claimed to be a storage where information from the loop, the visualsketchpad, long term memory is combined in a coherent episode (Baddeley, 2007, p:148).

A good example could be the time when a movie is being watched, during which one will need to link the visually presented scenes and the phonologically submitted speech. As each of these includes different modals of knowledge, episodic buffer serves in order to join these modals of knowledge. However, the level of the coherence and consistency between the modals of knowledge determines if any other source will be needed other than the components of working memory since the knowledge may need to be joined with and linked to other cognitive sources. (Baddeley, 2007).

Like the other components of the working memory, the capacity of the episodic buffer is still in question. The chunks and episodes determine the capacity as it will be greater if the chunks and episodes are in a coherent and consistent order (Lucy,2011).

2.2.3.4. Central Executive

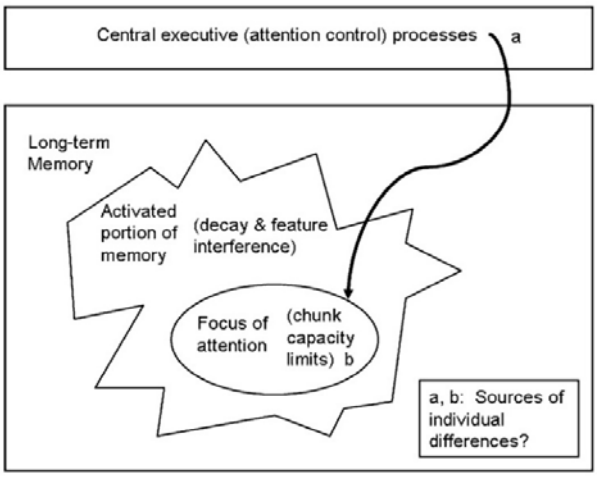
Among the components of the working memory model, central executive (CE) controls the working memory system and the integration of each individual component in the cognitive processes. With its limited capacity, it regulates the flow of information both within working memory and also the dependence of system on long-term memory (2007). Functioning as an operator in the system, CE is reported to be the most important subsystem of three component working memory model (Baddeley, 2007 p:117). The main function of central executive is to direct attention as it is the attention, which is the very first step for a cognitive process where any knowledge is stored. Moreover, Baddeley (2007) claims that the CE system resembles to Supervisory Attentional System (SAS) which is responsible for the control of attention in various situations. Adopting Supervisory Attentional System (SAS) model as a potential framework for executive proposed by Norman and Shallice (1980) and by Shallice (1982), Baddeley (2007) defines the CE as a rag bag proposing it would be a failure to claim that it is a unitary system. However, Baddeley (2007) avoids the misconception of the idea proposed by Kimberg *et al.* (1997) as a unitary system which could only be explained as a system on the grounds that the executive is a singular noun.

As a conclusion, based on the proposals discussed above, memory types are divided into three categories in the literature a) long term memory, b) short term memory, and c) working memory. In short, although each of these memory types functions for a specific purpose in the cognitive system, Baddelley (2007) puts forward that working memory is not unitary system functioning as a single unit but with four different subsystems a) central executive, b) visual sketchpad, c) episodic buffer and, d) phonological loop.

2.3. The Distinction Between Working Memory and Short Term Memory

Though both terms referring to the highly abstract mental functions for the storage and manipulation of knowledge can cause confusion, the distinction between working memory and short-term memory needs to be clarified, as both are often used interchangeably. A number of proposals have been made for the functional aspect of the memory type which stores limited capacity of knowledge for a limited period of time. On the other hand, some considered the function of storing limited capacity of knowledge for a limited period of time as a unitary and single component serving for the same purpose. Miller *et al.* (1960) did not make any distinction between short-term and working memory, claiming that it has a single function. Before referring to it as working memory with a multi-component system, Baddeley and Hitch (1974) claimed that short term is the unitary system and functions for the storage of limited capacity of knowledge for a limited period of time. However, the multi-component view was accepted also by Cowan (1988), who proposed that short term memory is a subdivision of working memory which was also claimed to be an activated memory (see Figure 2.6)

Figure 2.6. Theoretical modeling framework for memory (Cowan, 1988)



The earlier assumptions and proposals covered that they were distinct components (Baddeley and Hitch , 1974; Baddeley, 1986; Baddeley, 1997; Cowan ,1988; Daneman and Carpenter , 1980). The grounded distinction between short term memory and working memory was initially proposed when the short-term memory was considered as simple passive storage but the working memory functioned both for the storage and the processing (Engle *et al*., 1999; Kane *et al*.,2001). These claims were followed by a number of similar proposals in which the distinction between working memory and short term memory was clearly comprehensible as working memory was considered to be an active process triggered by attention and included both the storage and the processing (Conway *et al*., 2001; Cowan *et al*.,2005; Cowan *et al*.,2006b; Cowan, 2008).

In this sense, working memory in this study will be considered as "the limited capacity to process and store information for carrying out tasks" (Baddeley, 1986, 1997).

2.4. Studies on Working Memory and Intelligence

A number of studies have been conducted on the relationship between intelligence and working memory capacity (Unsworth and Engle, 2005; Colom, Mendoza, and Rebollo ,2003; Engle, Tuholski, Laughlin and Conway, 1999); Abreu, Conway and Gathercole, 2010; Sunderman and Kroll, 2009; Adams, Bourke and Willis, 1999).

Unsworth and Engle (2005) investigated the effects of individual differences in working memory capacity and fluid intelligence with hundred and sixty participants. The participants took the operation span tests and Raven Advanced Progressive Matrices test (Raven *et al*., 1998). The study showed the constant relationship between Operation Span and Raven across levels of difficulty, memory load, and rule type. However, the study provided evidence on the assumption that the inadequacy of the sub-tasks held in memory to explain the difference between working memory span measures fluid intelligence, which

contrasts with the idea that the relationship between the differences in working memory capacity and intelligence is caused by the differences in the retention of certain things in working memory (Carpenter *et al*., 1990). Based on all those, the researchers claimed that individual differences in working memory capacity indicate the variance in a domain-general executive attention component but do not indicate the variance of the number of the items kept in memory.

Colom, Mendoza, and Rebollo (2003) investigated the working memory and intelligence relation. One hundred and eighty-seven subjects participated the study, and seventy-one of the participants took the test in Brazil and hundred and sixteen were tested in Spain. Eight different span tests were given to the participants. Matrix span asks the participants where the visual stimuli given on a computer screen appear. Letter span ask s the participants to remember the ordered letters and reproduce them again in order. Digit span task includes the recall of several single digit numbers seen on a computer screen. The participants are shown squares with a pattern matrix of black and white squares on the left side of the computer screen and the participants are asked to decide if the square positively matches or negative matches with the squares shown. ABC numerical task adapted from Kyllonen and Christal (1990) ask the participants to retain an equation while waiting for another and also replace another specific item within the subsequent equations. ABCD Gram task which was adapted from Kyllonen and Christal (1990) presents three sentences shown in order and the sentences match with the relative position of two single letters. Participants choose which one of four alternatives reflect the position of the letters, such as ABCD: DCBA. Alphabet task includes an adapted version from Craik (1986) in which the participants retain the first letters of the word sequentially displayed on the computer screen, and write the retained letters through keyboard. In digit ordering task, the participants add

each pair digits presented sequentially on the computer screen and write the result of the summation retained and reproduce the numbers in an ascending order. For the intelligence tests, the researchers used two tests. The first test was the Primary Mental Abilities Test (Thurstone, 1938) in which the participant has to pick a letter which reflects the relationship established among several letters. Another intelligence test which was designed by J. Raven (CEPA, 1993) was used in the study. The results gathered through these all tasks revealed the significant relationship between working memory and intelligence.

Being one of the earliest studies in the literature, Engle, Tuholski, Laughlin and Conway (1999) conducted a study in which they wanted to see if working memory has a relationship with the general fluid intelligence. The participants were one hundred thirty-three undergraduates from University of South Carolina in the study. Accepting that working memory and short term memory are responsible for different cognitive performances, the researchers moreover tried to see how the working memory and short term memory differ in terms of the contributions they made during the cognitive performances. An operation span test was used to measure working memory capacity in which participants were asked to judge if the equation is right or wrong and retain a word for each equation item and by a reading span test in which the participants had to read a set of sentences and were to retain the unrelated word in the end of each sentence. Counting span tests were also used for the working memory capacity measure which displayed different shapes in different colors and the participant had to count the dark blue circles loudly. The researchers used three span tests for the short term memory capacity. In forward span dissimilar tests the participants had non-rhyming words displayed in sets and they had to remember those words, whereas the forward span similar tests had the same procedure but with the words having the similar rhymes. The last test used for short term memory was the backward span test which

resembled to forward span similar test but the participants had to report the words they remembered in the reverse order they were presented. Two tests used on general fluid intelligence were Cattell's Culture Fair test (Cattell, 1973) and Raven's Progressive Matrices tests (Raven, Court and Raven, 1977). Some additional tests were also used in the stud, such as Keeping Track (Yntema, 1963), Immediate Free Recalll, ABCD task, Continuous Opposites, and Random Generation tests. The working memory and short term memory are claimed to be tow distinguishable but related constructs through the results of the study. The link between General Fluid Intelligence and working memory was seen but no link between General Fluid Intelligence and short term memory. The researchers also claimed that both short term memory and working memory rely on the same memory system.

Abreu, Conway and Gathercole (2010) wanted to see the link between working memory and fluid intelligence in young children and development of these links. Moreover, the researchers tried to find out which function of the working memory system—short-term storage or cognitive control—leads the relationship with fluid intelligence. Hundred and nineteen children whose first language is Luxembourgish participated in the study. All of those were the learners of French and German as foreign languages. Fluid intelligence defined in the study as a “complex cognitive ability allowing humans to flexibly adapt their thinking to new problems or situations" was measured by the Raven Colored Progressive Matrices Test (Raven *et al*., 1986) in which the participants had to complete a figure by selecting the missing one among six possible drawings. Luxembourgish adapted versions of two memory span tasks were used in the study. The counting recall task (AWMA, Alloway, 2007) asked the participants to count and memorize the number of circles in a picture having circles and triangles, and in the end to report how many circles there were in each picture. Backwards Digit Recalll (AWMA, Alloway, 2007) asked the participants to remember the

reverse order of the spoken digits. Short term memory capacity was measured with the Luxembourgish translated Digit Recalll Task from the AWMA1 (Alloway, 2007) which asked the participants to immediately repeat the sequences of spoken digits as they were displayed.The results showed that STM and WM performance show different but linked processes, supporting the studies with by Baddeley (2000) and Engle *et al*. (Engle Kane, *et al*., 1999; Engle, Tuholski, *et al*., 1999) and consistent with earlier studies on children (Alloway *et al*., 2004, 2006; Gathercole *et al*., 2004; Kail and Hall, 2001; Swanson, 2008). However, the study provided little evidence for that working memory and short term memory are less distinguishable in younger children than in older children or adults. Complex span measures were seen to predict the performance on the Raven's Colored Progressive Matrices. Moreover, short term memory was not seen to have any specific links with Gf (fluid intelligence) when the complex span tasks was considered. The findings did not provide evidence on the proposal that the connection between fluid intelligence and working memory is supported by the short term memory capacity (Colom, Flores-Mendoza, *et al*., 2005; Colom *et al*., 2006, 2008); however, supporting the view that cognitive control mechanisms serve as a basis for the working memory capacity and fluid intelligence (Conway *et al*., 2002; Engle, Tuholski, *et al*., 1999; Kane and Engle, 2002).

Indirectly linking working memory with the lexical comprehension and production for the learners who studied and had not studied abroad, Sunderman and Kroll (2009) examined whether a specific level of internal cognitive resources is needed for the learners to benefit from studying abroad experience. For this purpose, forty-eight participants who were the native English speakers studying Spanish at a university in the United States took part in the study. Some of the participants had experienced of studying abroad. The participants were given a language history questionnaire for their L2 experience and the

proficiency in English and Spanish. Among the participants, thirty-four of them had not studied abroad while fourteen of them had. A reading span measure designed by Waters and Caplan (1996) was used as a working memory capacity test in which the participants had to judge the semantic plausibility of the sentences. The comprehension measure included a translation recognition task and the participants had to determine if the two words were the translation equivalents of each other. Another measurement used in the study was the production measure including a picture naming task. The participants had to name the pictures displayed as quickly as possible. Discussing the relationship between working memory and study abroad experience, the researchers proposed four hypotheses regarding this relationship; a) the *internal resource hypothesis*, b) the *external cue hypothesis, c)* the *interaction hypothesis* and d) the *threshold hypothesis.* The *internal resource hypothesis indicates* the ability to understand and produce quickly and accurately in the L2 which depends on working memory resources. *The external cue hypothesis* proposes that information salient in the L2 environment would give learners opportunities with which they directly process L2, not an opportunity possible in the classroom. The *interaction hypothesis* claims that learner outcomes display a mix of external and internal factors. The *threshold hypothesis* claims that the benefits of an immersion context during study abroad may not give an additional benefit to all individuals. Based on these hypothesis, the results of the study revealed that cognitive resources and L2 learning experience have an affect on L2 processing but the interactive effects of both (cognitive resources and L2 learning experience) are highly connected to L2 production. The production tasks indicated that people who do not have a certain threshold of resources cannot make of use of studying abroad context in terms of accurate production in the L2. Contrary to that, it was also seen

that individuals with higher working memory capacity benefit more from the study abroad experience.

Adams, Bourke and Willis (1999) fundamentally examined the predictive power of the working memory in individual differences in spoken language comprehension and investigated which components of working memory are associated with children's spoken language comprehension. Being one the earliest attempts on working memory research, the study included three hundred and ten children aged between 47 and 63 months. Phonological memory tests consisted of non-word repetition, Memory span for words and digits. The tests for nonverbal ability included four subscales; a) object assembly, b) block design, c) mazes and d) animal pegs. The second phase of the study was shaped by the scores and tests in the first phase. The participants were selected based on their nonverbal ability and their phonological memory skills. Sixty-six children took part in the second phase of the study. Visual-spatial memory ability and central executive functions were measured. Visuo-spatial memory ability was measured with corsi-blocks, visual patter span test and listening span test. In corsi blocks the participants had to display the sequence of randomly spaced blocks. The participants had to remember the positions of the filled cells in the matrices in the visual pattern span test. The participants had to complete the sentence with a final and also had to remember the correct word order. The participants were asked to come up with examples on two categories of animals, food and drink in the search and retrieval from long term memory test for the central executive functions. Another test for the central executive functions was dual-task coordination. The last test was sustained attention to response task (SART) in which the participants had to press the button as soon as they saw the stimuli that was initially displayed. Vocabulary and language comprehension were also assessed in the study. The study showed the relations between individual differences in vocabulary knowledge and

children's working memory skills. Moreover, the link between vocabulary comprehension and phonological memory was significant through the regression analyses. The relationship between the language comprehension and listening span and phonological memory skills was seen in the study. When it comes to the question of which components of working memory are connected with children's spoken language comprehension, no significant correlation was observed between these two constructs. The verbal fluency measure was the one which could define and underline the link between working memory and language comprehension.

As a result, it is evident by the studies discussed above that working memory has a connection with the intelligence either in a direct or indirect way. Moreover, working memory is a subcomponent of intelligence while defining the individual cognitive differences.

2.5. Measurement of Working Memory

Span tests differing in forms and modes have been used for the measurement of memory capacity in the field of cognitive science. The core rational behind the span tests relied on the capacity of storing the knowledge for a period of time. The first attempts in measuring memory, although the means have come a long way, were shaped by the working memory model proposed by Baddeley and Hitch (1974). The model, as discussed in details throughout previous sections, was an alternative to the previously proposed model of working memory with its multi components responsible for individual functions. These improvements in clarification of the functional aspect of working memory shaped the span tests used for working memory capacity. From this sense, memory demands in the span tasks were designed in accordance with the functional components proposed in the working memory model by Baddeley and Hitch (1974). The tasks offer either a simultaneous demand

individually on storage or a simultaneous demand on both storage and process. The distinction in the memory demands of the tests determines either it is a simple span task or a complex span task. In a broad sense, the distinction between short-term memory and working memory determines the nature of the span task. The basic structural difference in the tasks is defined with various names. Broadly, the span tests are categorized into two according to the construct they intend to measure. One of them is the simple span test which is used for the measurement of short term memory capacity in which the test taker retrieves the stimuli for a period of time. The other one is the complex span test which requires the test taker to store and process the knowledge simultaneously.

When both simple and complex span tests serving for the measurement of memory are examined, it is clearly seen that the nature and the structure may display differences. The span tests can include any stimuli that can be stored for a period of time. The literature contains span tests in which a) number digits, b) letters, c) words, d) sentences, e) equations, f) shapes and g) colors are used within various modes.

To be more precise, the simple span task includes only one process to be followed by the test taker. The test taker is asked to follow a number of sets of items either displayed on a computer screen or verbally presented one by one. It is expected to recall them individually. The way how to report the items recalled may vary as the study may either accept items in the right order as they are displayed or may accept the items recalled in any order.

The complex span tests differ from the simple span tests as they include two tasks to be carried simultaneously. The test taker has to carry out two tasks at once, one of which functions as a distractor. One of these tasks taps into the storage and the other requires a process. Making a grammatical or a semantical judgement while at the same time retrieving the final word of the same sentence or verifying a mathematical equation while storing a

word may be considered as examples of complex span tests. In these examples verifying a mathematical equation requires a process and retrieving a word requires the storage. Though the test takes place in a laboratory setting, the cognitive process reflected through the span tests resembles the natural daily cognitive practices carried out by the human kind. As presented earlier in previous sections, the complex span tests showed significant correlations with cognitive processes regarding learning and language. The wide and common use of span tests in different subfields of cognitive science has added new dimensions to the nature of the span tests. The scope of the test has been extended through the administration in various languages, which has illuminated the cognitive processes of population coming with varying language backgrounds or of the bilingual populations. Beginning with Osaka and Osaka (1992) who tried to see if working memory capacity is independent of language, the span tests serve for a wide array of population coming from distinct languages.

Although they are consistent with each other regarding the nature and the mode, the span tests, either complex or simple, serve with diverse ways of application. So as to get more reliable source of data through the span tests, the tests can be developed in consideration with the response time spent during the tests. The time interval between the sets of items may be fixed beforehand and the test taker remembers to report the answer in the given time period. On the other hand, to measure the speed while recalling and reporting the responses during the execution of the test, the test may be developed in accordance with tracking the response time in which the test taker proceeds on his/her own within the sets. The track of response time provides measures for the efficacy and the speed of the memory other than a core measure for memory capacity.

The items in the span tests are organized around the sets with an increasing pace throughout the test. For example, the first set may have three items in each sub-set and may

include three sub-sets, the second set may have four items in each sub-set and may have four sub-sets. The expansion of the test may go up to seven items with five or six sub-sets. However, the language used may change the structure or the length of the span test. Any language may offer up to twelve words for a semantically meaningful sentence in a span test but another language may go up to sixteen words while doing the same. The structural aspect of the language may also determine the mode of the span test. One language may offer the recall of the final word of the sentence in span test, but the final words may come out of the same pool of words in some languages, which makes it reasonable to ask to recall the first words of the sentences displayed.

As the span tests require a list of complicated procedures to be followed by the test taker, how and where they are administered can jeopardize the reliability of the test. For that reason, the span tests are given individually in a laboratory setting where each test taker will need have personal access to a computer and will not distract other test takers and will not be distracted either. Individually presented tests are claimed to lead to healthier experiment conditions. As writing and speaking span tests require the production of the language, the outcomes need to be handled cautiously by the experimenter not to cause any rater's impact on the results. The scoring process may need to have two raters to provide intra and inter rater reliability. The time given in a span test is another factor that may affect the reliability especially for the directly translated version of the span tests. The test timing should be taken into account the language. For example, it may not take the same time to pronounce the numbers in digit span test given to the individuals coming from two different languages. Rate of the presentation is another issue that needs to be considered in span tests. A pilot study may help to see the efficacy and the practicality of the tests in terms of time. The instructional phase of the test is yet another issue to be considered before the test

administration. The test takers must figure out how the process will be followed and keep the required conditions during the test. Being a demanding procedure, the administration of the test is usually provided with the trials at the beginning. The trials familiarize the test takers with the procedures. The literature supports the need of being cautious for the test administration as the nature of the test determines the construct to be measured. For example, reading silently or aloud the items can lead to the inclusion or exclusion of the phonological component of working memory.

2.5.1. Reading Span Test

The reading span tests serve as one of the fundamental measures in memory research. Being practical and functional, the test can be prepared for the populations with different language background and also with different ages. An ordinary reading span test may include a set of sentences to be read aloud and the final words of these sentences are needed to be recalled. The sentences are presented in sets. The nature of the reading span tests may also include both the storage and the process. Considering the reading span tests with a multitask nature, the reading span test aims at measuring the working memory capacity through two tasks, which tap on storage and process. As the storage function indicates a passive way of retrieving knowledge, the working memory capacity measurement requires the inclusion of the process function. From this point of view, reading span tests collegiate two separate tasks in a multitask nature providing a practice reflecting an authentic cognitive process. To be more precise, the general structure of a reading span test includes sets of sentences up to a specified number, the number of which increase throughout the test. Generally beginning with two or three sentences and going up to five or six sentences, the test requires the test taker to read the sentences aloud and remember either the first or the last word of the sentence. In addition to the recall of the final word or the first word of the sentence, the test

taker is loaded with another task taping onto the process aspect of the cognitive sources manipulated during the test. Although the general structure of span tests with the two tasks occurring simultaneously proceeds throughout each set, the procedural aspect of the test may vary with various alternatives. The common process is grammatical judgement or semantical judgement. The scoring of the reading span tests is seen to have a number of alternatives. The traditional way of scoring proposed in the literature is the one in which the highest level of the recalled items is counted among the trials, such as two out of three sets (Daneman and Carpenter, 1980; Miyake, Just, and Carpenter, 1994). Moreover, the scoring may also include the counting the total number of the words recalled sets (Engle, Tuholski, Laughlin, and Conway, 1999; McNamara and Scott, 2001; Friedman and Miyake, 2000; Tirre and Peña, 1992; Turner and Engle, 1989), or the average number of the words recalled across all sets (Kane *et al*., 2004). Friedman and Miyake (2005) discussed the ways to score the reading span tests under four basic titles in their study in which they compared these four common methods. The scoring method '*total words' refer to* the number of the words remembered in the test. The method '*proportion words'* covers the average score of the words remembered out of the words in each set. *'Correct sets words'* method includes the total number of words recalled perfectly in sets. The last method '*truncated span'* includes scoring the test with the highest level of the words recalled a majority of sets. The strength of the reading span tests has been a matter of concern leading to research on the issue. Friedman and Miyake (2004) tried to see the predictive power of the tests on reading comprehension and also examined if the strength of the test varies along with the way it is administered. The study on the power of the reading span test showed that the way the tests are administered affects the results and the validity of the measurement. The process time given in the test and the sentence position have also seen as factors affecting the validity of the reading span tests through the study

from Friedman and Miyake (2004). Other than that, the impact of interference during the administration of reading tests was a question for Lustig, May and Hasher (2001). The study on the proactive interference in span tests revealed that the interference has an impact on the success of reading span test. It is obvious that the way of administration and the content of the reading span tests have a determining impact on the measurement of the working memory capacity. The reading span test has shown that it has a correlation with retrieval and inference skill (Daneman and Green, 1986), a correlation with syntactic processing (King and Just, 1991) and also lexical ambiguity resolution (Miyake, Just and Carpenter, 1994). The reading span test has also shown its strength in predicting the individual differences in reading comprehension (Daneman and Carpenter, 1980; Daneman and Green, 1986; Just and Carpenter, 1992; Masson and Miller, 1983; Pamler, MacLeod, Hunt and Davidson 1985).

2.5.2. Listening Span Test

Being quite similar to reading span tests, listening span test covers the phonological aspect of the cognitive process. A general structure of a listening span test includes verbally presented sentences in sets through which the test taker is expected to make either grammatical judgement or semantic judgments while at the same time the final word or the first word has to be recalled. It is claimed that listening span tests can predict the comprehension in reading with it is multitask nature which requires both storage and process (Daneman and Capenter, 1980). The nature of the listening span test includes the sets of sentences like it is in reading span tests. The responses for the listening span tests may be recorded through a computer program or by the experimenter. The basic difference between the reading span tests and listening span tests lies in the cognitive channels they address. In a commonly used reading span test the test taker is expected to read the sentences aloud, which addresses the visual and phonological channels at once. However, the listening span

tests address only the phonological channel of the cognitive processing. In this sense, the phonological loop among the working memory components in the proposed model by Baddeley (1986) is activated and exploited during a listening span test, whereas the visual sketchpad and phonological loop would be exploited during a reading span test. As in every test, the reliability has been a matter of concern also in listening span tests. Salthouse and Babcock (1991) discusses in their study on adult age differences on working memory the internal consistency of the listening span tests done by split-half reliability. The results of the split-half reliability analysis showed 0.86 correlation degree for listening span tests used in the two experiments of the study.

2.5.3. Operation Span Test

Simply relying on the process and storage functions of memory, operation span tests included the general logic of the complex span test. The first and the earliest development of the operation span test was an attempt by Turner and Engle (1989), who had eighty-four mathematical equations. Being proposed as an alternative span test to reading span test, the first operation span test included a mathematical operation followed by a word to be remembered. Including mathematical equations rather than the sentences to be judged, the operation span test has the advantage of excluding the reliance on language (Conway *et al*., 2005). The less reliance on the language leads to a domain-general working memory capacity requiring a broad knowledge instead of domain-specific working memory capacity (Turner and Engle, 1989). However, Engle *et al*. (1992) modified the first version into a new one similar to the operation span tests being used today. The major difference between the first operation span test and the later versions was the manipulation of presentation order. The later version from Engle *et al*. (1992) had a randomized presentation order instead of

the operations span test items presented in an ascending order, such as the fewer items presented first.

2.5.4. Speaking Span Test

Having the same nature with writing span tests, the speaking span tests tap on the process and storage aspect of the working memory through the tasks of verbally producing a sentence after the display of a set of words. A common speaking test has sets of one-syllable words appearing individually with a specified interval, and the test taker is expected to recall the words and is expected to produce sentences verbally. The earliest uses of speaking span tests were seen in studies by Daneman and Green (1986) and Daneman (1991). The studies using speaking span test examine the speech production which is one of the productive skills. In a daily basis the nature of speaking requires the recall of the message to be conveyed and conveying the message through the sentences uttered. From this sense, speaking span tests reflect the daily and authentic process of speech production. The words to be recalled can be conveyed and the sentences uttered around the words recalled can be considered as the speech produced among the interlocutor. However, the nature of the speaking span tests may be modified based on the strictness of the experiment. Weissheimer and Mota (2009) used speaking span tests in the study examining the individual differences in working memory capacity and the development of L2 speech production, two ways of scoring were used. The strict speaking span test score included the sentences produced with the target word in the exact form and order of the presentation. The lenient speaking span test score included the sentences as long as they are produced with the target word, without considering if they are in the exact form and in order as they were presented. Each score type did not credit the ungrammatical sentences.

2.5.5. Digit Span Test

Digit span tests are used to measure working memory capacity through the numbers. A series of digits are presented to the test takers and the test taker is expected to repeat them verbally. The sets of digits proceed in an ascending order. The way the digits are displayed may vary up to the purpose of the study. The digit span tests usually tap on the verbal storage aspect of the cognitive sources. The verbally presented digits need to be recalled and reported verbally back. In this way, the phonological aspect of the working memory is activated and manipulated. As the digit span tests are used to store a set of digits without any manipulation of procedural cognitive sources, they are considered as simple span test (Engle *et al*., 1999). Digit span tests are seen to have two versions; a) forward digit span test, b) backward digit span test. As the names of the span tests reflect, the forward digit span test requires the test taker to recall the digits and report them as they are presented. The backward span test asks the test taker to remember the digits and report them in reverse order. The digits are presented in order with a specified interval. For example, one seconds and the number of digits presented in each string can go up from three to nine digits. The responses are recorded and the test end when the test taker fails in two consequent trials. The longest list recalled by the test taker is considered as the digit span. The common claim on the average number of digits that can be recalled is said to be up to seven digits (Baddeley, 1999).

Although reading span tests are the most commonly used ones in the literature, as discussed above, there are different span tests, such as a) listening, b) operation, c) speaking and d) digit span tests, each of which focuses on different channels of storage, such as visual or verbal to measure working memory. In other words, while speaking span tests ask for the test taker to report the items retrieved verbally, listening span tests may ask the test taker to retrieve the last word of the sentences and make grammatical judgements on the sentences

given. From this sense, the present study uses reading span test together with production span test, which is discussed in the following sections.

2.5.6. Writing Span Test

With inclusion of complex span tests as an alternative way of measuring working memory, the span tests were shaped in consideration of the construct that the working memory is expected to predict or to have a relationship. In other words, the best way to see the relationship between listening skill and working memory capacity would be using a listening span test or to see the relationship between reading skill and working memory capacity would be using a reading span test. Parallel to complex span tests including the focus of the construct to be examined, writing span tests are considered to measure the working memory capacity through a process resembling the one in writing process. The performance in a writing span test can be reflected through the percent of words recalled and mean sentence length, however, the core expectation has been the structurally and semantically correct sentences. In a common writing span test participants are asked to follow a list of words presented in sets in an ascending order. Each word displayed can only be used in one sentence and cannot be used as the first word of the sentence. Moreover, the last word displayed cannot be used in the first sentence uttered. Semantically and structurally correct sentences complying the instructions counted as the score referring to the working memory capacity through writing span test. Different modified versions of writing span tests can be seen in literature. The one used by McCutchen, Covil, Hoynes and Midles (1994) included the detection of the misspelled words in sentences and the recall of those words to insert into a story. The recent use of the writing span tests is seen in the studies (Alamargot *et al*, 2007; Chuy, Alamargot and Passerault, 2012) which aimed to see the relationship between writing skill and working memory capacity through the writing span tests. In

connection with the skills other than writing, Levy and Ransdell (1995) claimed that individuals with high reading comprehension ability are reported to have advantageous strategies during the writing span tests reflecting their strategy use in process and storage aspect of the memory. Considered to be more a difficult test than the reading and listening span tests, the writing span tests also has received the criticism on reliability. The major criticism came when the measurement considered the quality of the sentence in terms of length (Levy and Ransdell,1996). If the test takers are asked to write their best and the longest sentences, the nature of the test will not reflect the authentic process of an essay writing, and will lead to a drop in the number of the words recalled and affect the fluency. On the other hand, if the test takers are asked to write short sentences, the nature of the test will again not reflect the authentic process of an essay writing but increase the number of the words recalled.

2.7. Working Memory Training Programs

Memory enhancement has been an issue for the human beings dating back to the times when the need for keeping knowledge in mind was felt. As there was no device to store the knowledge, the early attempts relied on developing some methods through which the core cognitive burden on the mind would be decreased. Among those were the mnemonics which were devised by the Ancient Greeks so as to connect the unrelated ideas (Patten,1990). Throughout the history, the methods devised for the knowledge retention have been shaped in different ways up to the need. Association through the numbers, letters and images aided to retrieve the unrelated chunks of knowledge. The logic behind the association was to link any known mental representation with another mental representation to be retrieved. However, the efficacy of using different methods of retrieval has been a matter of concern. Although the strategies used to retrieve information is reported to be effective, the level of

the effectiveness is seen to vary among different age groups (Levin *et al*., 1992; O'Hara, 2007; McAlum *et al*.,2010, Brothle, 2011).

Changing and improving throughout the time, the training programs on memory enhancement were shaped in accordance with the technological developments. Technology contributed to the memory enhancement programs in a way that any individual could have opportunity to have access to a number of practical online training programs offered in the market. Although the nature of the training programs offered has different versions, the overall aim is reported to be improving and strengthening the cognitive abilities of the followers. In other words, the memory enhancement training is one of many other cognitive skills that can be improved through the online cognitive training programs. The fundamental difference among the training programs focusing on cognitive skills is that some offer free access to the training, whereas some ask the user to pay some amount of money. The registration options may differ according to the service to be received. The training programs offer tests to determine the cognitive needs of the individual before the training so as to make the training purposeful. Among the sub-cognitive skills are attention, speed, working memory which are the basic ones to be improved through the cognitive training programs available nowadays. (See Table 2)

Table 2. Working Memory Training Programs

Program	Publisher	Address	Qualities	Cognitive Skills
Brain Metrix	Digital Millenium	www.brainmetrix.com	Free access No registration No track of the trainings	Brain Reflection Test Brain Creativity Memory Test
Cogmed	Pearson Education Inc.	www.cogmed.com	Not free access Registration Tracking the trainings	Working Memory

Neuro Nation	Neuro Nation Team	www.neuronation.com	Free access Registration Tracking the trainings	Memory
Cogni Fit	Cogni Fit Ltd.	www.cognifit.com	Not free access Registration Tracking the trainings	Memory Working Memory Process Speed Attention Planning
Lumosity	Lumos Labs Inc.	www.lumosity.com	Not free access Registration Tracking the trainings Needs Assessment Training Reminders Access with multiple devices	Memory Attention Speed Flexibility Problem solving

2.6. Studies on Working Memory Enhancement

Considering the nature of memory, it is only recently possible to assess working memory enhancement through computational programs. Though not abundant, the literature includes few studies covering working memory enhancement.

Owen *et al.*, (2010) examined the impact of cognitive training on the cognitive functions through a computerized brain-training program. The study aimed to understand whether it is possible to improve cognitive abilities through computerized-programs and also to examine if any improvement in any cognitive ability can be transferred to other cognitive domains. The study included a six-week long online training of 11 430 participants. The study covered training on reasoning, verbal short-term memory, spatial working memory and paired-associates learning. The study revealed that there was a modest improvement for the cognitive functions on which the participants were trained, however; the improvement in those cognitive abilities were reported not to be transferred to other domains of cognitive

abilities. That is to say, Owen *et al*., (2010) put forward, in the light of the study, that improvement in any cognitive ability cannot be transferred to other cognitive abilities.

Being one of the studies including Lumosity for the cognitive improvement, Hardy *et al*., (2011) made use of Lumosity in order to see whether working memory capacity can be enhanced through a web-based program. The participants in the experimental group in the study were the volunteers who followed the cognitive training for five weeks once a day for twenty minutes and the participants in the control group were the ones who did not receive any cognitive training. The basic aim of their study was to see whether the cognitive abilities of healthy middle-aged adults can be improved. Visual attention and spatial working memory were the cognitive abilities that the training aimed to improve. The results of the study showed that the group which received training improved significantly more than the group not having training in visual attention and working memory.

Tulbure and Siberescu (2013) had a study so as to see if the working memory capacity can be increased through training. The participants were fifty young healthy adult undergraduate students who took the working memory test (Miclea and Domuta, 2003) a modified version of the letter number sequencing scale (Wechsler, 1997) which consists of numbers and letters presented verbally to the participant. The participants were randomly assigned to either the control or the experimental group in the study. The participants were given the memory tests before and after the online working memory training consisting of five modules for three weeks. The study showed that cognitive training led to significant improvements for the participants in the training group.

Carretti, Borella and De Beni (2007) tried to see the impact of strategic training on the performance of younger and older adults in working memory tasks. Participants were thirty younger adults and thirty older adult, all of whom were all native speakers of Italian.

Fifteen participants from each group were assigned to either experimental or control group in the study. The participants took two tests for the measurement of the working memory capacity. Immediate list recall task was one of the working memory tasks used for the memory capacity measurement in which the subjects were asked to remember as many items as they could. Categorization working memory span task (De Beni *et al*., 1998) included the lists of words presented at a specific rate in which the participants were asked to tap their hand on the table when they heard an animal word and also they were asked to recall the last word of each list at the end of the series. The participants in both groups had five sessions within two weeks; however, the participants in the control group were not instructed to use any strategy. The analysis included the comparison of control and experimental groups regarding also the age; younger and older adults. The results gave strong evidences on the positive effect of the strategic training for the enhancement of working memory and immediate recall both for the younger and older experimental group. The results also revealed that the performance of younger and older experimental groups in working memory task and the immediate recall measure was comparable regarding the gains of the training.

Holmes, Gathercole, and Dunning (2009) wanted to see if any adaptive training will help the children with poor working memory. The participants were selected among the children who scored low on two tests of verbal WM, listening recall and backward digit recall, a version of AWMA (Alloway, 2007). Forty-two children participated in the study, twenty-two of which attended the adaptive program and twenty of which attended non-adaptive version of the program. The pre tests for the memory included five subtests of AWMA, through which the verbal short term memory, visuo-spatial short term memory, visuo-spatial working memory, and verbal working memory were tested. The post tests included eight subtests on verbal short term memory, visuo-spatial short term memory,

visuo-spatial working memory, and verbal working memory. Working memory training took twenty days in a computerized game environment. Two versions of the training program were used in the study. The standard adaptive version had the level of task difficulty matching with the participant's current memory span on a trial-by-trial process for the task. The non-adaptive version had a fixed level of task difficulty throughout the training period. The participants completing the adaptive program were observed to have improved working memory capacity. However, the adaptive training did not lead to a significant change on verbal short term memory.

As a result, although they are few, these studies discussed above focused on the working memory enhancement using different tasks to improve working memory capacity. Among these, two of them (Owen *et al*., 2010; Hardy *et al*., 2011) used Lumosity as the working memory training program. From this sense, the instruments or programs used in recent studies to improve working memory capacity include limited computational programs either developed by the researchers or developed by commercial purposes. The present study uses Lumosity as the computational program to improve working memory capacity. The following section discusses and compares the available programs, also including Lumosity, to improve working memory capacity.

2.7.1. Lumosity

The present study used Lumosity in order to give an eight-week long training to the participants assigned to control and experimental group. The online cognitive training programs available on lumosity were evaluated through the meticulous examinations during the design of the research in terms of their functionality and practicality. So as to be sure for their functions, the programs were used for a short period of time and also the publisher was asked to provide some details on the track of the data to be stored during the study while the

participants are following the online training program. All things considered, the major reasons for including Lumosity as the working memory training program into the study can be explained in the sub-topics given below;

a) Lumosity has a user-friendly template. Lumosity offers the users access to the applications to follow and the users can see their progress throughout the training by the help of template on the website. The registration allows the users to have a username and a password with which the training can be followed on any device with an internet access. Upon the preference, Lumosity sends regular emails to the users to remind their daily training and also offers the users to proceed up to the desired or pre-determined number of training sessions.

b) Lumosity has practical applications. Above all other reasons, Lumosity offers a number of applications which work for the improvement of different cognitive skills. Working memory is one of the five subskills which are flexibility, speed, memory, attention and problem solving. The cognitive training is given through the games which either implicitly or explicitly covers one the sub-cognitive skill. The user goes through a number of practices provided with the games. The training may focus a number of sub-cognitive skills or only one sub-cognitive skill at once. The user can also shape his personalized training with going though a number brief questions asking the needs felt by the user in daily life practices. The overall number of the games offered around five sub-skills reaches up to forty games.

c) It is easy to track the training of the participants on Lumosity. The main reason apart from the others lies in the feature to track the training of the participants by the researcher. In other words, researcher can follow the progress of the online training followed by the participants during the study. Considering the need to complete the research in a

specified time period, the attendance and the progress of the participants are quite essential for the validity and the reliability of the study. In an individually followed online training it is hard to follow the track of the progress with a number of participants taking the training at the same time. From this sense, Lumosity provides daily report to the researcher with the detailed progress of the participants. This report helps the researcher to remind the participants to follow the daily training to go hand in hand with the other group members. Lumosity also gives the researcher the opportunity to shape the training of the participants, which is to say that the researcher makes up a pack of applications for the participants and the participants cannot go out of the loom because of their individual preferences on the training program. The completion of the training with the exact number of participants as planned can only be achieved and attained in an online training setting by following the progress of the participants in regular and daily basis.

Taken together, compared to the programs available on working memory training, Lumosity provides more functional and practical features, such as easy access and easy track. For the all features discussed above, the present study uses Lumosity for the working memory training.

2.9. Studies on Working Memory and Language Learning

Although not focusing on a specific domain of language, such as listening, speaking, reading and writing, studies were conducted on the relationship in general between working memory and language learning in regard to participants with different L1 and L2 backgrounds (Ellis and Sinclair, 1996; Noort, Bosch and Hugdahl, 2006; Kormos and Safar, 2008; Abreu, Gathercole and Martin, 2011; Tagarelli, Mota and Rebuschat, 2011).

Working memory has been the focus of the studies examining language learning. Being one the first attempts to investigate the relationship between working memory and

language learning, the study carried by Ellis and Sinclair (1996) focused precisely on the contribution of the role of articulatory rehearsal in phonological short term memory to language learning. Eighty-seven non-Welsh- speaking students in an undergraduate program participated in the study. Participants were instructed on the English translations of Welsh utterances. The instruction phase was carried out in three conditions. Participants in the silent condition remained silence. Participants in the repetition condition always repeated aloud the Welsh utterances after they heard them. The participants in the articulatory suppression condition counted from one to five while listening to the Welsh stimuli and typing in the correct translations. Three tests were given to the participants after the learning phase. The well- formedness test covered the elicitation judgments of grammatical correctness. The rule test phase examined the explicit metalinguistic awareness of the rule structure. The speech production test assessed the oral production of the utterances heard previously in Welsh. The results clearly demonstrated that rehearsal in phonological short term memory provides advantages on language-learning. Moreover, it was seen that short-term repetition of foreign language utterances leads to the consolidation of long-term representations of words and word sequences.

Masoura and Gathercole (2005) wanted to see the relationship between short-term memory skills and children abilities to learn the vocabulary of a foreign language. Forty-five children at a primary school in Greece, aged between 8 years and 11 years were the participants of the study. The Children's Test of Nonword Repetition (Gathercole and Baddeley, 1996) was used for the phonological short-term memory. Each child was given Raven's Coloured Progressive Matrices (Raven, 1986) for the nonverbal ability. Two measures of receptive and productive tests were used for the native vocabulary knowledge. The participants took two tests for the knowledge of English vocabulary, both involving

translation between the spoken English and Greek forms of words. As a result, the study showed significant correlations between children's phonological memory skills, measured by nonword repetition accuracy, and their knowledge of vocabulary in both native and foreign languages.

In addition to these, Noort, Bosch and Hugdahl (2006) carried out a study so as to see if the working memory capacity has a connection with (foreign) language proficiency in the multilinguals. The subjects were twelve Dutch native speakers having fluency in German (L2) and were the learners of Norwegian (L3) for the last 6 months. Twelve native Germans and twelve native Norwegians took part in the study and were only tested in L1. Reaction times and reading span were measured with a computerized version of reading span task in Dutch, German and Norwegian. Digit span and letter-number ordering tests were also given to the participants. The study showed parallel results with the previous findings that the performance on working memory task differs between native language and foreign languages. With the evidence from the comparisons of the total number of words remembered in Dutch, German and Norwegian, the researchers claimed that the functional working memory capacity was higher in L1 than in L3 and also that working memory capacity has an interaction with language proficiency. Parallel to Osaka and Osaka (1992), the study showed significant correlations for the multilinguals between the scores on the reading-span tasks in Dutch, German, and Norwegian.

Kormos and Safar (2008) examined the connection between phonological short-term and working memory capacity and performance in English test including reading, writing, listening, speaking and use of language. A hundred and twenty-one secondary school students aged 15–16 in a bilingual education program in Hungary participated in the study. Participants took a non-word repetition test, backward digit span task, and Hungarian version

of the non-word span test for the phonological short term memory. A Cambridge First Certificate Exam, having five sections on different domains of language, was given to the participants for the language level. However, the researchers could not find a meaningful correlation between performance on the backward digit span and the phonological loop task, and they claimed that the general working memory and phonological loop are distinct constructs. With these results, the study highlighted that the role of phonological short-term capacity differs beginners and pre-intermediates. The study also showed that there is a high correlation between the overall English language competence and the backward digit span test.

Similarly, Abreu, Gathercole and Martin (2011) had a study in order to see the relationship between working memory and language in young children growing up in a multilingual environment. Participants were 119 Luxembourgish 6-year-old children, who took the complex span and simple span tests for working memory. Furthermore, fluid intelligence through Raven's test (Raven, Court, and Raven, 1986), rhyme awareness, Luxembourgish and German expressive vocabulary level, syntax and letter decision (Baddeley, Gathercole, and Spooner, 2003) for reading were determined in the study. The results through the correlation and regression tests confirmed that different components of working memory interact differently with the language learning process as seen through the interaction of simple and complex span tests with language learning. Precisely, vocabulary knowledge and verbal short-term storage were strongly related to each other and also the contribution of verbal short-term storage to the syntactic comprehension was seen through the results. It was also seen that the contribution of verbal short-term storage to the syntactic comprehension was mediated by vocabulary knowledge.

Tagarelli, Mota and Rebuschat (2011) examined the relationship between L2 learning and working memory with 62 native speakers of English with no background of L2 language. The aim of the study was to see if working memory has different effects on learning under implicit or explicit learning conditions. The study had two groups: incidental and rule-search. The experimenters used a semi-artificial language consisting of English words and German syntax for the study. The participants took two sessions of training; a session on an artificial language learning and a session on WM. Artificial language learning session consisted of two parts. The exposure phase included the presentation of 120 instances of the artificial language randomly and the testing phase covered the rule-judging of the sentences according to the rules shown in exposure phase. The working memory capacity was measured through the operation-word span task (OWST, Turner and Engle, 1989; Unsworth, Heitz, Schrock and Engle, 2005) and the letter-number ordering task (LNOT, Wechsler, 1997). The results revealed that WM does not affect learning syntax in L2 in incidental learning conditions, but affects learning it more in explicit conditions.

As a result, the studies individually showed the correlation between working memory and a) language learning (Ellis and Sinclair, 1996), b) vocabulary (Masoura and Gathercole, 2005), c) language proficiency (Noort, Bosch and Hugdahl, 2006), d) language competence (Kormos and Safar, 2008), e) language learning (Abreu, Gathercole and Martin, 2011), f) implicit and explicit language learning (Tagarelli, Mota and Rebuschat, 2011).

2.10. Studies on Working Memory and L2 Reading

Studies were carried out to see the relationship between working memory capacity and language skills. Among these skills, reading is the most investigated skill in the literature with the studies focusing on different component of reading skill with participant groups having different language backgrounds (Baddeley and Wilson, 1988; Rai, Loschky,

Harris and Peck, 2011; Naumann *et al.*,2008; Payne *et al.,* 2009; Abu Rabia ,2001; Dyke, Johns and Kukona, 2014; Pae and Sevcik, 2011; Fontanini and Tomitch, 2009; Friedman and Miyake, 2004; Chun and Payne, 2004; Walter, 2004; Alptekin and Ercetin, 2009; James, Krishnan and Aydelott, 2014; Otten and Berkum, 2009).

In as single case study, Baddeley and Wilson (1988) examined a participant, T.B. who could only store a digit span of two items and a sentence span of three words. His working memory capacity was measured with a) digit span test, b) Phonological Similarity c) Word-Length Effect d) Free Recalll e) Sentence Span tests. Phonological processing was tested through sound matching task, auditory word checking, phonological awareness, and rhyme judgement tests. The results showed that T.B. had serious problems with the short term memory. After a series of tests given to T.B, he was compared to K.J who is an amnesic control patient in the second phase of the study. With the similar tests including word reading, sentence reading and verification, Trog reading. He was tested for the auditory comprehension through the sets of 16 simple, 16 verbal, and 16 complex sentences in which he was asked to determine if these sentences were true or false. The results showed that he had serious problems in comprehending the long sentences. Another test was given to TB in which he was read individual sentences and he was asked to show the picture linked to the sentence. T.B. got low scores almost equal to Broca's aphasic patients although he was not aphasic. Bishop's (1982) Test for the Reception of Grammar (TROG) was another test used in the study. Trog included 80 sentences split into 20 sections, and the comprehension of each sentences was tested by asking the participant to show one of the four sentences. The results highlighted that that T.B. had serious impairment in the comprehension of both spoken and written material. It was also clear that he had deficit in short term memory performance which was parallel to a problem in the functioning of the articulatory loop

component of working memory. The researchers cautiously claimed that the evidence gathered in the study showed that T.B.'s comprehension deficits are caused by his big impairment in short-term phonological storage; however, they could not find any evidence to explain the syntactic processing deficits.

Together with the effects of stress, Rai, Loschky, Harris and Peck (2011) examined the impact of working memory capacity inferential processing for reading. Accepting that working memory capacity predicts strongly the comprehension in reading while reading in first language and foreign language, six different hypotheses were proposed by Rai, Loschky, Harris and Peck (2011) in reference to the literature on a) working memory, b) stress, c) inference type d) interaction of stress and WM, e) interaction of inference type and WM, f) interaction of stress and inference type. The participants were English native speakers with the intermediate level of Spanish as foreign language from a university in US and the level of Spanish reading proficiency was recorded based on their self report. The participants were given Foreign Language Reading Anxiety Scale (Saito *et al.,* 1999) which includes the self reports of the participants on a) anxiety over some aspects of reading, b) reading difficulties c) comparative difficulty of reading among other skills. The STAI-Trait Anxiety Inventory (TRAIT) and The STAI-State Anxiety Inventory (STATE) were the tests given for the anxiety level measure. Automated Operation Span Task was used for the working memory capacity and a Reading Comprehension Task for measuring foreign language readers' inferences ability for comprehension in Spanish. Rai, Loschky, Harris and Peck (2011) interpreted the results referring to the consistency with the Attentional Control Theory. The overall study highlighted the learners with high working memory capacity used reading speed (processing efficiency) for a better comprehension accuracy (processing effectiveness). However, the learners with lower working memory capacity had the stress

impeding the comprehension accuracy. The results show that, together with the interactions between WM capacity and inferential complexity, stress stands as a hindrance in foreign language reading comprehension.

Naumann *et al.* (2008) investigated the effectiveness of strategy training, and working memory resources on the learning with hypertext. Throughout the study including three dependent variables; reading skill, strategy training and working memory, the researchers gave either cognitive or metacognitive strategy training to 64 participants who were grouped into three. Explained through the hypothesis 'the richer get richer', the results of the study underlined that the participants with high working memory capacity benefited in the cognitive and metacognitive trainings compared to the ones with low working memory capacity. The same results were seen in the reading skill as a moderator in learning with hypothesis. The conclusion was that the indirect effects were positive for the learners with high working memory capacity or reading skill, but the indirect effects were negative for learners who are low on working memory or reading skill.

Payne *et al.* (2009) examined impact of the working memory capacity (WMC), first language comprehension, and domain experience on second language reading comprehension in Spanish. The connection between the ability and experience was investigated by assuming that the differences in working memory capacity can be removed with the knowledge. The participants were the seventy-three native English college students aged between 18 and 22. Comprehension in English and Spanish was examined with the pre-tests and counting span test was used for the working memory capacity. The participants had to count the target items on a computer screen and had to report the final number seen during the counting span test. Pearson correlations revealed the significant correlation between all variables and Spanish reading comprehension. The strongest predictor of L2 was the number

of classes taken on Spanish. Both L1 comprehension and L2 comprehension strongly correlated with working memory capacity. The regression analysis showed that L1 reading comprehension determined the L2 reading comprehension, but the working memory capacity had no interaction with the L1 and L2 reading comprehension.

Investigating the relationship between reading, syntactic, orthographic, and working memory skills in English and Russian with fifty students aged between 25 and 30, Abu Rabia (2001) aimed at seeing the difference between the two different orthographies. Considering that reading is a multi-task formed of different subskills, the study examined the contribution of each on the languages with different orthographies. Fourteen tests were administered, seven in Russian and seven in English in the study. The tests were on working memory, spelling, oral cloze, visual condition, phonological condition, orthographic skills, word attack, and word identification. As a working memory test, Abu Rabia used a sentence completion task rather then only remembering the final words of the sentences. In sets, the participants had to complete the final words of the sentences and then had to recall all the missing words. The correlation between English and Russian reading, language, and memory skills indicated that the individual differences are more significant regarding the reading skills than the difficulties of a particular language. Regarding the orthography, the correlation within each specific language was significant but not across the languages. The results of the study supported Cummins's interdependence hypothesis, however; orthographic distances may lead to some cross-linguistic transfer difficulties between the languages having unique and specific mechanisms. Other than the orthography, the study revealed that the other linguistic skills have a significant correlation both within and across languages.

Dyke, Johns and Kukona (2014) critically approached the case of working memory claiming the memory should be considered as a core contributor to the reading comprehension in regular basis. Accepting the existence of a limited source of memory during sentence processing, the researchers cautiously hypothesized that there are other confounding factors contributing to the comprehension during the retrieval of any knowledge. In other words, the rationale was that not every chunk or item has the same load on memory and can be stored in the same fashion. Inference increases due to the insufficient retrieval cues and leads to an overload and distraction on memory (Gordon, Hendrick, and Levine, 2002). However, the items sharing common features tend to be retrieved in reading comprehension. The study was carried out with 65 participants aged between 16-24 and had 24 tests measuring different constructs, such as reading skill, oral language use, memory, spelling and intelligence. An auditory version of the Daneman and Carpenter (1980) Sentence Span task was used to asses the verbal working memory. The researchers claimed that the results of the study highlighted three issues regarding reading comprehension. The first implication was that accurate comprehension depends on the retrieval inference but the differences in reading skill may be linked to the susceptibility in reading skill not to the the working memory capacity of the individual. Secondly, it clarifies the working memory and language relation and mechanism with an alternative model of relationship. Finally, the study underlines that alternative factors may contribute to poor comprehension regarding the relationship between working memory span and language comprehension.

In comparison of the two languages regarding the working memory contribution to the reading fluency was examined by Pae and Sevcik (2011). Fifty first and second grade bilingual students in two groups, English-Korean bilinguals in the U.S. and the Korean-English bilinguals in Korea, took part in the study. The participants were given different

types of tests to assess memory and reading skills. In order to measure specifically working memory and short term memory different sub-tests were used. The forward digit span test (Wechsler,1991) was the scale for measuring phonological working memory, the backward digit span test (Wechsler,1991) for the verbal digit working memory, and the sentence repetition test (Korkman, Kirk, and Kemp, 1998) for the performance to remember sentences which increase in terms of difficulty and length. The study revealed varying results regarding the relationship between working memory and reading comprehension. The predictive consequences were seen with the L1 forward and backward digit span test for the fluency in second language reading and comprehension for the English speaking participants, but the L1 forward digit span tests were seen to be more predictive in determining the fluency and comprehension in second language reading than backward digit span and sentence recall tests for the Korean speaking participants.

With the overall aim of examining the relationship between working memory capacity and L2 reading comprehension through linear texts and hypertexts, Fontanini and Tomitch (2009) did a study with the two groups of participants with different L1 backgrounds. Not only the working memory but also the comprehension performance in the two modes of text presentation was compared. The participants were the forty-two speakers of English as L2 from the L1 speakers of Brazilians and Chinese. A free recall task, a multiple- choice questionnaire, a detection of contradictions task, and a retrospective questionnaire were used so as to see the reading comprehension level of the participants. A modified version of reading span test (Daneman and Carpenter, 1980) was used in the study for the measurement of working memory capacity. As the participants were the L2 speakers of English, the level of English was either tested with an English test designed for the study or an IELTS certificate was asked from the participants. The study revealed some moderate

correlations among which both groups showed moderate correlations between the WM scores and the recall tests of the linear texts. Both groups had positive correlations between the WM scores and the recall tests of the hypertexts. However, no significant correlation was seen between the WM capacity and the recall tasks of the hypertexts.

As discussed earlier in a number of studies, the working memory capacity, regarding the storage and the manipulation of knowledge indicated contradictory results, received a number of contrasting hypothesis. Among these, two had attracted much more attention than the others. One proposed that different resources of working memory are used to process (Baddeley and Hitch, 1974; Baddeley, 1986; Hanley, Young and Pearson, 1991; Jonides *et al.,* 1993; Shah and Miyake, 1996; Vallar and Shallice, 1990) but the other one put forward that cognitive tasks use the same resources for verbal working memory (Just and Carpenter, 1992; King and Just, 1991). In this view, Fedorenko *et al.* (2006) aimed to see if it is the single pool of working memory or separate pools responsible for the working memory resources which are used in sentence comprehension through a dual-task experiment. The participants were the forty-four native speakers of English and took tests on memory and sentence comprehension. The syntactic complexity of the sentences differed due to the plausibility level. The sentences had four components; (1) a noun phrase, (2) a relative clause, (3) a main verb with a direct object, and (4) an adjunct prepositional phrase. Each of these were shown on a different region and a noun was shown before each sentence on the computer screen. After seeing the sentence, the participants pressed the space bar in self-paced nature to show the region that the component belonged. The comprehension of the sentences was tested with a comprehension question following each experimental trial. They were also asked to report the nouns and write as many nouns as they could remember after the completion of the sentence task. The results of the study provided evidence on that verbal

working memory resources for sentence comprehension is not domain specific as against to Caplan and Waters (1999). The results showed the significant interaction between the difficulty of syntax and similarity between the memory-nouns and the sentence-nouns in the three memory-nouns conditions. One outcome of the study would be that the load on the capacity of working memory may be reduced, while the sentence-nouns are stored into memory, if the nouns are stored have a similarity and if the nouns have been already stored in the memory.

Friedman and Miyake (2004) examined the effect of the way working memory span test and reading span tasks administered and also the relationship between processing and storage in reading span task. Test and re-test reliability was investigated with the two versions of each test on 168 native-English speaking participants. The reading span test was originally from Daneman and Carpenter (1980) which was augmented with sentences up to 212 selected from college-level reading material. The two reading tasks had different nature of administration, one as experimenter-administered and other as participant-administered. The sentences were shown on a computer screen one by one. Participant-administered group members pressed the button when they were ready for the next sentence but the experimenter pressed the button for the next sentence for experimenter-administered group members. The participants had to remember the final words of the sentence in the order they were shown. The participants had to recall the words shown on computer screen in different sets and verbally report the recalled words at the end of each set. Practice SAT reading comprehension tests published in Brownstein and Weiner (1974) were used as reading comprehension tests. After the completion of span tests, the participants were interviewed on if they used a strategy during the span tests. The results illuminated a number of aspects regarding the administration of the span tests. It was seen that some of the participants use

extra time for the strategies which may help in storing the target words, which may result in higher span scores. Pointing out importance of initially measured criterion validity, the study revealed the way the tests administered may lead to the changes in the criterion validity. The study showed the negative correlation between the reading span scores and both reading span reading times and baseline reading times in the experimenter-administered tests, however, there was a positive correlation between the reading span recall and reading times in the participant-administered group. The regression analysis showed that reading span scores predicted the reading comprehension and Verbal SAT scores for the experimenter-administered group.

. Assuming the need for the working memory capacity while going through the hypertexts, Chun and Payne (2004) investigated the impact of WM while reading on Multimedia CD Rom. The long debated strategy use for the compensation of the memory constraints were also visited in the study. The participants read short stories in German with the vocabulary load given through the short stories and the moves that the participants resorted while reading were recorded. The participants were 13 native speakers of English who were learning German in the second year of a public university. The process of reading recorded and four dependent variables were observed regarding the reading process; (a) look-up behavior; (b) comprehension test scores; (c) vocabulary test scores; (d) recall protocol scores. In addition to reading, two working memory measures were used in the study. The participants were given the tests of tests of nonword repetition and reading span. The study showed the strong relationship between phonological working memory and look-up behaviour while reading an L2 text. There was also a striking difference between the learners with low phonological working memory and high phonological working memory

regarding the look-up behaviour. The ones with low phonological working memory resorted to look-up three times more words than the ones with high phonological working memory.

Walter (2004) examined the transfer of reading comprehension skills to L2 with two groups of French learners of English. The overall aim of the study was to see if the transfer of mental structure-building skill associated with the level of success in L2 reading comprehension and if the transfer from L1 to L2 is linked to the development of verbal working memory in L2. In this sense, the study had two dimensions. The first one was the transfer of L2 reading comprehension related mental representation skill and the second one was the effect of working memory on the transfer of reading comprehension skill from L1 to L2. For this purpose, Walter (2004) used a modified version of Daneman and Carpenter (1980) reading span test in which the participants had to judge the sentence if it is a logical or an illogical one in addition to the recall of the final word in each sentence. The participants were grouped into as upper-intermediate and lower-intermediate. A baseline comprehension tests which included summary completion tasks in two languages were given to the participants. The study provided evidence that there is a transfer of skill for mental structure-building which is linked to the level of success in L2 reading comprehension. Although both groups were observed to be skilled comprehenders in L1, they differed in transferring their comprehension skill in L2. They could mentally build representations in L1 but they differed in building mental representations in L2. Through the results gathered in the study, Walter (2004) put forward that it is the structure- building ability which appears to be transferred from L1 to L2 and that the development of WM in L2 is linked to the transfer. Moreover, it was claimed that someone successful in structure building may lack the precondition of the required level of L2, all of which will eventually lead to the problems in structure building in L2.

Discussing the importance of the appropriate working memory test, Alptekin and Ercetin (2009) wanted to compare the performance of L2 readers on two L2 reading span test differing in the test type. The study was carried out with 30 participants having a Toefl score over a determined level of English. The basic difference between the two tests they used was that one had a recall task while the other included a recognition task. Through that way, they tried to compare the predictive power of the two tests. In addition to that, they investigated the relationships between L2 reading and both storage and processing performances. However, the reading was considered with its two dimensions; literal and inferential. The reading span tests focusing on the recall included remembering the final words of the sentences seen on computer screen and ones focusing on recognition included choosing the final words of the sentences given on a list. The findings in the study highlighted that the recognition tasks do not determine the individual differences in working memory. The study also underlined that composite scores of storage and processing have a correlation with the inferential dimension of L2 reading but not with literal dimension when the reading span tests on recall are used, not ones on recognition. The overall conclusion was that working memory has a significant relationship with reading only on the inferential comprehension through the recall-based reading span tests.

James, Krishnan and Aydelott (2014) examined the individual differences in cognitive functions with older adults in a dichotic listening setting. Twenty native British speakers between the ages of 50 and 80 participated in the study. The right and left channels of hearing were given different forms of stimuli. The stimuli given for sentence completion were in three forms, the first one with a strong bias, the second one with weak bias and the third one being neutral. The participants were asked to match the target words complying with these sentences on a computer screen. Within the diochotic listening nature, the

participants had to complete these sentences they were hearing through one ear and while at the same time hearing either nothing or a distractor on the other ear. The participants showed different performances regarding their ages. Younger adults were successful compared to the older listeners since the older listeners could not successfully complete tasks with the strong bias presented to the left ear when a distractor speech was presented to the right one. Older listeners had advantages on the younger ones by being faster in giving responses to the word matching of sentences presented to the right or left ear in the neutral baseline. It is seen in the study that older adults are more susceptible than the young adults in the interference of distracting speech form the right ear, showing greater working memory capacity does not compensate for speech comprehension. However, working memory was predictive while the inference speech was received through the right ear for the younger adults.

Otten and Berkum (2009) examined if the ability of making rapid predictions in discourse is linked to the working memory capacity. Confirmed by a couple studies that working memory has a predictive power in upcoming language (Lau *et al.,* 2006; Federmeier, 2007; Kamide *et al.,* 2003; Keefe and McDaniel, 1993; DeLong *et al.,* 2005; Van Berkum *et al.,* 2005; Wicha *et al.,* 2004), the researchers tried to see if the predictive power changes between the ones with low and high working memory capacity. The participants were 38 native speakers of Dutch, who were grouped into two as ones with low working memory capacity and ones with high working memory. The reading span test used in the study was a computerized Dutch version of the Reading Span Task (Van den Noort *et al.,* 2005), which was originally designed by Daneman and Carpenter (1983). The predictive power of the participants was assessed through 160 mini short stories including a context sentence followed by a target word. The target words were linked to a) predictive context

sentences at a message level and also linked to b) prime control context sentence which was not predictive at message level. The participants had to predict these target words in mini short stories. Strikingly, the study was carried out by use of event-related potentials to see if the the rapid predictions rely on the reader's working memory. The results of the study highlighted that the differences in working memory capacity shape the way how the information is dealt by the readers but working memory does not effect the ability to predict the words.

As a conclusion, reading has been one of the most investigated skills in the field of language learning. The results, as a summary, from the various studies with different outcomes have been presented above. Fifteen studies on the relationship between working memory capacity and reading skill have been discussed above with various dimensions and components of reading skill. Six of them were precisely focusing on the relationship between reading skill and working memory capacity, whereas nine of them covered any of the components contributing the reading skill in order to see the relationship between reading skill and working memory capacity. Moreover, six of these studies openly reported that reading has a relationship with working memory capacity. On the other hand, Payne *et al.* (2009) proposed that reading has no connection with working memory capacity when they examined the contributions of working memory capacity on L2 reading comprehension in Spanish. To be more precise about the studies discussed above, Baddeley and Wilson (1988) claimed that comprehension problems in reading result from the impairments in working memory linking it to the impact of working memory capacity on reading. Moreover, Rai, Loschky, Harris and Peck (2011) found that high working memory capacity leads to processing efficiency for a better comprehension. Similarly, Naumann *et al.* (2008) saw indirect positive effects of high working memory capacity for the reading skill. Abu Rabia

(2001) and Dyke, Johns and Kukora (2014) proposed that working memory capacity has connection with reading skill but stressed the individual differences and the alternative factors contributing to reading skill. In addition to these studies, Pae and Sevcik (2011), Fontanini and Tomitch (2009), Friedman and Miyake (2004), and Alptekin and Ercetin (2009) found the direct contribution of working memory to the reading skill, proposing that reading skill has a relationship with working memory capacity. Otten and Berkum (2009) claimed that the differences in working memory capacity shape the way how information is dealt, and similarly, Jannes, Krishan and Aydelott (2014) proposed that working memory is predictive when the there is an inference on the comprehension. In short, reading is the most examined skill in terms of its relationship with working memory capacity. Among the fourteen studies out of fifteen proposed that working memory has connection with the reading skill either directly or indirectly, whereas only one study contradicted with these studies.

2.11. Studies on Working Memory and L2 Listening

A number of studies were carried in the field of language learning in L2 on the relationship between working memory capacity and L2 listening skill (Was and Woltz, 2007; Gu and Wang, 2007; Waters and Caplan, 2004; Tsuchihira, 2007).

Was and Woltz (2007) examined the the relationship between working memory and listening comprehension within two experiments in a study. The first study was completed by one hundred seventy-six participants. Three tests on attention based working memory were used. In alphabet working memory test, the participants had to recode the letters based on a given value, such as RT-2 = OR. The participants had to respond to a question in the order of the number in numeral string working memory test. Let's say the digit string was 8 3 5 7 4 6, the question would be what number can precede 4? ABCD working memory tests

included the interpretation of the letter order. For example, saying F comes before G, it is FG. The listening comprehension was tested by three versions of listening comprehension tests including science, history, and literature. Acquired long term memory was tested through three sets of tests, Category Priming, Synonym Priming, and Attribute Priming, with each having the same structure in which five words presented aurally were asked to either put in categories, or to match the synonyms, or to find the attributes. The second study had two hundred and three participants. The procedures were similar to the ones in the first study except for the content of the listening comprehension tests. The second study included the business passages so as to isolate background knowledge. The results provided evidence on that working memory measures can strongly predict the language comprehension with the increased availability of knowledge in long term memory.

With fifty-nine freshman Chinese students, Gu and Wang (2007) carried a study so as to see the connection between working memory and listening. Working memory capacity tests were a modified version of Daneman and Carpenter (1980) reading span test, in which the participants were asked to remember the final words of unrelated sentences and also were asked to report if the sentences were logical or not according to the common sense. College English Test Band four, a used commonly in China as a test for the proficiency of English, was used for listening comprehension. The correlation, one-way ANOVA and regression analyses were carried out for the tests in two languages; Chinese and English. The significant correlation was seen between the working memory capacity tests in two languages. The listening comprehension skills correlated significantly with the working memory span test scores. Regression analysis showed that working memory span test scores explained the individual differences in listening comprehension skill. The overall results in the study

provided evidence on the relationship between the listening comprehension and working memory capacity.

Waters and Caplan (2004) carried out two experiments in a study in order to examine the relationship between verbal working memory and on-line construction of syntactic form. The two experiments differed in terms of the tests given to the participants. The first experiment was done with hundred participants, whose working memory capacity was determined with a version of the Daneman and Carpenter (1980) reading-span task, in which the participants had to make plausibility judgments and also had to remember the final words of the sentences. For the on-line syntactic processing, the participants were given a self-paced listening task including 104 plausible sentence and 104 implausible sentences, and the participants had to make plausibility judgments on those sentences. The sentences were formed around the two formation; a) simple subject relative and b) complex object relative. Moreover, the vocabulary subtest of the Wechsler Adult Intelligence Scale (WAIS) (Wechsler, 1981) was given as a subtest. The second experiment had the similar procedures with different tasks carried out with 48 participants. The working memory was measured with the alphabet span (Craik, 1986), subtract 2 span (Salthouse, 1988), and two versions of the reading-span task (Waters and Caplan, 1996b). The alphabet span task included words presented auditorily and the participants had to remember them after putting them in an alphabetical order. The subtract 2 span tasks covered the repetition of a randomly sequenced digits after subtracting 2 from each. One of the reading span tests used in experiment 2 was the same as the first one and the other one had syntactically more complex sentences, all of which asked the participants to make plausibility judgments and to remember the final words of the sentences. Background testing included the vocabulary subtest of the WAIS–Revised (Wechsler, 1981) and the reading comprehension, reading rate, and vocabulary subtests of

the Nelson Denny Reading Test (Nelson and Denny, 1960). Waters and Caplan (2004) discussed the results of each separate experiment individually. The results of the first experiment showed evidence on the separate resource theory indicating that the participants with low working memory failed to show and increase in the listening of more complex sentences requiring a capacity on memory. Although the data did not support the relationship between verbal-working memory capacity and on-line sentence processing efficiency, the participants with the low working memory capacity were less accurate than the participants in the medium-or high working memory capacity especially for the complex object relative and simple subject relative sentences. The second experiment showed significant relationship between accuracy scores on plausibility judgments and measures of working-memory for the reading-span tasks; however, did not show correlation for the other working memory tests. The results also showed significant relationship between comprehension scores on the Nelson Denny test and all working-memory measures, but the measures of working-memory lacked the correlations with on-line syntactic processing efficiency.

Tsuchihira (2007) carried a study to see if there is a relationship between L2 working memory and L2 listening ability and also if there is a relationship between L1 working memory capacity and L2 working memory capacity. For this purpose, 22 Japanese students participated in the study. The participants first took the L1 Japanese listening memory span test, and then the L2 English listening memory span test. The participants listened the sets of sentences and had to remember the last word of the sentences in English but the first word of the sentences in Japan as Japanese ends with the similar words. The participants had to answer yes/no questions regarding the sentences they read. The participant took the STEP (Eiken) 2nd test for the listening comprehension. Based on the results gathered in the study, Tsuchihira (2007) briefly stated that there is a significant relationship between L1 working

memory capacity and L2 working memory capacity, between L2 working memory and L2 listening ability and between L1 working memory and L2 listening ability.

As can be seen from the above discussions, listening is one of the skills on which studies have been conducted to see its relationship with working memory. As a summary, regarding the listening and working memory connection, four studies discussed above (Was and Woltz, 2007; Waters and Caplan, 2004; Tsuchihira, 2007; Gu and Wang, 2007) indicated that there is a significant relationship between listening and working memory capacity.

2.12. Studies on Working Memory and L2 Speaking

A few studies were carried out on the connection between working memory and speaking skill in L2 (Weissheimer and Mota, 2009; Prebianca, Finardi and Weissheimer, 2014).

Weissheimer and Mota (2009) investigated the relationship between L2 speech development and individual differences in working memory capacity. The study was conducted giving a two-month period between the two data collections. Participants were thirty-two undergraduate students who speak English as a foreign language in Brazil. The proficiency of the students was tested through a speech generation task adapted from the Cambridge First Certificate in English speaking assessment scale and Iwashita, McNamara and Elder's scale (2002). Participants were given speaking span tests as the two versions of Daneman's (1991) speaking span test, in which the participants were asked to produce grammatically and semantically correct sentences in English with the words they saw in sets on a computer screen. The participants were also given a speech generation task in which they were asked to describe a picture-cued narrative with as many details as possible. Speech production in the speech generation task was analyzed in consideration of the fluency, accuracy and complexity. The results contradicted with the previous claims that that working

memory capacity in L2 is a function of an increased command of language (Harrington, 1992; Berquist, 1998; Harrington and Sawyer, 1992). In comparisons with lower span and higher span subjects, the study showed that only lower span subjects had an improvement in speech production and working memory capacity. The high span subjects improved in speech production but remained stable in working memory. The study also revealed that working memory capacity significantly correlates with the accuracy and complexity of the speech production for all participants.

Prebianca, Finardi and Weissheimer (2014) examined if working memory capacity differs across languages and around the L2 speech proficiency levels. For that purpose, they worked with three proficiency levels (elementary, intermediate and advanced) and two languages (L1-Portuguese and L2-English). Sixty young adult learners of English with three different levels of proficiency (elementary, intermediate and advanced) participated in the study. The speaking span test in L1 and in L2 included the formulation of oral sentences with each word seen in a particular set. Prebianca, Finardi and Weissheimer (2014) discuss in their conclusion that memory capacity measured with a speaking span test in L2 defines the relationship between proficiency level and working memory capacity.

As can be seen, although few studies exist in the literature on the relationship between speaking and working memory capacity, the two studies (Weissheimer and Mota, 2009; Prebianca, Finardi and Weissheimer, 2014) present that there is a relationship between speaking skill and working memory.

2.13. Writing from a Cognitive Perspective

A better understanding of writing has always required the consideration of the factors contributing to both the writing process and the final product. The fundamental shift from the product approach to the process approach in writing throughout the early 1970s led to a

number of changes in writing instruction and writing research. However, this shift is claimed to be best understood through the review of the major developments over the past 30 years (Grabe and Kaplan, 1996). Although briefly categorized in the literature, the stages that the writing went through are summarized in and divided into four stages. These can be outlined as follows:

1. Expressive
2. Cognitive
3. Social
4. Discourse Community

As Grabe and Kaplan (1996) assert, these stages should not be considered as a general historical transition from one to the other but as stages that lead to an analytic scheme representing new insights for a better understanding of writing. To be more specific, the major realization from a cognitive perspective began with the pioneering study from Emig (1971), through which she ascertained that the writing process included sub-processes, such as prewriting, planning, rewriting and pauses. Emig concluded that these writing sub-processes were recursive rather than linear. By realizing the factors involved in writing through these developments, though once seen as a product, writing began to be considered as a set of recursive sub-processes from a cognitive perspective. Throughout the basic studies that will be briefly discussed in the next sections, several psychological theories and models about the cognitive processes in writing have been proposed. Besides all these new theories and models embodying the nature of writing, the shift from product approach to process approach also caused various changes in the research paradigm, with the emphasis on the process of writing, to understand the cognitive journey that the writers followed.

The writing process has been the focus of research studies. In the light of the new research perspective, the researchers came up with using new methods of examining the

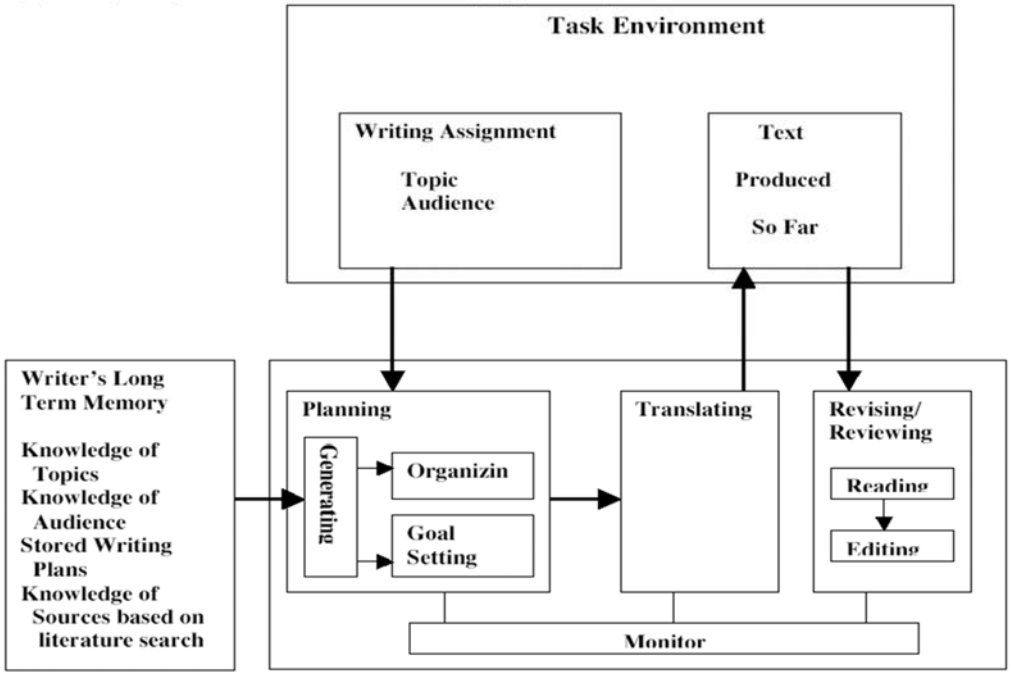
writing process through retrospection and introspection within naturalistic observation, video-based observation and think-aloud protocols (Latif, 2008). The results of the studies using retrospective and introspective methods yielded detailed accounts of individual differences of the writing process about the evolutionary stages from being a novice writer to an expert writer. Of these individual differences, the cognition behind writing has been one of the major focuses of research on writing. Moreover, the researchers aimed at defining not only the impact of cognitive overload in writing process but also understanding the use of available cognitive resources efficiently. Among the current approaches to writing, the cognition behind text production is thought to cover distinct processes which can only be defined through precise examination. Fundamentally from a psycholinguistic perspective, writing is not a reflection of translating ideas to compose a text; however, it requires more than a translation to express the thought and content in an appropriate way. It is compared to a switchboard operator juggling the demands and constraints, which requires a variety of processes to be carried out simultaneously (Flower and Hayes 1980a). Moreover, writing requires the use of memory and knowledge types efficiently to coordinate the complex sub-processes either directly or indirectly ascribed to a well-formed text (Flower and Hayes 1980b). The storage limitation of mind in any productive skill has always been the basic propulsive force for understanding how working memory functions in writing.

2.14. Cognitive Models of Writing

The models defining the cognitive processes in writing have been proposed with a number of formulations. Among these models, Hayes and Flower's (1980a) model proposed the cognitive variables representing the process as illustrated in Figure 2.7 Considering writing as “a set of hierarchical and recursive thinking processes”, Hayes and Flower (1980a) categorized writing into sub-processes as (a) planning, which covered generating ideas,

organization and goal setting; (b) translating plans into text; and (c) reviewing, which was composed of reading and editing.

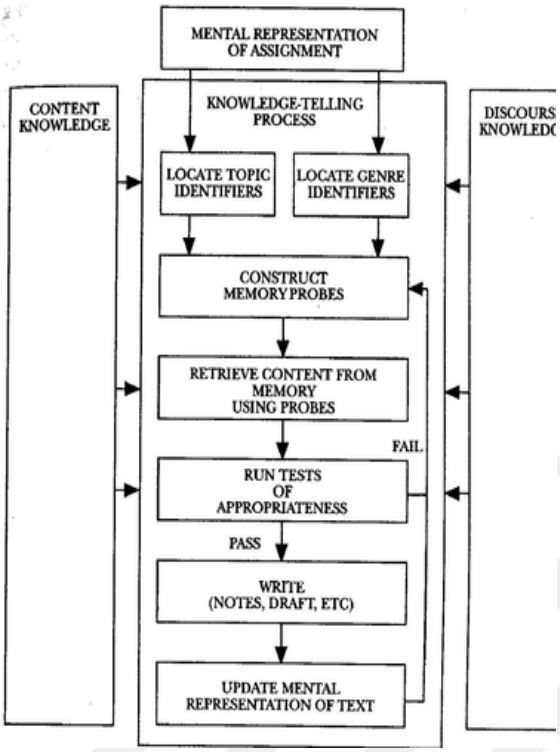
Figure 2.7. Structure of the Writing Model (From Lee W. Gregg and Erwin R. Steinberg (Eds.) (1980), Cognitive Process in Writing (pp. 3-30). Hillsdale, NJ: Lawrence Erlbaum.



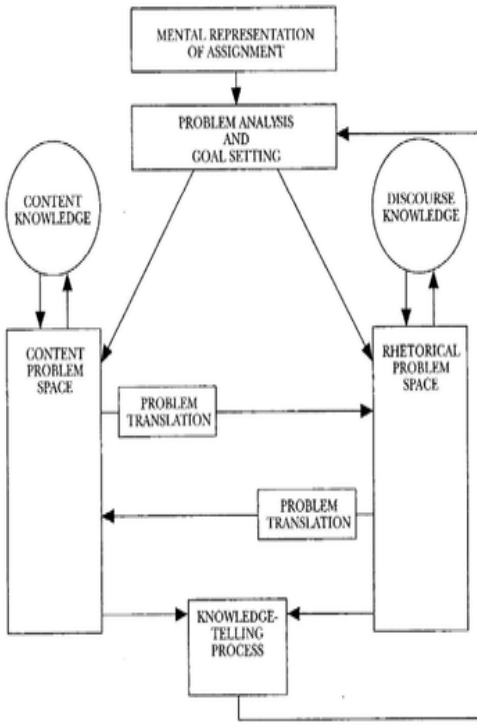
In Hayes and Flower's model three cognitive processes- planning, translating, and reviewing- function recursively with each other in relation to the writer's long-term memory and the task environment.

In addition to these, Bereiter and Scardamalia (1987) proposed two models distinguishing knowledge tellers and knowledge transformers from each other in the way of putting knowledge into writing and in the way of processing writing (Figure 2.8).

Figure 2.8. The psychology of written composition. (Bereiter, C., and Scardamalia, M., 1987). Hillsdale, NJ: Erlbaum.



Structure of the knowledge-telling process



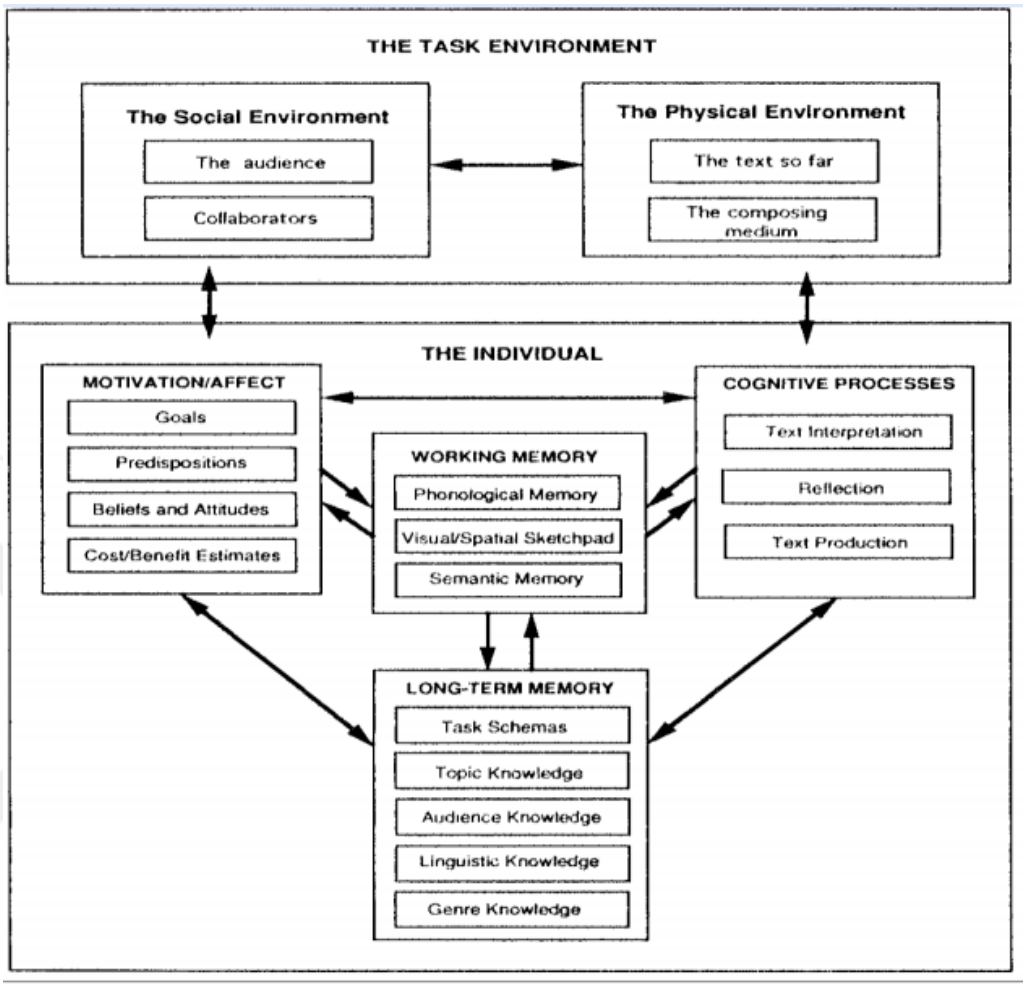
Structure of the knowledge-transforming process

Knowledge telling, used by younger and novice writers, includes the retrieval of the content from memory and translating into the text, however; knowledge transforming, used by older and expert writers, includes composing the text in the light of the communicative goals while at the same time evaluating the text appropriateness. In other words, the fundamental difference between knowledge tellers and knowledge transformers lies in the way they both approach the text. While knowledge tellers convey the content about the topic, knowledge transformers not only convey the knowledge they possess but also take the rhetoric into the consideration. Consequently, the cognitive load on knowledge tellers and knowledge transformers differs during the text production resulting from the differences in the way the text is composed. In a sense, the process in text production followed by knowledge tellers demands memory use while retrieving the content and discourse knowledge in memory and translating it into the text. On the other hand, knowledge

transformers retrieve the communicative goals while, at the same time, adapting the available knowledge to rhetorical goals to be achieved in the text by spending more amount of time to reflect the rhetorical representation. The knowledge-telling process and the knowledge-transforming process are illustrated in Figure 2.

With some revisions, a new model of writing was proposed by Hayes in 1996. The new model included a) text interpretation, b) reflection, and c) text production with the heading of cognitive processes. Hayes (1996) defined the text interpretation as "*a function that creates internal representations from linguistic and graphic inputs"*, the reflection as *"an activity that operates on internal representations to produce other internal representations"* and text production as *"a function that takes internal representations in the context of the task environment and produces written, spoken, or graphic output"* (p.13). Hayes (1996) made some major revisions in the new model, one of them being the inclusion of the working memory at the center of the writing process. The new model included phonological memory, visual/spatial sketchpad, and semantic memory as the subcomponents of working memory. In the models previously mentioned, there was the memory but Hayes (1996) put the working memory in the center of the model newly proposed. The new model is illustrated in Figure 2.9.

Figure 2.9. Hayes Model (1996)



In addition to the ones proposed previously by Hayes and Flower (1980a) and also Bereiter and Scardamalia (1987), Kellogg (1996) put forward the function of working memory in the writing process, adopting three basic processes from Flower and Hayes (1981) and including the components of working memory model proposed by Baddeley (1986). The model consisted of three systems, each of which was connected to three components of working memory model proposed by Baddeley (1986). Kellog's model (1996) covered (a) formulation, (b) execution and (c) monitoring. Formulation refers to the planning in which the writers determine the goals of writing, namely, outlining the ideas to include in the text to be composed. Execution encompasses the generation of the text in the light of the ideas stored during the formulation component of writing. Monitoring includes

the examination and the revision of the text produced. Kellogg (1996) elaborated all three components; formulation, execution and monitoring in consideration with functional requirement of the components of Baddeley's (1986) working memory model (central executive, visuospatial sketchpad, and phonological loop) in text production.

As discussed above, from the cognitive perspective, working memory is one of the components in writing (Grabe and Kaplan, 1996; Hayes and Flower, 1980a; Bereiter and Scardamalia, 1987; Hayes, 1996).

2.15. Working Memory in Writing

Being one of the earliest metaphoric illustrations of the cognitive processes in writing, Hayes and Flower (1980) provided the articulation of long term memory in text production. There was little emphasis on working memory (WM) in the initial proposal. However, within the revised model differing from the previous one in terms of the memory articulation in text production, Hayes (1996) offered a new model, providing a more intervening role for working memory and space for the knowledge sources within long-term memory (LTM).

The role of working memory in writing was further discussed by McCutchen (1996) in relation to the three basic components: planning, translating and reviewing processes, as a preliminary framework for the developmental and individual differences in writing in relation to working memory. While providing a framework for writing ability, McCutchen (1996) linked Just and Carpenter's (1992) capacity theory in which verbal working memory was claimed to be related to sentence comprehension. The capacity theory, originally proposed by Just and Carpenter (1992), discussed the limited set of processing resources available to verbal tasks. McCutchen (1996), comparing writing process to sentence comprehension, claimed that the exchanges between processing and storage in working

memory imposed multiple demands on writing process. The overload, in turn, led to resorting to alternative writing strategies especially by novice and younger writers.

With the explicit emphasis of working memory on text production, Kellogg (1996) discussed the impact of WM components in the writing process, and presented a model of working memory in writing. The model covered six components of writing and the role of working memory components: visuo-spatial sketchpad, central executive and phonological loop, on these six components. The model proposed the fundamental involvement of central executive in basic processes of writing. According to Kellogg's model of working memory in writing (see Table 2.3.), the planning component requires both the visuo-spatial sketchpad and the central executive. The translation component requires the manipulation of the central executive and the phonological loop. Programming requires central executive. Reading requires the central executive and the phonological loop, editing requires the visuo-spatial sketchpad**.** The use of different working memory components in different writing components reflects the required information processing and storage during writing.

Table 3. A model of working memory in writing

The resources of working memory used by the six basic processes of writing

	Working Memory Resource		
Basic Process	**Visuo-Spatial Sketchpad**	**Central Executive**	**Phonological Loop**
Planning	✓	✓	
Translating		✓	✓
Programming		✓	
Executing			
Reading		✓	✓
Editing		✓	

2.16. Attention in Writing

In a general meaning, attention refers to the mental approach directed on a specific component, action or activity in our daily life. Regarding the field of language, attention is reported to be one of the contributing components to the writing skill in the literature. The amount of attention paid on different types of processes in writing (such as revision, editing, organization) changes the quality, content and grammar of the writing. Similarly, the attention paid on the quality, content and grammar may also change the amount of time spent on the processes, such as revision, editing and organization (Rouiller 2004).

To be more precise, in the working memory model proposed by Baddeley (2001), the central executive functions as an attentional system controlling storage components, such as the phonological loop and the visual-spatial sketchpad. Moreover, not only within short term memory functions, attention can retrieve the knowledge from the long-term memory and bring it into the short-term memory to be used. Similarly, regarding the writing process, Traxler and Gernsbacher (1993) discusses that attention is a source linked to the working memory storage which is active for the representation of author, text and reader. Particularly, for the text production, the writer consumes attention for any linguistic output, planning ideas, and reviewing ideas. In the writing model proposed by Flower and Hayes (1980), it is seen that limited executive attention is allocated to the monitor component rather than the planning, translating, and reviewing. Similarly, Kellog (1994) discusses the importance of attention in writing process as source exploited for the content and the rhetoric of the writing. Moreover, Kellog (1994) claims that expert writers rely on the central executive for the coordination of attention in the complex interaction among planning, generation, and reviewing coordinated. From this sense, studies in the field of writing researchers showed the role of executive attention in managing the writing process either by the interference of

secondary task during the primary writing task that relies on the executive attention (Olive, Kellogg, & Piolat, 2002; Piolat, Olive, & Kellogg, 2004).

2.17. Studies on Working Memory and L1 Writing

The role of working memory in L1 writing has been reported in a number of research studies covering different participants and writing components (Kellogg, 2001; Tetroe, 1984; Fayol, Largy, and Lemaire, 1994; Swanson and Berninger, 1994; McCutchen, Covill, Hoyne, and Mildes, 1994; Lehto, 1996; Swanson and Berninger, 1996b; Hoskyn and Swanson, 2003; Galbraith *et al.,*2005; Kellogg *et al.,*2007; Olive *et al.,*2008).

The empirical support for the explicit analysis of working memory based on the model proposed by Kellogg (1996) was reflected in Kellogg's (2001) new study which investigated the contribution of each working memory components was discussed in detail. Kellogg (2001) investigated the role of working memory in writing totally with 48 participants by assigning 16 participants for each of the three writing task groups: narrative, persuasive and descriptive. Using longhand writing and word processor, each participant composed two texts during the experiment. In this study Kellogg tested whether the same component of working memory contributed to the three components of writing processes: writing-planning, translating, and reviewing. The results indicated that the central executive contributed to each component of text production.

Tetroe (1984 reported in Bereiter and Scardamalia, 1987) investigated the link between working memory and L1 writing in a study in which working memory was assessed and children were asked to end a story with a specific sentence *(e.g., That's how Melissa came to be at the laundromat with a million dollars in her laundry bag* compared to *That's how Melissa came to be at the wrong laundromat with a million dollars in her laundry bag and*

a trail of angry people behind her). Tetroe (1984) observed that there is a negative correlation between memory span and the ending-sentence constraints in writing process.

Fayol, Largy, and Lemaire (1994) examined the impact of memory load increase on writing outcomes with French students. The memory load was increased by the inclusion of extra tasks to be carried out while at the same time the participants listened and evaluated sentence structure. The participants focused on the sentences presented orally and then they had to write them down. For example, sentence recall and the click-counting were included into the study in which the memory load was increased to see the interference of extra memory load in writing tasks. By using three experiments in the study, Fayol *et al.* (1994) asserted that there was a causal rather than only correlation relationship between memory demands and writing outcomes.

Swanson and Berninger (1994) compared transcription and text generation processes in order to see the impact of individual differences in working memory. The results of the study revealed the higher correlation between working memory and text generation than the correlation between working memory and transcription. The study also revealed that transcription required the storage of knowledge through short term memory and that text generation required the use of working memory since text generation fundamentally necessitates both storage and manipulation of different types of knowledge, such as linguistic knowledge, background knowledge and rhetorical knowledge.

In a comparative study of elementary and middle school writers, McCutchen, Covill, Hoyne, and Mildes (1994) examined the relationship between writing and working memory through working memory tasks. In comparison of two groups of participants, each group was asked to write an essay and to complete two working memory tasks. Working memory tests covered a reading span test asking to recall the final word of the sentences and a

speaking span test asking students to generate a sentence for each word in a list and to recall the words in the list. However, the tasks completed differed in terms of the cognitive load on the task accomplishment. One group of participants were asked to read and generate sentences unrelated to each other. The other group of students was asked to read and generate brief stories. The study focusing specifically on subcomponents of the translating process and processing constraints imposed by working memory limitations revealed that lexical retrieval was among the dominant factors determining the skill for writing. Skilled writers were observed to be faster and more accurate compared to the less skilled writers in lexical retrieval. McCutchen *et al.* (1994) concluded that skilled elementary and middle school writers had a larger capacity of working memory than less skilled writers, and skilled writers were more fluent in writing sentences during the span task and were faster in accessing words in memory compared to less skilled writers.

Similarly, Lehto (1996) investigated the relationship between writing and working memory through a correlation study in which 60 ninth-grade Finnish students were asked to summarize a modified expository text. The text to be summarized was categorized into four levels according to the macrostructures. The inclusion of the macropositions (main ideas) into the summaries was focused to determine the relation between working memory and writing. The number of the macropositions in summaries significantly correlated (r = .42 to .71) with the working memory measures. The lower-level macropositions reflected the high correlation results, whereas the higher-level macropositions (topics and subtopics) did not reflect a similar correlation indicating the cognitive load on working memory for text production at high level information processes.

Swanson and Berninger (1996b) aimed at investigating which specific working memory system is related to writing. Moreover, the study focused whether individual

differences in reading share the correlations between WM and writing, in other words; whether working memory contributes to writing in the same way as it contributes to reading. Two studies were carried out for these purposes with different number of participants and with different subtests. The tests included a sentence span test, a standardized writing test and a reading comprehension test. The results of the study supported the hypothesis that working memory contributes to both written composition and reading comprehension in the same way. In addition to that, the study highlighted that good writers have more functional working memory capacity for writing than the low-level writers.

Hoskyn and Swanson (2003) examined the relationship between working-memory span and writing performance among three age groups with the ages of 15, 30, and 77. In addition to several other tasks, such as spelling, word knowledge and reading, a narrative writing task was administered to each participant. Participants were asked to write a narration on an important event in their life from a personal point of view. The correlation analysis of a number of tasks related to writing revealed that the capacity demands were greater for older participants than younger ones. In addition to that, the overall analysis showed the correlation between verbal WM and structural complexity ($r = 0.65$) and the correlation between visual-spatial WM and text generation ($r = 0.44$).

Galbraith et al (2005) conducted a study on the contribution of working memory on knowledge transformation. In the study, knowledge transformation referred to the distinction between 'knowledge telling' model of writing and 'knowledge transforming' model of writing from Bereiter and Scardamalia (1987). Two groups of participants with different education background as one from the undergraduates at a university in England and the other from the ones applying for university entry after completing secondary education (Formal Education students) were compared in the study in the light of the process while

writing and also in the light of the essay written on a discussion topic. In order to see the contribution of different components of working memory (such as the central executive and visual-spatial sketchpad components) on the outlining process, a cognitive load as a secondary task was imposed during outlining. The study included the random assignment of 72 participants to four secondary task conditions. Secondary task conditions included (a) a foot-tapping task, (b) random number generation, (c) a spatial tracking condition, (d) a visual noise condition. Foot-tapping task refers to participants' tapping one of his/her feet regularly considering that it requires extra attention while doing something else. Random number generation includes generating 5-digit number strings out loud while at the same time focusing on writing. The spatial tracking condition, requiring extra cognitive load on the spatial component of working memory involves tracing a velcro track with their non-writing hand (Quinn and Ralston, 1986). The visual noise condition required participants to look at flickering black and white dots shown on a computer monitor. A number of components of writing were taken into consideration to see the multifaceted nature of writing process and the contribution of working memory on outlining process. Among those facets were (a) the number of ideas, (b) number of words per idea, (c) number of new ideas included and old ideas excluded, (d) degree of rhetorical organization evident in plans, (e) text properties, (f) objective features of the texts, (g) stylistic quality, and (h) content quality. The results of the study in relation to working memory indicated that both the central executive and visuo-spatial sketchpad from working memory were used with different roles in the transformation of knowledge.

Another study in which dual tasks were used to examine impact of the working memory in writing process came from Kellogg *et al.* (2007). The study included three experiments in which different tasks were carried out by the participants while writing. The

participants were asked to write the definitions of either abstract or concrete nouns while at the same time performing a concurrent working memory task. However, the working memory was categorized into three subcomponents; verbal, visual, and spatial. The first experiment included 60 college students in which they were asked to respond by clicking a mouse button if the target was different from the previous one presented in order to assess the detection of a visually presented target and a speeded decision. The task was carried out through SCRIPTKELL computer program (Piolat, Olive, Roussey, Thunin, and Ziegler, 1999) and correctly detected targets were taken into consideration for the visual memory capacity in terms of the time take to respond. The verbal memory task in the experiment covered the presentation of two syllables (ba and da) on computer screen, whereas the visual working task included the same procedure but the stimuli were visual shapes (triangle or circle). During the tasks, the participants had to write the definitions of abstract and concrete nouns with their dominant hand on paper. The second experiment differed from the first experiment in terms of the visual stimulus presented. The first experiment covered the visual shapes of a triangle or a circle, however; the second experiment included the shapes reflecting the spatial properties of an object. The third experiment used the aural presentation of the verbal task to see the impact of the phonological representations stored during language production. Although the results of each experiment in the study were discussed individually, the general discussion proposed the importance of working memory in written language production. Visual memory was found to support optional processes related to a) planning of image-based conceptual content and b) definition writing on concrete and abstract noun. These processe were observed to be slowed down by the concurrent verbal task in the study. The importance of verbal memory and visual memory in language production was emphasized through the results of the study. The study also highlighted the

use of dual task method in the examination of working memory contributions to written language production (Olive, 2004).

Using a dual task method, Olive et al., (2008) examined the impact of verbal, visual, and spatial components of working memory in writing. The primary aim of the study was to see whether the demands through these components of working memory changed throughout a writing task. The study included two experiments. First experiment included verbal, visual, and spatial components of working memory, however; second experiment focused only on the verbal and spatial components of working memory. The participants generated texts while at the same time performing one of the concurrent tasks on verbal, visual, or spatial memory. For the verbal task, the participants had to determine whether the stimulus presented matched the previous one presented. As each task had its own stimuli, the verbal memory task included the "ba ba da ba" syllable. The visual task included shapes which were different from each other and the participants had to remember whether the shape presented matched the last one presented. The spatial task was composed of the shapes, however not asking the match with the last one but asked whether the exact place matched with the place of the of the last shape appeared on the screen of a computer. The quality of the text produced in the study was assessed in consideration of a) use of language, b) information, and c) arguments. In addition to the quality of the text, the number of the words, words per minute and words per sentence were the other subcomponents in the study considered to be a source of comparison and analysis. The statistical analysis of the data revealed that the response time to each task was long and there were few correct responses. The overall findings indicated that there was minimal demand on spatial memory, whereas the demands on visual working memory and verbal working memory were equally high during writing process (Olive *et al.,* 2008).

As can be seen, among eleven studies on writing in L1, ten of the studies found either direct or indirect relationship between WM capacity and writing in L1; however, only Fayol, Largy and Lemaire (1994) proposed that WM capacity has a causal connection with writing in L1 rather than a correlational relationship.To be more precise, Swanson and Berninger (2004) and Kellog (2007) found the working memory capacity as an important factor in terms of writing skill claiming that the higher working memory capacity, the better writing production. However, going into the detailed subcomponents of working memory, Kellog (2001), Olive *et al.* (2008), and Galbraith *et al.* (2003) proposed the relationship between central executive and visual sketchpad components of working memory and the writing skill. Rather than explaining the relationship through the working memory capacity, Mc Cutcher, Covill Hoynes and Mildes (1994) discussed that skilled writers are faster and more efficient in using the working memory capacity regarding the writing skill. In other words, they claimed skilled writers can make use of the working memory sources more than the less skilled writers during text production. Moreover, Hosky and Swanson (2003) claimed that the connection between working memory capacity and writing differs according to the age by the study in which they compared three age groups and observed that working memory capacity demands were higher for older people. Tetro (1984) proposed that the working memory capacity has a connection with the ability to end sentences having constraints in his study. In addition to these, Lehto (1996) determined that cognitive load on working memory affects the text production, which was another indication of the relationship between working memory capacity and writing. Last but not least, Swanson & Berninger (1996b) found the relationship between writing and working memory capacity and proposed that working memory capacity contributes to writing in the same way it contributes to reading. Moreover, Swanson & Berninger (1996b) claimed that good writers have a functional

working memory capacity than the low-level writers. As a conclusion, the studies in the field show that there is a relationship between L1 writing and working memory capacity.

2.18. Studies on Working Memory and L2 Writing

In addition to L1, working memory has also been examined in terms of its relation to L2. Ransdell *et al.* (2001) compared bilinguals and multilinguals in terms of the long-term working memory use while writing during the presence of an unattended irrelevant speech and a concurrent 6-digit memory load. Long term working memory was operationalized in the study as the efficient retrieval and use of domain-specific knowledge (Ericsson and Kintsch, 1995). The comparisons were made through two experiments. The first experiment included multilinguals of 42 native speakers of Estonian who could speak and write in two other languages. In order to examine the coordination of long-term working memory resources in first language and second language writing, the study focused on seeing whether fluent multilinguals have particularly efficient access to long-term memory knowledge while at the same time being disrupted by an irrelevant speech or a 6-digit memory load. The second experiment, with the same procedures in the first experiment, included 40 Spanish–English bilinguals and 40 Polish–English bilinguals. The participants in two experiment groups were asked to write five essays during the study. The first two essays were written one in L1 and one in L2. The second two essays were written one in L1 and one in L2 with a secondary task of L1 irrelevant speech. As the final essay, the participants were asked to write in L1 with a secondary task of a concurrent 6-digit load. During the final essay writing, the participants were presented a series of 6 random digits in L1 in every 30 seconds through the headphones and were required to report loudly the digits they could store when they were asked and then they continued writing and waited for the next set of digits. The texts produced in the study were assessed in the light of a number of

facets of writing process. Writing fluency was considered as the words processed per minute. Writing quality was based on the average of the holistic composite scores from two peer raters. Total planning referred to the total number of planning in writing greater than 5 seconds in length. The average sentence length and the percentage of planning located at grammatical boundaries were the other facets of writing in the study. The hypothesis of the study was that language fluency in another language would provide benefits for the long-term working memory in dual task language conditions for bilinguals and for multilinguals. In comparison of the two groups; one multilingual and one bilingual, 42 multilinguals could represent native language writing quality and fluency during the unattended irrelevant speech and a concurrent 6-digit memory load, whereas 80 bilinguals had less fluency while writing in the presence of the 6-digit load. The overall study showed the advantage for bilinguals to suppress irrelevant information, which, as a conclusion, proved that having fluency in another language would provide benefits for the long-term working memory in dual task language conditions for bilinguals and for multilinguals.

Classifying writing process into two categories as the macrostructure (e.g., planning, writing, and revision) and microstructure (e.g., grammar, punctuation), Vandenberg and Swanson (2007) investigated the relationship between components of working memory and the macrostructure and microstructure of writing with 160 high-school students who represented a combination of different ethnic groups. A number of different tests were given to the participants, such as The Standardized Testing and Reporting (STAR) including the Total Reading Section, Vocabulary Subtest, Reading Comprehension Subtest, Language Mechanics Subtest, and Language Expression Subtest. Both short term memory and working memory were tested through the word span, digit span and sentence span tests. Using correlation and regression analyses in the study, Vandenberg and Swanson (2007) divided

the results of the study into three categories as (a) short term and working memory, (b) the relationship of the short-term memory and working memory model with the components of writing (c) the relationship between the short-term/ working memory model and the three macro-components of writing: planning, writing, and revision. The results of the analysis showed that there is a relationship between the macrostructure and the executive component of working memory but not between the phonological and visuospatial components of working memory. The same relation was also seen between the central executive component of working memory and microstructure components of writing. The overall study revealed that the central executive system significantly predicted the higher-order writing skills, vocabulary skills, punctuation skills, the structure, the vocabulary, and grammar measures.

Being one of the recent studies, Lu (2010) carried out a study in which she examined the cognitive factors that might influence Chinese L2 learners of English while writing an argumentative essay in English. The factors that were examined in the study were proficiency in L2 English, writing ability in L1 Chinese, knowledge on genre, use of writing strategies, and working memory capacity in L1 and L2. Using correlations, paired-samples t-tests, analysis of variance and multiple regressions, she found out that proficiency in second language predicts second language writing more than genre knowledge and L2 writing strategies. Surprisingly, the results did not reveal any correlation between working memory capacity and writing ability in L1 and L2.

Regarding the studies on writing in L2, only few studies specifically focused on the relationship between L2 and working memory capacity. Strikingly, Lu (2010) did not find a relationship between L1 writing and working memory capacity, and also between L2 writing and working memory capacity. Although it has an indirect link regarding the relationship between L2 writing and working memory, Ransdell *et al.* (2001), tapping into the long term

working memory function, discussed the advantage of having fluency for long term working memory in L2 writing when they compared the monolinguals and bilinguals. In contrast to these, Vandenberg Swanson (2007) examined various subcomponents of writing skill and found a relationship between working memory capacity and writing. As a conclusion, among the rare studies, only one of them is seen to have found a direct relationship between working memory capacity and writing.

As can be seen, to the knowledge of the researcher, rare studies exist in the field of L2 on the relationship between writing skill and working memory. There is a need to see the relationship between writing skill and working memory in both L1 and L2. Moreover, although there are few studies examining the impact of working memory training on working memory capacity, there is a gap in the field since there is no comparative study in L1 and L2 focusing on the impact of working memory training on working memory capacity and writing process.

2.19. Computational Programs for Examination of Writing Process

Writing, seen as "a step child of psycholinguistics" (Bonin and Fayol, 1996), had been neglected by the early 1980s due to the challenges in investigating cognitive aspects of text production. Due to the lack of abundant instruments directly observing the psycholinguistic aspect of the writing process, "think aloud protocols" and video recordings were commonly used by the researchers seeking to examine the process followed by the writers. As these methods rely on the intrusion of the researcher, the validity of the research has been considered to be low and the results have been thought to reflect the cognitive processes partially. However, recent technological developments in computational sciences have made it possible to observe the processes in the text production (Miller *et al*., 2008). The developments in computational sciences have come up with computer programs

allowing the researchers to observe the process in detail in terms of pauses, syntactic revisions and lexical choices. Among those programs were the keystroke logging software and computer-aided analysis programs (Latif, 2008). Going one step further, these programs have made it possible to eye track the real time paid at different parts of the text. The computer programs reflecting real-time processes with their unobtrusive data collection nature (Leijten and Van Waes, 2006) provide the researcher a transparent observation in terms of the time and effort allocated during writing since it does not interfere with the writer unlike the research methods, such as think aloud protocols.

Through the use of developing computational programs, a better understanding of the underlying cognitive processes in text production can be achieved to highlight not only the instruction but also the ways to handle the problems that the writers experience in language learning. Although some of them have been experiencing their infancy, the real-time computer-aided programs developing every other day uncover the writing process and make text production a unique research field which is still in need of in-depth studies mirroring the skills at different settings and levels of language.

There are a number of studies examining the writing process through the use of computational programs. In his review of the real-time computer-aided studies, Latif (2008, pp: 39) classifies the studies examining the writing process conducted through keystroke logging into five categories which are a) studies on revision; b) studies on the temporal aspects of the writing process; c) studies on using the logged data to stimulate writers' retrospection; d) studies on the writing process as a whole; and e) studies on the other aspects of the writing process.

The present study included a keylog program regarding the data collection on writing process. InputLog (Leijten and Van Waes, 2006) was used as the keylog program and it

provided the detailed quantification of the writing process up to the preferred subcomponents. The data provided through Inputlog included the individual quantified scores on eleven subcomponents of writing process. The revisions and editing done by the participants were quantified after the individual analysis of the writing process by the help of the recording function in InputLog.

2.20. Chapter Summary

The literature review in this chapter has examined and discussed a) memory types b) span tests, c) working memory training programs, d) studies on working memory and language learning relationship and moreover, the studies on the relationship between working memory and reading, listening, speaking and writing.

The literature consists of span tests developed to measure working memory capacity and these span tests in the literature tap on different cognitive aspects of perception and on different skills, such as reading, listening, speaking, and operation.

The studies discussed have an emphasis on the relationship between working memory capacity and language learning. However, most of the studies investigated the relationship between working memory and reading or listening. Additionally, there are only rare studies focusing on investigating the relationship between writing process and quality in L1 and L2 and working memory. Moreover, no study examines the impact of working memory training on the writing process and quality in L1 and L2.

Considering that there is a gap in the literature with no study existing on the impact of working memory training on the writing process and quality in L1 and L2, to fill this gap, this study combines both developing a production span test and investigating the relationship between working memory capacity and writing process and quality.

Specifically, this study comprises two parts. The first part includes a) developing a production span test to measure working memory capacity in L1 Turkish and L2 English and the second part consists of b) investigating the relationship between writing process and quality in L1 and L2 and working memory, c) examining the impact of training on the writing process and quality in L1 and L2.

CHAPTER 3

METHODOLOGY

3.1. Introduction

This chapter includes the methodology of the study. Listing the research questions, this section describes the setting of the study, the participants, the data collection instruments, the treatment, the writing process components, the data collection procedures, the scoring of the data and the data analysis procedures followed in the study.

3.2. Aim of the study

The current study aimed to shed light on a number of issues associated with writing and working memory. The first aim was to develop a production span test. The second aim was to examine whether there is a relationship between working memory capacity and writing processes in L1 Turkish and L2 English. The third aim was to examine whether there is a relationship between working memory capacity and writing quality in L1 Turkish and L2 English. The fourth aim was to investigate whether working memory training leads to any effect on working memory. The final aim was to see if eight weeks training period effects L1 and L2 writing process and quality. The study tried to answer following research questions:

First part of the study

1. To what extent does production span test measure working memory capacity compared to reading span tests?

As for the second part of the study,

1. Is there a relationship between working memory capacity and Turkish and English online writing processes of EFL students?

2. Is there a relationship between working memory capacity and Turkish and English online writing quality of EFL students?

3. Does working memory training lead to any effect on working memory capacity of EFL students taking working memory training?

4. Is there a difference in L1 Turkish and L2 English writing processes and quality of EFL students' after the eight weeks training period?

3.3. Participants

Twenty-eight EFL students participated in the study. They were all native speakers of Turkish freshman composition students (ten males, eighteen females) with 14 in control and 14 in experimental group. The study used convenience sampling regarding the participant selection process. The proficiency level of the participants ranged between B1 and Pass A level considering Cambridge FCE test.

3.4. Setting

The present study was conducted in an undergraduate program of an English Medium University in Izmir, Turkey. The students register in the program with a specified score after taking the national university entrance exam. The graduates of the program receive the diploma of English language teaching to serve as teachers at both public and private schools.

3.5. Research Design

The current study employed a quasi-experimental design with pretest posttest nonequivalent groups. Considering the scope and the purpose of the study, quasi-experimental design with pre-test and post-test most suitably fits for the present research. In order to examine the impact of the treatment, having a control and an experimental group gives the opportunity to compare the difference between the ones who follow working memory enhancement training and the ones who do not. Having limited pool of prospective

participants restricted the study with convenience sampling as the participants were readily available and this led to non-random sampling of the participants. In addition to all, the nature of the data collected through the instruments is quantitative since each instrument gives quantified results. Due to these conditions, a quasi-experimental design seemed most appropriate for the study.

3.6. Data Collection Instruments

3.6.1. Topic Familiarity Survey

It is discussed in the literature that the topic influences the success and the productivity of any writing and it is already known that the topic and the cultural factor based knowledge affect the text quality (Akyel, 1994; Friedlander 1990**). I**n order to reduce the impact of the topic related knowledge on the text quality, the study included a topic familiarity survey so as to determine the topics to be used in writing tasks. The main aim was to see if the participants have the background knowledge on the topic they will write. For this purpose, the potential topics were pooled by the researcher and another instructor working at the same institution giving writing courses. There were 15 topics proposed and used in the survey (see appendices). The participants who were volunteered in to participate in the study were given the test online with a likert-scale answer list from 1 to 5 asking questions ranging from 'I know a lot about the topic' to 'I have no idea about the topic'. In the light of the answers, four topics, two in English and two in Turkish, on which the participants would write were determined.

3.6.2. Proficiency Test

So as to see the level of proficiency of the participants and also determine the possible participants in the study, a language proficiency test in L2 was given before the treatment. The language test was the *Cambridge English: First (FCE) Examination,* as a standardized

test assessing the test taker's overall language proficiency in different domains of grammar. The *Cambridge English: First (FCE) Examination* was one of the original tests from the published official examination papers by the Cambridge University press in 2008. The FCE which is a standardized test includes five sections each of which contribute %20 to the overall score. The sections in the official test are a) reading, b) writing, c) listening, d) language use, and e) speaking. However, the current study used the listening, reading and language use sections so as to lower the test overload on the participants. The scores are distributed around five bands as shown in table 3.1 Considering this range, the sections have different number of questions; reading with 30, Use of English with 42 and Listening with 20 questions. In this case, the scores are converted into 100 scale band (www.cambridgeenglish.org). Since the participants would already have a writing task both in L1 and L2 in the study so as to see the process of writing, the writing section in FCE was excluded. Due to the overload of the tests in the study, the speaking was also excluded from FCE. The participants in the study took the reading, language use and listening sections in the proficiency test.

Table 4. FCE Score Band

FCE Grade	**Score Range**
Pass A	80 to 100
Pass B	75 to 79
Pass C	60 to 74
Level B1	45 to 59
Fail	0 to 44

3.6.3. Writing Tasks

The participants wrote four essays in total during the study. Two of them were composed before the treatment and two were composed after the treatment. As the study focuses on the working memory capacity in both L1 and L2, two of the essays were in L1 and the other two were in L2. As mentioned before, the study included a topic familiarity test to determine with which topics the participants were familiar. Topic familiarity test guaranteed that the participants had the background knowledge about the topic they would write on. The study included two argumentative essays on two topics. The genre of the composition was argumentative since the focus of the instruction was teaching argumentative essay during the time in the research period. The essays were composed in InputLog (Leijten and van Waes, 2006) on a computer. The participants composed their essays in a computer lab in which there were 40 computers available. The participants first practiced the use of InputLog program in the guidance of the researcher. The internet connection was not available and the students were not able to use online dictionaries. Moreover, the computers did not have any online dictionary programs set up. In the light of topic familiarity test, four different topics were determined to be used in the study, two in English and two in Turkish.

The researchers in the field discuss the use of argumentative essay to compare L1 and L2 writing. Chandrasegaran (2008) claims that argument construction is an ability owned by most students even though it is not formally taught. Along the same line, Promwinai (2010) discusses in her study examining the demands of argumentative essay writing that argumentation is a part of daily life and every individual implicitly raised by being involved in daily arguments. When the research on writing is examined, it is seen that the studies commonly use descriptive, narration and persuasive essays (Glynn *et al.,*1982).

However, when it comes to the comparison of the two languages while writing in terms of cognitive aspects, argumentative and persuasive essay types are more common than the other types of essays (Machon, Roca and Murphy, 2000; Wang and Wen, 2002; Weijen, *et al.*,2009; Murphy and Roca, 2010; Glynn, *et al.*,1982; Ismail and Alsheikh, 2012).

Following the research tradition, argumentative essay as a text type was used in this study with L1 and L2 text production while comparing the impact of working memory on the writing processes in both languages. Two essays in Turkish and two in English with topics that required producing arguments were used as pre and post writing tasks.

Pre - Writing

1. Okul uniformasi ogrenciler icin zorunlu olmali mi?

2. Should university students be free to choose their courses related to their departments?

Post - Writing

3. Universite ogrencileri bolumleri ile ilgili derslerin seciminde ozgur birakilmali mi?

4. Should people have more vacations and holidays so as to be successful in their life?

3.6.4. Reading Span Test

As for the measurement of working memory capacity, reading span tests in addition to production span tests, given both in L1 and L2, were used in the study. Reading span test was originally developed by Daneman and Carpenter (1980) in order to measure the working memory capacity. It requires the participants read a number of sets of sentences ranging between 2 to 5 aloud and then are asked to write the final words of the sentences in order. It is commonly used in studies exploring the WM capacity in different languages. The tests used in this study were the adapted versions of the ones used by Daneman and Carpenter

(1980). The Turkish version was the one used by Alptekin and Erçetin (2009). In the present study, both Turkish and English versions of Reading Span Tests included 42 sentences. The main logic behind the inclusion of a reading span test, in which the participants had to both process and also store the input, was to see the capacity of working memory rather than the short term memory. The tests beginning with two sentences and having at most five sentences in each set were displayed through a computer program. Among the 42 sentences in both English and Turkish versions of reading span tests, 21 of the sentences were syntactically ungrammatical. The number of the words in the sentences ranged between 11-13 in the English version and ranged between 10-11 in the Turkish version. As an overall process, the sentences were displayed on the computer screen one by one and the participants were asked to type the recalled final words of the sentences. In addition to recalling the final words, the participants had to judge the sentences and determine if they were ungrammatical or grammatical (e.g. The girl picked up her bag and down to went the gym.). While performing the task both in English and Turkish tests, the participants were required to press "T" on the keyboard to show the given sentence was grammatical or to press "F" on the keyboard to show the given sentence was ungrammatical. The tests were given in the computer labs at the university.

3.6.5. Production Span Test

In addition to reading span tests, production span tests were given in L1 and L2 in the study. In general, span tests which differ in terms of forms and modes have been used for the measurement of memory capacity in the field of cognitive science. The capacity of storing the knowledge for a period of time is the rationale behind the span tests. The working memory model proposed by Baddeley and Hitch (1974) shaped the early attempts on how to measure memory. Further improvements in clarifying the functional aspect of working

memory shaped the span tests used for working memory capacity. In other words, memory demands in the span tasks were considered in accordance with the functional components proposed in the working memory model by Baddeley and Hitch (1974). The tasks include a simultaneous demand only on storage or a simultaneous demand on both storage and process. The distinction in the memory demands of the tests determines either it is a simple span task or a complex span task. The nature of the span task is shaped considering the distinction between short-term memory and working memory and span tests are categorized into two in terms of the construct they intend to measure. One of them is the simple span test used for the measurement of short term memory capacity in which the test taker retrieves the stimuli for a period of time and the other one is the complex span test in which the test taker stores and process the knowledge simultaneously.

The items in the span tests are organized around the sets with an increasing pace throughout the test. For example, the first set may have three items in each sub-set and may include three sub-sets, the second set may have four items in each sub-set and may have four sub-sets. The expansion of the test may go up to seven items with five or six sub-sets. However, the language used may change the structure or the length of the span test, such as the use of twelve words or sixteen words for a semantically meaningful sentence in a span test. Moreover, the structural aspect of the language may also determine the mode of the span test. That is to say: the span tests may include the recall of either the final word or the first word of the sentence.

With inclusion of complex span tests as an alternative way of measuring working memory, the span tests were shaped in consideration of the construct that the working memory is expected to predict or to have a relationship. In other words, listening span test should be used to see the relationship between listening skill and working memory capacity

and similarly reading span test should be used to see the relationship between reading skill and working memory capacity. Parallel to complex span tests including the focus of the construct to be examined, writing span tests and production span tests are considered to measure the working memory capacity through a process resembling the one in writing process.

The performance in a writing span test can be scored by a) the percent or the number of words recalled, b) the number of the sentences uttered, and the mean of sentence length; however, the sentences uttered during the tests have to be structurally and semantically correct. Participants taking the writing span or production test are asked to follow a list of words presented in sets in an ascending order. After the display of the word list, participants are asked to make up sentences using the words listed. Every displayed word can only be used in one sentence and cannot be used as the first word of the sentence. Moreover, the last word displayed cannot be used in the first sentence uttered. Semantically and structurally correct sentences complying the instructions are counted as the score of the span test which is considered as the working memory capacity measured through production span test.

Considering the nature of the study that focuses on text production, the production span tests were included in the study. As discussed in the previous section for the span tests, simple span tests reflect a passive nature of a processing in which the test takers do not produce anything with the given items. However, the nature of the production span tests, which is a complex span test, resemble the process of writing. In a regular writing, the writer forms up a meaningful and structurally correct sentence with the message being conveyed and, similarly, the productions span tests include forming sentences with the given words. Different modified versions of production span tests exist in literature. For instance, a production span test was used by McCutchen, Covil, Hoynes and Midles (1994) that

included the detection of the misspelled words in sentences and the recall of those words to insert into a story. Production span tests were also used in the studies (Alamargot et al, 2007; Chuy, Alamargot and Passerault, 2012) which aimed to investigate the relationship between writing skill and working memory capacity through the writing span tests.

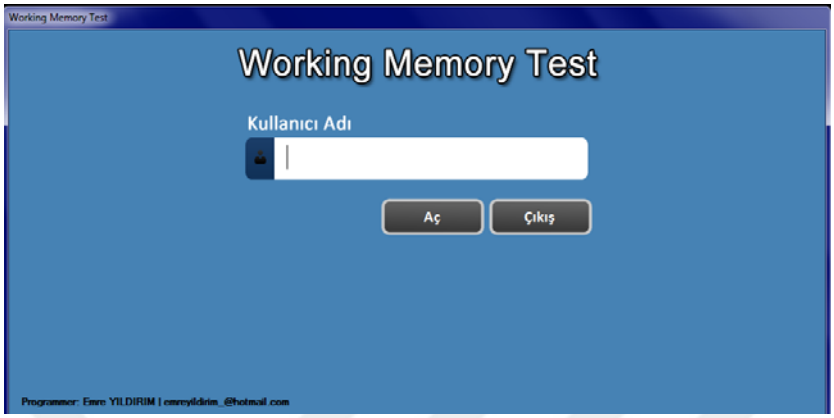
Practically, the production span tests used in this study consisted of a series of written words, the number of which gradually increased in test. The participants had to remember as many words as they could to write a sentence around each word. In line with the ones used in literature, several instructions had to be followed by the test taker. The first rule to be followed was to write a meaningful and syntactically or grammatically correct sentence. The second rule to be followed was not to use the word seen on the screen as the first or the last word of the sentence. Following these steps, production span tests which included as many features mentioned in the literature as possible, were developed in L1 Turkish and L2 English.

As the first step of developing production span tests from scratch, British National Corpus for English and Turkish National Corpus for Turkish were used. To have access for British National Corpus (BNC) and Turkish National Corpus (TNC) (Aksan, Y. et al. 2012), registrations were made through the websites. The words selected from the 2500 most frequent words provided on the corpora used and were put in order in L1 and L2.

As the second stage, the researcher used the nouns in the list in order to form up production span test items in English and Turkish through both TNC and BNC. Care was taken to have nouns for the items in the word span tests so as not to include abstract tokens and verbs.

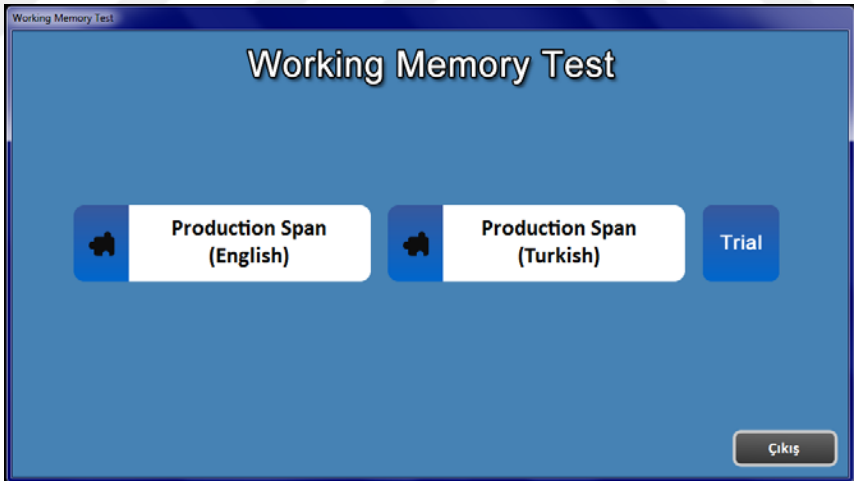
After determining the word list, the words were grouped in sets (3x3, 4x3, 5x3, 6x3 and 7x3). Technical support was received from an IT expert in order to develop a software.

Figure 3.1. Working Memory Span Test Preface



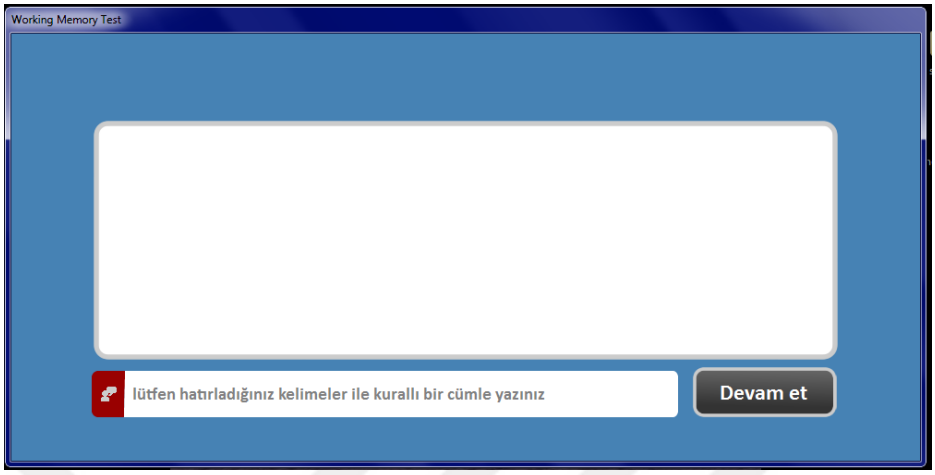
The software developed included the production span tests in two languages. As the first step, the participants had to click on the start button and could have the trial version of the test to be familiar with it.

Figure 3.2. Working Memory Span Test Template



After the words were displayed in a fixed time and order, the participants were asked to write a sentence with the words they remembered. However, while writing their sentences, the participants had to follow the instructions given at the beginning of each test.

Figure 3.3: Working Memory Span Test Answer Template



After the software was prepared, it was set up in a computer lab where the participants could take the test. The software used for the production span test was user friendly with its template which asks the participants name at the beginning and saves the sentences compiled by the participants during the test. After the practice, the participants could individually take the production span test. *(please see appendix 3 for the span tests developed)*

3.7. Treatment for Working Memory and Attention on Lumosity

Among a number of cognitive training programs, Lumosity, which is an online program, was used into the study. Lumosity is a commercial online program that has been developed by Lumos Labs. Lumos Labs is a cognitive neuroscience research company that develops software tools for improving brain health and performance. The online programs developed by Lumosity has been used in a number of studies examining cognition from different perspectives (Sarkar, Drescher, and Scanlon,2007; Hardy *et al.*,2011). As discussed in the previous section in details, the eight-week long cognitive training was given to the participants who were assigned to either control or experimental group through lumosity. Lumosity was included into the study for three reasons.

First of all, Lumosity has a user-friendly template which offers the users access to the applications to follow and the users can see their progress throughout the training by the

help of template on the website. When the participant's register, they receive a username and a password with which the training can be followed on any device with an internet access. Upon the preference, the participants may opt receiving regular emails to remember their daily training sessions.

Secondly, Lumosity has practical applications which serve the improvement of different cognitive skills. Among five cognitive skills (working memory, speed, attention, problem solving, flexibility), working memory training is provided through a number of games. The control group could follow a pack of attention training so as to prevent the Hawthorne effect in the study. Having multiple sub-cognitive skills in the training so as to offer a placebo to the control group was another reason for including Lumosity into the study. That is to say; if the experimental group was the only one which had a training, the participants in the experimental group would feel themselves privileged and the ones in the control group would easily feel themselves prevented.

Last but not least, Lumosity offered possibility to monitor the training of the participants. It provided daily report to the researcher with the detailed progress of the participants during the study. As the training had to be completed in a specified time period, the progress of the participants in the training were quite essential for the validity and the reliability of the study.

The experimental group participants receiving working memory training and control group participants receiving attention training were assigned a pack of 120 training sessions through six games. In order to complete the training, the participants had to complete two sessions daily which was equal to 30 minutes. Considering the length of the training, which was eight weeks, each participant had to spend 30 minutes daily and the total time for the training would be 28 hours. Participants followed the games listed below during the training

through Lumosity. Briefly, the games were composed of visually presented interactive online tasks. These tasks differed in terms of the underlying cognitive requirement. The games given to the experimental group were designed to tap the use of working memory in which the participants had to rely on their working memory to complete the tasks, such as hitting the spots where the birds appear one by one. In order to accomplish the task in the game, the participants had to remember the visually given details.

Table 5. The Game List on Lumosity for Each Group

Experimental Group Working Memory Training	Control Group Attention Training
1.Memory Lane	1.Bird Watching
2.Pinball Recall	2.Lost in Migration
3.Memory Match	3.Top Chimp
4.Monster Garden	4.Eagle Eye
5.Memory Match Overload	5.Observation Tower
6.Follow that Frog	6.Space Junk

3.8. Inputlog for the Examination of Writing Process

InputLog (Leijten and van Waes, 2006), which is among the keystroke programs, has been specifically developed for the assessment of writing process. It offers modules for the detailed analysis of the process followed during text composing. The program allows the researcher to reach the data on pauses, deletions, and revisions in addition to the quantitative data, such as the length, the duration and also the number of characters, words, and sentences produced during writing. Since the aim of the study was to see the detailed writing process, InputLog fit the aim of the present study which used the detailed recordings of the writing process followed by the participants in order to answer the research questions of the study.

To be more precise on why InputLog was used to collect the data regarding the research questions in the study, the modules that Inputlog includes are summarized below. When the functions described in five modules are examined, it is quite plausible to say that InputLog serves best for the data required in the current study.

Inputlog includes five modules:

1. *Record module* records the keylog actions while writing. The program functioning parallel with Microsoft Word and the operating system of the computer in which the writing is carried out. The keylog actions recorded include every action regarding the writing, such as characters used, deletions made, copy/paste actions done and also the time for every action during writing.
2. *Pre-process module* includes the recording of the functional applications, such as internet use and mouse or the keyboard use during writing.
3. *Analyze module* allows the researcher to have retrospective access to the quantified representations of the writing process, such as the number of the pauses, revision and deletions.
4. *Post-process module* provides access to the single or multiple log files from Inputlog or other tools and allows the researcher to integrate multiple output files into each other for statistical analysis to be used in SPSS.
5. *Play module* functions as a replay feature through which the researcher can go back to the recorded session and play it to see the development of writing.

The data collected through Inputlog program on the writing process followed by the participants in L1 and L2. covered the quantification of the 13 components shown in Table 6 through InputLog on page 118.

Some of the individual data components need to be explained in detail in terms of what they refer to and include. The term burst is not new in writing process and the bursts are claimed to occur in two ways; a) creative bursts (Fayol,2012) cover the productive writing period after a short pause in which any individual is assumed to accumulate the abstract ideas to put into wording, and b) pause bursts explain the waiting time in which any individual is assumed to get prepared for the next stage which is putting forward the ideas in a productive writing. After investigating the impact of the length of the bursts for writing fluency measured regarding composing rate, Chenoweth and Hayes (2001) proposed the bursts as the contributing processes to the idea development and as a factor affecting the fluency in writing.

The bursts in this study are considered as the creative bursts in which the writer puts the abstract ideas into wording through writing. As given above, t*he total number of the burst* refer to the quantified number of the writing in which the participants compose during the process of writing. The pauses in the writing refers to planning in the study. *Total planning time* explains the total time spent with the planning while composing. *Total number of the planning* show how many times the writer pauses during the writing process. *Mean planning time per each planning* gives the average time for each planning, *the total time of the planning* is divided by the number of the planning to have the *mean planning time per each pause*. *Total active writing* time gives the total time spent while composing.

Editing and the revision, regarding how they are considered in the current study, need a detailed explanation as the two terms are usually used interchangeably although each of them refers to two distinct operations during writing. Revision and editing, having multiple subcomponents, have led to a disagreement for the writing process. Being one of the most comprehensible reviews on the comparison of studies on writing through the computer,

Goldberg, *et al.* (2003) discussed how diverse the revision in writing was operationally defined across studies. Some studies defined revision as deleting and inserting words or sentences or correcting the sentences (Grejda and Hannafin, 1992; Peterson, 1993), whereas other studies defined it as the surface and format changes, such as grammar, punctuation, and spelling or the changes in content and meaning (Hagler, 1993; Head, 2000; Olson, 1994; Peterson, 1993; Seawel, 1994).In the middle of the blur picture stemming from the interchangeable use of revision and editing, Breidenbach (2006) uses the metaphor of the ants-at-a-picnic metaphor while discussing the different aspects of revision and editing. As being lack of errors will not indicate that the writing is flawless, revisions helps with the genre, view, purpose, knowledge, audience, and using the right tone. On the other hand, editing deals with spelling, grammar, mechanics, word-usage, and local concerns (Horning and Becker, 2006). Haar (2006) also touches the distinction between revising and editing by claiming editing involves spelling, grammar, mechanics, word-usage and local concerns, whereas revising may cover adding new sections and substantial changes regarding the content of the writing.

In the light of the proposals and claims made in the literature (Grejda and Hannafin, 1992; Peterson, 1993; Hagler, 1993; Peterson, 1993; Seawel, 1994; Olson, 1994; Head, 2000; Goldberg, *et al.,* 2003; Breidenbach, 2006; Horning and Becker, 2006; Haar, 2006), editing and revision operationally defined as two distinct processes in the current study. *Total number of the editing* refers to the surface level changes and local rearrangements regarding the grammar, spelling errors, punctuation mistakes, incorrect words, sentence fragments, and other mechanical problems in the writing. However, *Total number of revisions* are considered as the global changes in terms of the content, purpose, flow of the ideas, organization, and focus.

Table 6 Writing Components

	Components of Writing Process
1	Number of Characters in Writing Process
2	Number of Words in Writing Process
3	Number of Sentences Uttered in Writing
4	Number of Characters Uttered in Writing
5	Number of Words Uttered in Writing
6	Total Time for the Writing Process
7	Total Number of the Bursts during the Writing Process
8	Total Planning Time During the Writing Process
9	Total Number of the Planning during the Writing Process
10	Mean Planning Time Per Each Planning During the Writing Process
11	Total Active Writing Time During the Writing Process
12	Total Number of the Editing during the Writing Process
13	Total Number of Revisions during the Writing Process

3.9. Data Collection

The study followed the procedures listed on Table 6 while collecting the data with the instruments defined in previous section.

Any study having multiple instruments would need a pilot study so as to evaluate the feasibility of the instruments (Baker, 1994). With its multitask nature in terms of the data collection procedures, the current study had a pilot study. The study was piloted with a group of ten sophomores and juniors in the ELT department. All the tasks included in the study were examined in order to avoid possible problems during main data collection. The first step was the Cambridge English: First (FCE) test. So as to see how the timing and the administration procedures worked, students were given a sample of Cambridge English: First (FCE) examination with listening, reading and language use sections. The administration of the test at once worked quite well according to the feedback from the test takers in the pilot study. The second step included administering the span tests in laboratory setting. However, the span tests were given on different dates since the overload of the test

requirements were thought to affect the results. The observed conditions revealed that the test takers should be well informed of the instructions of the span tests. The test takers were cautiously informed of basic rules. Another process included into the pilot study was the trial of the treatment through an online program. The students involved in the pilot study were registered for the online treatment and were observed for five days so as to see the feasibility and the practicality of the online programs. All things considered, the overall feedback, other than some minor problems regarding the tests rules to be stressed particularly, was quite positive.

With its experimental design including pre and post stages, the study covered the steps listed below during the data collection procedures.

1. The researcher used a topic familiarity questionnaire before the study in order to see what possible topics can be covered during the study.
2. The participants were assigned either to the experimental or the control group before the memory instruction.
3. The participants were given a proficiency test at the beginning of the study in order to assess their overall language ability level and to control any possible significant difference related to proficiency.
4. Working memory tests (Reading Span and Production Span) were given to the participants to see their working memory capacity.
5. The participants composed four essays through the computer program, two in L1 and two in L2.
6. The participants in the experimental group received working memory instruction through the online software for eight weeks.

7. The participants in the control group received attention training through the same online software which was expected to serve as placebo in order to avoid Hawthrone effect.
8. Working memory tests (Reading Span and Production Span) were given to the participants before the treatment and after the treatment to see if working memory training led to any improvement on working memory capacity of the participants.
9. Both the experimental and the control group composed four essays through the computer program two in L1 and two in L2 (for each language one in pre tests and one in the post tests).

The summary of the study regarding pre tests and post tests for the data collection are outlined below in Table 7.

Table 7. Data Collection Procedures

Pilot Study	Proficiency Exam 1	Working Memory Tests	Writing Tasks	Treatment	Working Memory Tests	Writing Tasks
2 Weeks	1 Week	1 Week	1 Week	8 Weeks	1 Week	1 Week

As it is outlined above, the study included a number of tests and tasks in order to examine and assess the participants' language level, writing process and working memory capacity for the data collection. The study also included working memory instruction in order to see if there is an impact of working memory instruction on the working memory capacity. With the headlines of each in reference to the data collection procedures, the further

procedural details regarding the dates of the tests, the computer programs, the tasks and the treatment included in the study are seen with the exact dates for the data collection procedures and the treatment in Table 8.

Table 8. Dates of the Data Collection and Treatment

Dates	Research Component
25 Feb, 2013 - 04 Mar, 2013	Topic Familiarity Survey
01 Apr, 2013 - 15 Apr, 2013	Pilot Study
13 May, 2013 - 20 May, 2013	Proficiency - Pre -Working Memory Tests
20 May, 2013 - 27 May, 2013	Pre- Writing Tasks
27 May, 2013 - 22 July, 2013	Treatment
22 July, 2013 - 29 July, 2013	Post-Working Memory Tests
29 July, 2013 - 05 Aug, 2013	Post- Writing Tasks

3.10. Scoring

The present study had a number of tests and each of them was scored and quantified in the light of a scale. The scoring included the proficiency tests, writing tasks, reading span tests, production span tests, and quantification of the InputLog program output on writing components and finally, the quantification of the editing and revision in the writing tasks.

3.10.1. Scoring Proficiency Tests

The answers on the FCE tests were marked according to the official answer key given in the test. Each right answer received 1 for each individual question. The scoring was adapted into the overall scoring band of the *FCE*. As the sections on writing and speaking excluded, the contribution of each section to the overall grade was 3.3 out of 10. In this case, the contribution of the questions each section was calculated considering 33.3 out of 100. Each question in reading had 1.33 and listening sections had 1.14 value, whereas each

question in use of English section had 0.92 value. The scores for the language proficiency test ranged around B1 and B2 level on the Common European Framework of Reference for Languages (CEFR) scale. As mentioned above, the participants below that level were excluded considering since they did not meet the language proficiency requirements of the study.

3.10.2. Scoring Writing Tasks

The writings completed by the computer program were collected and printed out. The writings were coded in order to keep the writer anonymous. On a voluntary basis, two raters with at least five years of teaching experience and with an MA degree in language teaching scored the writing tasks in English and Turkish. Individual norming sessions with each pair of raters were set and the raters were informed about the tasks and the global scoring. Having the approval of the raters on the job, another session was set by the researcher. In the second session, ten samples from the pilot study were brought for each rater for the moderation of the scoring. Step by step, each writing was scored by the raters and the scores were compared with in the group of raters. After having five practices for each language, the raters were given time for scoring the other five sample essays. The scores from the practice were coherent and plausible showing the readiness of the raters for the rest of the essays.

After the completion of the scoring of essays in a limited time, the final scores were compared within the group of raters to be included as a final writing quality score into the study. The existing discrepancies above five points were resolved through discussion among the raters. The same procedures were followed for scoring writing tasks in English and Turkish. The scoring sessions were effective since the inter-rater reliability coefficients calculated through Spearman's rank order correlation were high. The results revealed reliability coefficients ranging from .794 to.958 as shown in Table 9.

Table 9. Correlations Scores on Interrater Reliability

Writing Quality Scores	**Correlations**
Turkish_Pre_Writing Grammar	.874**
Turkish_Pre_Writing Content	.836**
Turkish_Post_Writing Grammar	.768**
Turkish_Post_Writing Content	.944**
English_Pre_Writing Grammar	.958**
English_Pre_Writing Content	.910**
English_Post_Writing Grammar	.777**
English_Post_Writing Content	.896**

3.10.3. Scoring Reading Span Tests

In the present study, both Turkish and English versions of Reading Span Tests included 42 sentences. As the participants had to both process and also store the input so as to see the working memory capacity, the results were three scores for further analysis. Grammatical judgement of the sentences was the first phase for the sentences displayed consecutively on the computer screen. That is to say the participants had to first decide whether the sentence displayed was grammatically correct or not. Then the second task was to recall the last word of the sentence. The sentences were displayed in sets increasing gradually in terms of the number. With this nature of the reading span test, each participant received three scores on the reading span test. The first one was the number of the correct responses on grammatical judgement of the sentence. The second one was number of the correct final words remembered. The third one was the score received from the responses given on both judgement and recall processes.

3.10.4. Scoring Production Span Tests

The scoring of the production span tests covered the storage and the process scores of any sentence produced. Since the participants had to both process and also store the input so as to see the working memory capacity, two separate scores were received, which were

further analyzed. The test takers who produced a sentence in line with the rules given were considered to have accomplished the procedural aspect of the test item and received one score for it. However, the tests takers who produced a sentence but did not follow the rules were considered to have accomplished only the retrieval aspect of the production span test, so they received one score for the storage. The number of the sentences which included both aspects of the production span test, which are process and storage, was recorded as a separate variable, which referred to the third score.

3.10.5. Scoring Inputlog Program Outputs

Being one of the most developed keylog programs regarding the data collection on writing process, Inputlog gives a detailed quantification of the writing process on the preferred subcomponents (See the sample output from Inputlog in appendix). The detailed quantified data on the items given in Table 10 below was taken for each participant on the writing tasks. The editing score covered all changes including local and global changes. However, a meticulous process explained in the next section was followed to distinguish editing and revision.

Table 10. Writing Components

1. Number of Characters in Writing Process
2. Number of Words in Writing Process
3. Number of Sentences Uttered in Writing
4. Number of Characters Uttered in Writing
5. Number of Words Uttered in Writing
6. Total Time for the Writing Process
7. Total Number of the Bursts during the Writing Process
8. Total Planning Time During the Writing Process
9. Total Number of the Planning during the Writing Process
10. Mean Planning Time Per Each Planning During the Writing Process
11. Total Active Writing Time During the Writing Process
12. Total Number of Editing during the Writing Process
13. Total Number of Revisions during the Writing Process

3.10.6. Quantification of Editing and Revision

Quantification of the writing components which include editing and revision had a more elaborate process. After the study was completed, the writing process recorded by InputLog program helped to quantify the editing and revision processes. For this purpose, two experienced language teachers for English and other two for Turkish voluntarily participated in the quantification process of editing and revision. The initial phase included the short training of the scorers on the difference between editing and revision. Then, the scorers practiced on three samples to have a moderation regarding the difference between editing and revision. Using the recording function of InputLog, the writing process from each participant was observed at a reasonable speed on a computer screen. The moderation sessions worked well so as to avoid the disagreement on the quantification. The quantification required watching the recorded process twice. The scorers individually watched it first to determine the editing and revision in writing and then watched again to eliminate any disagreement on each revision and editing done by the participants.

3.11. Data Analysis Procedure

The analysis covered the statistical examination of data collected through a) writing on InputLog, b) working memory span tests, d) *Cambridge English: First Examination (FCE),* and e) text quality scores. Specifically, the data collected in the light of the research questions through the instruments discussed above was analyzed as presented in Table 11.

Table 11. Data Analysis

Research Question	**Data Collection Instruments**	**Statistical Analysis**	**Content**
For the first part of the study;			
Research Question 1 To what extent does production span test measure working memory capacity compared to reading span tests?	**1.**Reading Span Tests in L1 and L2 **2.**Production Span Tests in L1 and L2	**1.**Varimax rotation	WM Scores
For the second part of the study;			
Research Question 1 Is there a relationship between working memory capacity and L1 Turkish and L2 English online writing processes of EFL students?	**1.**Reading Span Tests in L1 and L2 **2.**Production Span Tests in L1 and L2 **3.**Writing Tasks in L1 and L2 **4.**Pre Proficiency Test in L2 **5.**InputLog Program	**1.** Descriptive Statistics **2.**Spearman's rank order correlation	WM Scores InputLog Scores
Research Question 2 Is there a relationship between working memory capacity and L1 Turkish and L2 English writing quality of EFL students?	**1.**Reading Span Tests in L1 and L2 **2.**Production Span Tests in L1 and L2 **3.**Writing Tasks in L1 and L2 **4.**Proficiency Test in L2	**1.** Descriptive Statistics **2.** Spearman's rank order correlation	WM Scores Global Scoring

Research Question 3 Does working memory training lead to any effect on working memory capacity of EFL students taking working memory training?	**1.** Pre and Post Reading Span Tests in L1 and L2 **2.** Pre and Post Production Span Tests in L1 and L2	**1.**Descriptive Statistics **2.**Mann-Whitney U Tests	InputLog Scores Global Scoring
Research Question 4 Is there a difference in L1 Turkish and L2 English writing processes and quality of EFL students' after the eight weeks training period?	**1.** Pre and Post Reading Span Tests in L1 and L2 **2.** Pre and Post Production Span Tests in L1 and L2 **3.** Pre and Post Writing Tasks in L1 and L2 **4.** Proficiency Test in L2 **5.** InputLog Program	**1.** Descriptive Statistics **2.** Mann-Whitney U Tests **3.** Spearman's rank order correlation	InputLog Scores Global Scoring

a) The study included the assessment of the working memory capacity on a computer program through span tests. The span test scores were assigned in accordance with the correct answers given to each item. Individual scores to each test and also to each set in the tests were considered so as to have a detailed scoring on the working memory capacity of the participants. That is to say, in addition to the total numbers of the correct answers to each span test, the total numbers of the correct answers to each set in the span tests were also considered for further analysis.

b) L2 language proficiency of the participants in both experimental and the control groups were assessed through *Cambridge English: FCE* at the beginning of the study. The

analysis includes the scores gathered from each section in the proficiency test. These scores were used for further comparisons and correlations.

c) In addition to the process, the quality of the composed texts was scored using global scoring method by two raters. The writing quality scores were used so as to make comparison between control and experimental groups and also to have further understanding regarding the relationship between other variables in the study.

d) The distribution of the scores was examined through SPSS with the Kolmogorov-Smirnov tests.

e) The global scores on the writing quality given by two raters were analyzed for inter-rater reliability.

f) The number of revisions during the writing process was quantified by two raters in L1 and L2

g) As it is one of the aims of the study to see whether there is a relationship between working memory capacity and the writing processes in L1 and L2, the correlation analysis *(*Spearman's rank correlation coefficient as it is non-parametric data analysis*)* was performed. The same correlation analysis was also performed in order to see whether there is a relationship between working memory capacity and writing quality in L1 and L2.

h) In order to see whether working memory instruction leads to an effect in working memory capacity and whether it leads to any change in the writing process and quality, Mann-Whitney U tests were carried out.

CHAPTER 4

RESULTS

4.1. Introduction

This chapter presents the results of the statistical analyses carried out to answer the research questions in the study. As the data has a number of variables differing in nature, different analyses were used for each set of data through using SPSS.

The present study had two dimensions. The first dimension of the research included statistical examination of the production span test developed specifically for this study. The other dimension focused on four research questions. The first research question investigates the writing skill and working memory relationship in L1 and L2. The second question asks if there is a significant difference between control group and experimental group after the working memory training regarding the working memory capacity. Third research question focuses on the effect of working memory training on working memory capacity of EFL learners. The last research question asks if there is a difference in L1 Turkish and L2 English writing quality and process after the working memory training period.

The findings in this chapter are presented in two parts. The first part includes factor analyses focusing on scores of both production span and reading span tests. The first question asks to what extent production span test measures working memory capacity compared to reading span tests. Namely, the study aims at investigating the construct validity of production span tests developed in the current study compared to the operation span tests already available, both of which are expected to measure working memory capacity. For that purpose, factor analyses were carried out with the data collected through two span tests. The results of the factor analyses with the factor loads are presented.

The second part includes the statistical findings regarding the other four research questions. The first section in part two includes the findings on the relation between the WM and L1 and L2 writing process. The second section is on the correlation analysis focusing on the relation between the WM and L1 and L2 writing quality. The third section focuses on the results of T-tests done in order to see if working memory training was effective in improving working memory capacity. The last section focuses on the findings answering if there is a difference in L1 Turkish and L2 English writing processes and quality of EFL students after the eight weeks training period.

4.2. Findings of the First Part of the Study

In an attempt to answer the question included in part one, namely, to what extent production span test measures working memory capacity compared to reading span test, statistical analyses on production span tests and reading span tests were conducted. The findings on the factor analyses are presented in the following sections.

4.2.1. Statistical Analysis on Production Span Test

The statistical analysis included factor analysis of the scores on span tests used in the study. The purpose was to investigate whether the tests showed construct validity by measuring what they were theoretically intended. Also, to avoid spurious factor loadings, Varimax rotation was used to remove the effect of intercorrelations of the underlying latent variables. Table 12 below presents the factor loadings for the two span tests.

Table 12. Factor Loadings

	Factors			
	F1	F2	F3	F4
Tr_Pre_Pro_Sp_Process		0.86		
Tr_Pre_Pro_Sp_Storage		0.86		

Tr_Post_Pro_Sp_Process		0.90		
Tr_Post_Pro_Sp_Storage		0.88		
Tr_Pre_Op_Sp_Correct			0.83	
Tr_Pre_Op_Read_Sp_Both	0.78		0.44	
Tr_Pre_Read_Sp_Correct	0.85			
Tr_Post_Op_Sp_Correct			0.66	
Tr_Post_Op_Read_Sp_Both	0.59		0.41	
Tr_Post_Read_Sp_Correct	0.69			0.36
Eng_Pre_Pro_Sp_Process		0.72		0.43
Eng_Pre_Pro_Sp_Storage		0.70		0.42
Eng_Post_Pro_Sp_Process		0.88		
Eng_Post_Pro_Sp_Storage		0.84		
Eng_Pre_Op_Sp_Correct				0.90
Eng_Pre_Op_Read_Sp_Both	0.66			0.59
Eng_Pre_Read_Sp_Correct	0.87			
Eng_Post_Op_Sp_Correct				0.60
Eng_Post_Op_Read_Sp_Both	0.67			0.43
Eng_Post_Read_Sp_Correct	0.86			

(Loadings below .30 were ingored)

As shown in table 4.1, the data revealed four underlying factors, whereas theoretically there should have been three factors because span tests had the following three components: a) reading span scores b) operation span correct answers, c) operation span and reading span correct answers. Loadings on factor 1 seem to indicate that reading span test scores and operation span and reading span scores have similar underlying constructs. Operation span test scores in Turkish seem to load on Factor 3, whereas operation span correct answers in English loads on factor 4. On the other hand, production span tests in both languages loaded on factor 2. As a result, the factor analyses show that language (ability or

the language of the test) is a factor in the reading span tests, which leads to another underlying variable although the span tests are supposed to measure the same underlying factor independent of the language used. For this reason, the factor analysis provides evidence on the construct validity for the production span tests developed in the study, all of which indicate working memory is independent of language. Further analyses covering the relationship and correlation include the findings from individually from reading span test and production span test. However, these findings are discussed in detail in reference to similarities and contrasts by stating the nature of each span test.

4.3. Findings on the Second Part of the Study

For the purpose of the study, findings of the research questions in part two will be discussed in terms of a) the statistical findings regarding the relation between the WM and L1 and L2 writing process, b) the relation between the WM and L1 and L2 writing quality, c) the results of T-tests done in order to see if working memory training was effective in improving working memory capacity and finally d) the findings answering if there is a difference in L1 Turkish and L2 English writing processes and quality of EFL students after the eight weeks training period.

4.3.1. The Relationship Between Writing Processes and Working Memory

A number of correlation analyses were performed to see the relationship between different variables and components related to WM. This part of the study covers the results of the correlation analyses on the relationship between writing process and working memory.

Due to small number of participants, the normality assumption was not met. Therefore, nonparametric correlation analysis using Spearman's rho coefficient was carried out for different variables.

4.3.1.1. The Relationship between in L1 Turkish Writing Processes and Working Memory

The Spearman's correlation analyses show the relationship between L1 Turkish writing processes and working memory. The correlation values are presented in Table 13.

Table 13. Correlation Values between L1 Turkish Writing Processes and Working Memory

		Tr Pro Sp Process	Tr Pro Sp Storage	Tr Op Sp Correct	Tr Op Read Sp Both	Tr Read Sp Correct
Tr Wri Num Characters	Exp Con	-	-	-	-	-
Tr Wri Num Words	Exp Con	-	-	-	-	-
Tr Wri Num Sent Out	Exp Con	-	.588*	-		
Tr Wri Num Chrac Out	Exp Con	-	-	-	-	-
Tr Wri Num Words Out	Exp Con	-	-	-	-	-
Tr Wri Tot Prces Time	Exp Con	-	-	.567*	-	-
Tr Wri Num Bursts	Exp Con	-	-	-	-	-
Tr Wri Tot Planning Time	Exp Con	-	-	.623*	-	-
Tr Wri Num Planning	Exp Con	-	-	.-	-	-
Tr Wri Mean Planning Time	Exp Con	-	-	-	-	-
Tr Wri Active Wri Time	Exp Con	.563*	.559*	-	-	-
Tr Wri Editing	Exp Con	-	-	-	-	-
Tr Wri Revision	Exp Con	-	-	-	-	-

As indicated in table 13., there are five statistically significant correlations between writing in L1 Turkish processes and working memory span tests. Statistically significant correlations exist between a) production span test storage and the number of sentences

produced (r=588), b) operation span test correct answers and total process time (r=567), c) total planning time and operation span test correct answers (r=623) for control group and d) active writing time and production span test process (r=563) and production span test storage (r=559) for the experimental group.

All these results suggest that the text composer in L1 who scores high on working memory capacity wrote more sentences in any given time. Moreover, the correlations in the sentences, process time, active writing time and planning show that the higher working memory leads to longer time of writing, and more planning during writing. In other words, the same findings can be interpreted as the lower working memory capacity leads to fewer sentences, less time, and fewer planning.

4.3.1.2.. The Relationship between L2 English Writing Processes and Working Memory

The results of the statistical analyses reveal that there are three statistically significant correlations between L2 English writing processes and working memory.

Table 14. Correlation Values between L2 English Writing Processes and Working Memory

		Eng Pro Sp Process	Eng Pro Sp Storage	Eng Op Sp Correct	Eng Op Read Sp Both	Eng Read Sp Correct
Eng Wri Num Characters	Exp Con	-	-	-	-	-
Eng Wri Num Words	Exp Con	-	-	-	-	-
Eng Wri Num Sent Out	Exp Con	.573*	.565*	-		
Eng Wri Num Chrac Out	Exp Con	-	-	-	-	-
Eng Wri Num Words Out	Exp Con	-	-	-	-	-
Eng Wri Tot Prces Time	Exp	-	-	-	-	-

	Con					
Eng Wri Num Bursts	Exp	-	-	-	-	-
	Con					
Eng Wri Tot Planning Time	Exp	-	-	-	-	-
	Con					
Eng Wri Num Planning	Exp	-	-	.-	-	-
	Con					
Eng Wri Mean Planning Time	Exp	-	-	-	-	-
	Con					
Eng Wri Active Wri Time	Exp	-	-	-	-	-
	Con					
	Exp	-	-	-	-	-
Eng Wri Editing	Con					.544*
	Exp	-	-	-	-	-
Eng Wri Revision	Con					

As indicated in table 14., there are three statistically significant correlations between writing in L2 English processes and working memory span tests. Statistically significant correlations exist between a) reading span correct answers and the editing (r=544) for control group, b) production span test storage and number of sentences produced (r=565) and production span test process and number of sentences produced (r=573) for the experimental group.

All these results suggest that the text composer in L2 who has high score on working memory capacity wrote more sentences in any given time. Moreover, the correlation in the editing shows that the higher working memory leads to editing during writing. In other words, the same findings can be interpreted as the lower working memory capacity leads to less editing.

4.3.2. The Relationship between Writing Quality and Working Memory

In an attempt to answer research question two asking if there is a relationship between working memory capacity and L1 Turkish and L2 English writing quality of EFL students,

Spearman's rho correlation analyses were carried out. This section provides the correlation analysis results on writing quality and working memory. As discussed earlier, writing quality is determined by scores on three attributes. The first score on writing quality reflects the overall score on grammatical accuracy. The second score is an indication of the quality of the content of writing. The third score is the average of global score on grammar and content score. Working memory span tests include scores on a) production span, b) operation span, and c) reading span tests. The following sections show the correlation analyses of writing quality scores and working memory span test results. More specifically, the correlation analyses are presented separately for L1 Turkish and L2 English with pre and posttests.

4.3.2.1. The Relationship between Writing Quality in L1 Turkish and Working Memory

None of the items regarding the writing quality scores (grammar, content, quality) in L1 Turkish and working memory span test scores (production, operation and reading span) in L1 Turkish correlate with each other. This may mean that writing quality in L1 Turkish has no relationship with working memory capacity in L1 Turkish.

4.3.6. The Relationship between Writing Quality in L2 English and Working Memory

The relationship between writing quality in L2 English and working memory was analyzed using the Spearman's rank order correlation. The values of correlation coefficients are shown in Table 15.

Table 15. Correlation Values between L2 English Writing Quality and Working Memory

		Eng Pro Sp Process	Eng Pro Sp Storage	Eng Op Sp Correct	Eng Op Read Sp Both	Eng Read Sp Correct
Eng Wri Gra	Exp	-	-	.585*	-	-

	Con	-	.594*	-	-	-
Eng Wri Cont	Exp	-	-	.684*	-	-
	Con	-	.555*	-	.550*	-
Eng Wri Quality	Exp	-	-	.716*	-	-
	Con	-	.543*	_	-	-

As indicated in Table 15, there are seven statistically significant correlations between a) production span storage and grammar scores (r=594), b) production span storage and content scores (r=555) c) production span storage and writing quality scores (r=543), d) operation and reading span both correct answers and content scores (r=550) for the experimental group. Moreover, statistically significant correlations exist between e) operation span test and grammar scores (r=585), f) operation span test and content scores (r=684), and g) operation span test and writing quality socres (r=716). All these results indicate that all components related to writing quality in L2; namely grammar, content and overall writing quality, are related to the working memory capacity in production span storage, operation span test and operation and reading span both correct answers. In other words, the positive correlation suggests that the writers with higher working memory capacity write better in L2 English.

4.3.2. Experimental and Control Group Comparisons

To answer research question three asking if working memory training led to any effect on working memory capacity of EFL learners, Mann-Whitney U tests were carried out. In this section, the results indicating whether there is a meaningful difference between the scores of participants in working memory capacity between control and experimental groups are presented separately. The purpose of the analysis was to find out whether the treatment was effective for the experimental group compared with the control group

considering the working memory capacity improvement. The results of analyses are presented in the following section.

4.3.2.1. Experimental and Control Group Comparisons on L1 Turkish and L2 English Span Tests

The results indicated that there is no significant difference between the control group and experimental group in terms of a) production span process, b) production span storage, c) operation span test correct answers, d) correct answers given both for operation span and reading span tests, e) reading span test correct answers in the pre tests and post tests in L1 Turkish and L2 English.

The results may suggest that the training on working memory did not make any difference in the working memory capacity in L1 Turkish or L2 English for experimental group to surpass the control group after the treatment.

4.3.3. Pre and Post comparisons within Experimental and Control Group

In this section, the results of statistical analysis done in order to see if there is a meaningful difference between pre tests and post tests scores of span tests for control and experimental groups are given. The purpose of the analysis carried out was to figure out whether the working memory treatment worked for each individual group.

4.3.3.1. Pre Test and Post Test Comparisons on L1 Turkish Span Test Scores

Below in table 16 is seen the comparisons between pre and posttest scores on L1 Turkish production span test.

Table 16. Pre Test and Post Test Comparisons on L1 Turkish Production Span

	Test	N	M	MD	sd	Sig.
Tur Cont Production Span Process	Pre	14	35.14	1.29	6.41	0.61
	Post	14	36.43		8.86	
Tur Exp Production Span Process	Pre	14	33.71	6.07	9.82	0.00
	Post	14	39.79		10.77	
Tur Cont Production Span Storage	Pre	14	36.21	0.86	6.45	0.97

	Post	14	37.07		8.74	
Tur Exp Production Span Storage	Pre	14	35.07	6.29	9.39	0.00
	Post	14	41.36		9.05	

As presented in Table 16 , there is a statistically significant difference between the pre and the posttest for the experimental group on a) production span process (Cont: p= .61 / Exp: p=.00), b) production span storage (Cont: p=.97 / Exp: p= .00) but no statistically significance for the control group on the both a) production span process and b) production span storage scores.

These findings indicate that experimental group had an improvement leading to a significant change between the pre test and post test in L1 Turkish regarding the working memory capacity.

The results of the comparisons between pre and posttest scores on L1 Turkish reading span test are given below in table 17.

Table 17. Pre Test and Post Test Comparisons on L1 Turkish Reading Span

	Test	N	M	MD	sd	Sig.
Tur Cont Read Span Correct	Pre	14	27.64	2.14	4.16	0.00
	Post	14	29.79		4.84	
Tur Exp Read Span Correct	Pre	14	26.50	0.86	6.16	0.44
	Post	14	27.36		6.76	

Table 17 shows that there is a statistically significant difference between pre tests and post tests for the control group but no statistically significant difference for the experimental group on the reading span test correct answers in L1 Turkish (Cont: p=.00 / Post: p= .44).

This finding shows that the control group had an increase in the working memory capacity in L1 Turkish compared to the experimental group during the training period.

However, there exists no statistically significant difference between pre and the post tests in terms of operation span test correct answers and the correct answers given both for operation span and reading span tests items in L1 Turkish.

4.3.3.2. Pre Test and Post Test Comparisons on L2 English Span Test Scores

The statistical results of the comparisons between pre and posttest scores on L2 English production span test are given below in table 18.

Table 18. Pre Test and Post Test Comparisons on L2 English Production Span

	Test	N	M	MD	sd	Sig.
Eng Cont Production Span Process	Pre	14	33.71	2.07	7.21	0.40
	Post	14	35.79		7.98	
Eng Exp Production Span Process	Pre	14	31.43	6.57	9.78	0.00
	Post	14	38.00		9.18	
Eng Cont Production Span Storage	Pre	14	34.93	1.86	7.08	0.48
	Post	14	36.79		8.01	
Eng Exp Production Span Storage	Pre	14	32.07	7.36	9.72	0.00
	Post	14	39.43		8.73	

Table 18 shows that there is a statistically significant difference between pre tests and post tests for the experimental group in a) the production span test process (Cont: p= .40 / Exp: p=.00), b) the production span test storage (Cont: p=.48 / Exp: p= .00). However, there is no difference for the control group. This implies that the experimental group had an improvement in working memory capacity in L2 English during the training period, whereas control group had no change during the same period according to the production span storage and process tests.

Table 19 below shows the comparisons between pre and posttest scores on L2 English operation span test for the correct answers.

Table 19. Pre Test and Post Test Comparisons on L2 English Operation Span

	Test	N	M	MD	sd	Sig.
Eng Cont Operation Span Correct	Pre	14	33.29	0.36	3.54	0.529
	Post	14	33.64		4.38	

Eng Exp Operation Span Correct	Pre	14	28.64	2.93	6.16	0.025
	Post	14	31.57		5.03	

Table 19 reveals that there is no statistically significant difference between pre and posttest for the control group but a statistically significant difference for the experimental group between the pre and posttest in the operation span test correct answers in L2 English (Cont: p=.052 / Exp: p= .02). This means the expreriemental group had an improvement in terms of the working memory capacity during the working memory treatment period in L2 English; however, the control group does not show any improvement regarding operation span correct answers.

Table 20 below shows if there is a statistically significant difference between pre tests and post tests regarding the correct answers given both for operation span and reading span tests items.

Table 20. Pre Test and Post Test Comparisons on L2 English Operation Reading Span Both

	Test	N	M	MD	sd	Sig.
Eng Cont Operation Read Span Both	Pre	14	20.57	3.29	5.05	0.019
	Post	14	23.86		5.38	
Eng Exp Operation Read Span Both	Pre	14	17.64	2.79	6.22	0.122
	Post	14	20.43		6.03	

The results of the statistical analysis indicate that there is a significant difference between pre test and post test scores on operation and reading span correct answers for control group but there is not a statistically significant difference for the experimental group (Con: p=.01 / Exp: p= .12). It suggests that control group had an improvement regarding the working memory capacity in L2 English, whereas the experimental group had no change during the training period.

The results of the statistical analyses on pre and post comparisons on L2 English reading span test scores for both control and experimental groups are given below in table 21.

Table 21. Pre Test and Post Test Comparisons on L2 English Reading Span Correct

	Test	N	M	MD	sd	Sig.
Eng Cont Read Span Correct	Pre	14	26.00	3.50	5.67	0.00
	Post	14	29.50		5.88	
Eng Exp Read Span Correct	Pre	14	24.43	1.86	6.11	0.23
	Post	14	26.29		5.41	

Table 21 shows that there is a statistically significant difference for the control group (Cont: p=.00 / Exp: p= .23) but there is no such difference between pre and the post tests in terms of the span test correct answers in L2 English for the experimental group. These findings suggest that control group had an improvement in terms of the working memory capacity in L2 English.

4.3.3.3. Experimental and Control Group Comparisons on L1 Turkish Writing Process

In an attempt to answer research question four asking if there is a difference in L1 Turkish and L2 English writing quality and process after the working memory training period, Mann-Whitney U tests were carried out. Regarding the writing process in L1 Turkish, experimental and control groups were compared using Mann-Whitney U tests.

The results of comparisons between pre and posttest scores on the total process time and number of bursts of L1 Turkish writing process are presented in Table 22 below.

Table 22. Control and Experimental Group Comparisons on L1 Turkish Number of Bursts

	Groups	N	M	MD	sd	Sig.
Tur Pre Wri Number Bursts	Cont	14	42.57	-2.86	20.11	0.66
	Exp	14	45.43		30.73	
Tur Post Wri Number Bursts	Cont	14	65.14	-23.93	33.57	0.05
	Exp	14	89.07		34.94	

As shown on table 22, there is a significant difference in the post writing process on c) the number of the bursts in L1 Turkish (Post: p= .05) but not a significant difference in the pre writing process for the number of the bursts (Pre: p= .66). This table indicates that, the number of the burst during writing in L1 Turkish had a significant change after the treatment in favour of experimental experimental group. This may be interpreted as the experimental group relied on the bursts while writing more than the ones in the control group.

However, there is no significant difference between the pre tests and post tests for both control and the experimental group on a) the number of the characters used a) the number of the sentences produced, b) the number of the characters produced, c) the number of the words produced, d) the total process time, e) total planning time, f) the number of the planning, g) mean planning time, h) active writing time, i) the number of editing, j) the number of editing.

4.7. Experimental and Control Group Comparisons on L2 English Writing Process

In terms of the components of the writing process in L2 English, experimental and control groups were compared with Mann-Whitney U tests to see if there is a significant difference between the two groups. In the following sections, the results of statistical analyses on the components of the writing process are presented.

The statistical results of the comparisons between pre and posttest scores on the number of sentences in the final output of L2 English writing process are given below in table 23.

Table 23. Control and Experimental Group Comparisons on L2 English Number of Sentence Out

	Groups	N	M	MD	sd	Sig.
Eng Pre Wri Number Sentence Out	Cont	14	18.36	-6.57	4.48	0.02
	Exp	14	24.93		9.35	

Eng Post Wri Number Sentence Out	Cont	14	29.93	-5.14	9.6	0.26
	Exp	14	35.07		12.47	

The results show that there is a significant difference between the control and experimental groups regarding a) the number of the sentences produced (Pre: p= .02) in the pre tests but no significance in the post tests for the same writing component. This implies that that experimental group members produced more sentences in the pre tests compared to control group; however, the difference fades away in the post test for both groups.

The comparisons between pre and posttest scores on the total process time and number of bursts of L2 English writing process are given below in table 24.

Table 24. Control and Experimental Group Comparisons on L2 English Total Process Time and Number of Bursts

	Groups	N	M	MD	sd	Sig.
Eng Pre Wri Total Process Time	Cont	14	1150.21	-62.22	360.71	0.58
	Exp	14	1212.43		702.6	
Eng Post Wri Total Process Time	Cont	14	2260.00	-646.00	691.5	0.01
	Exp	14	2906.00		675.54	
Eng Pre Wri Number Bursts	Cont	14	52.64	-13.72	24.09	0.66
	Exp	14	66.36		45.7	
Eng Post Wri Number Bursts	Cont	14	145.93	-40.28	48.78	0.03
	Exp	14	186.21		40.36	

The results show there is a significant difference in the post writing process time between control and experimental group regarding a) the total process time (Post: p=.03), b) the number of the bursts (Post: p= .03) but no significant difference in c) pre the total process time (Pre: p= .58) d) the number of the bursts (Pre: p= .66). The tables show the change both for total process time and bursts in L2 English writing. It is seen that total process time used while writing had an increase in the post test where the change is significant and the experimental group members spend more time than the control group.

The results of the statistical analyses on group comparisons on number of planning of L2 English writing process are given below in table 25.

Table 25. Control and Experimental Group Comparisons on L2 English Number of Planning

	Groups	N	M	MD	sd	Sig.
Eng Pre Wri Number Planning	Cont	14	51.71	-13.65	24.12	0.66
	Exp	14	65.36		45.7	
Eng Post Wri Number Planning	Cont	14	144.93	-40.50	48.78	0.03
	Exp	14	185.43		40.31	

As shown in table 25, there is a statistically significant difference between the control and the experimental group regarding the post writing process in a) the number of planning (Post: p=.03), but no significant difference in the pre writing process for the same component (Pre: p= .66).

On the other hand, there is not a significant difference between control and experimental groups in the pre tests and post tests for a) number of characters, b) the number of words used, c) the number of the characters produced, d) mean planning time, active writing time, e) the number of editing, f) the number of revision, g) total planning time.

4.3.3.4. Pre Test and Post Test Comparisons on L1 Turkish Writing Process

Regarding the writing process in L1 Turkish, pretests and post tests scores were compared to see if there was a significant difference between them. The following sections present results of the writing process sub topics in five separate tables.

Table 26 presents the results of comparisons between pre and posttest scores on characters and words used in L1 Turkish writing process.

Table 26. Pre and Post Comparisons on L1 Turkish Number of Characters, Number of Words

	Test	N	M	MD	sd	Sig.
Tur Cont Wri Number Characters	Pre	14	1915.07	871.14	512.99	0.001
	Post	14	2786.21		698.84	

Tur Exp Wri Number Characters	Pre	14	1984.36	1267.79	732.90	0.001
	Post	14	3252.14		899.32	
Tur Cont Wri Number Words	Pre	14	232.64	103.43	68.71	0.001
	Post	14	336.07		77.87	
Tur Exp Wri Number Words	Pre	14	238.79	162.00	85.63	0.001
	Post	14	400.79		110.99	

As shown in table 26, there is a significant difference between pre and posttest scores in writing process in L1 Turkish regarding a) number of characters (Cont: p= .00 / Exp: p=.00), b) and the number of words (Cont: p= .00 / Exp: p=.00). This table indicates that both groups had a change during the training period in terms of the number of characters and number of words used while writing in L1 Turkish.

The results of the statistical analyses on pre and post comparisons on the number of sentences, words and characters in the final output of L1 Turkish writing process are given below in table 27.

Table 27. Pre and Post Comparisons on L1 Turkish Number of Sentences, Number of Characters, Number of Words

	Test	N	M	MD	sd	Sig.
Tur Cont Wri Number Sentence Out	Pre	14	16.93	6.36	5.89	0.019
	Post	14	23.29		8.68	
Tur Exp Wri Number Sentence Out	Pre	14	17.71	10.21	6.74	0.001
	Post	14	27.93		10.59	
Tur Cont Wri Number Characters Out	Pre	14	1648.79	623.93	457.22	0.002
	Post	14	2272.71		478.10	
Tur Exp Wri Number Characters Out	Pre	14	1718.00	840.71	598.41	0.001
	Post	14	2558.71		601.03	
Tur Cont Wri Number Words Out	Pre	14	209.71	74.07	66.83	0.004
	Post	14	283.79		65.48	
Tur Exp Wri Number Words Out	Pre	14	214.79	114.86	77.76	0.001
	Post	14	329.64		80.65	

As can be seen in table 27, there is a significant difference between pre test and post test scores both for experimental and control group in terms of a) the number of the sentences

produced (Cont: p= .01 / Exp: p=.00), b) the number of the characters produced (Cont: p= .00 / Exp: p=.00) c) the number of the words produced (Pre: p= .00 / Post: p=.00).

Table 28 presents the comparisons between pre and posttest scores on the total process time and number of bursts of L1 Turkish writing process.

Table 28. Pre and Post Comparisons on L1 Turkish Total Process Time, Number of Bursts

	Test	N	M	MD	sd	Sig.
Tur Cont Wri Total Process Time	Pre	14	991.86	312.57	332.54	0.026
	Post	14	1304.43		404.95	
Tur Exp Wri Total Process Time	Pre	14	1124.07	536.71	943.11	0.011
	Post	14	1660.79		615.90	
Tur Cont Wri Number Bursts	Pre	14	42.57	22.57	20.11	0.011
	Post	14	65.14		33.57	
Tur Exp Wri Number Bursts	Pre	14	45.43	43.64	30.73	0.001
	Post	14	89.07		34.94	

As indicated in table, there is a significant difference between pre and posttest scores in writing process in L1 Turkish in terms of a) the total process time (Cont: p= .02 / Exp: p=.01), b) the number of the bursts (Cont: p= .01 / Exp: p=.00).

Table 29 below shows the comparisons between pre and posttest scores on the number of planning and mean planning time of L1 Turkish writing process.

Table 29. Pre and Post Comparisons on L1 Turkish Number of Planning, Number of Planning Time

	Test	N	M	MD	sd	Sig.
Tur Cont Wri Number Planning	Pre	14	41.57	22.57	20.11	0.011
	Post	14	64.14		33.57	
Tur Exp Wri Number Planning	Pre	14	44.43	41.64	30.73	0.001
	Post	14	86.07		35.92	
Tur Cont Wri Mean Planning Time	Pre	14	10.21	-4.21	8.41	0.090
	Post	14	6.00		1.96	
Tur Exp Wri Mean Planning Time	Pre	14	9.36	-3.86	5.27	0.005
	Post	14	5.50		1.29	

As shown in table 29, there is no statistically significant difference between pre and post writing process regarding a) mean planning time for control group (Cont: p= .09), but

there is a statistically significant difference regarding b) the number of the planning (Cont: p= .01 / Exp: p=.00) d) mean planning time for only experimental group (Exp: p=.00). The table shows that the number of planning while writing in L1 Turkish changed for both groups during the training and participants relied more on planning. However, the table indicates that the mean time for planning while writing in L1 Turkish significantly changed only for the experimental group showing that this group spent more time for planning in the post test compared to that of pre test.

The results of the comparisons between pre and posttest scores on the active writing time, the number of editing, and the number of revisions of L1 Turkish writing process are given in table 30.

Table 30. Pre and Post Comparisons on L1 Turkish Active Writing Time, Number of Editing, Number of Revision

	Test	N	M	MD	sd	Sig.
Tur Cont Wri Active Wri Time	Pre	14	578.43	307.57	128.25	0.002
	Post	14	886.00		225.60	
Tur Exp Wri Active Wri Time	Pre	14	676.21	440.93	381.53	0.001
	Post	14	1117.14		461.73	
Tur Cont Wri Number Editing	Pre	14	68.93	38.64	22.25	0.017
	Post	14	107.57		66.74	
Tur Exp Wri Number Editing	Pre	14	60.57	82.79	46.62	0.001
	Post	14	143.36		91.94	
Tur Cont Wri Number Revision	Pre	14	10.86	7.14	5.14	0.005
	Post	14	18.00		7.27	
Tur Exp Wri Number Revision	Pre	14	13.79	4.50	8.35	0.131
	Post	14	18.29		8.58	

The results show that there is a statistically significant difference between pre test and post test scores for both groups for a) the active writing time (Cont: p= .00/ Exp: p=.00), b) the number of editing (Cont: p= .01 / Exp: p=.00), c) the number of revision for control group (Cont: p= .00), but no statistically significant difference for d) the number of revision for the experimental group (Exp: p=.13). However, statistical analyses revealed that there is

not a statistically significant difference between pre and post writing process for both control and experimental regarding the total planning time.

4.9. Pre Test and Post Test Comparisons on L2 English Writing Process

In terms of the writing process in L2 English, experimental group and control group were compared to see if there was a significant difference between the pre tests and post tests for two groups. In following sections, the results of the analyses of writing process sub topics are presented.

Table 31 below shows the comparisons between pre and posttest scores on characters and words used in L2 English writing process.

Table 31. Pre and Post Comparisons on L2 English Number of Characters, Number of Words

	Test	N	M	MD	sd	Sig.
Eng Cont Wri Number Characters	Pre	14	2247.14	677.00	428.44	0.074
	Post	14	2924.14		1136.42	
Eng Exp Wri Number Characters	Pre	14	2484.29	343.14	858.61	0.048
	Post	14	2827.43		579.31	
Eng Cont Wri Number Words	Pre	14	271.79	193.14	57.17	0.001
	Post	14	464.93		180.50	
Eng Exp Wri Number Words	Pre	14	301.21	144.86	101.92	0.002
	Post	14	446.07		90.98	

The results indicate that there is no significant difference between the pre tests and post tests for control group on a) the number of characters (Cont: p= .07), but there is a statistically significant difference for the experimental group on b) the number of characters (Exp: p=.04), c) the number of words (Cont: p= .00 / Exp: p=.00). This finding shows that the experimental group members used more characters in the post test than they did in the pre test while writing in L2 English. Moreover, the table shows that both groups used more words used in the post test writing than the words they used in pre test writing in L2 English.

The statistical results of the comparisons between pre and posttest scores on the number of sentences and words in the final output of L2 English writing process are given below in Table 32.

Table 32. Pre and Post Comparisons on L2 English Number of Sentences, Number of Words

	Test	N	M	MD	sd	Sig.
Eng Cont Wri Number Sentence Out	Pre	14	18.36	11.57	4.48	0.001
	Post	14	29.93		9.60	
Eng Exp Wri Number Sentence Out	Pre	14	24.93	10.14	9.35	0.011
	Post	14	35.07		12.47	
Eng Cont Wri Number Words Out	Pre	14	235.79	118.21	55.10	0.004
	Post	14	354.00		130.69	
Eng Exp Wri Number Words Out	Pre	14	267.50	71.71	82.89	0.026
	Post	14	339.21		88.26	

The results of the statistical analysis show that there is a significant difference between pre and posttest scores for both groups regarding a) the number of the sentences (Cont: p= .00 / Exp: p=.00), b) the number of the words produced during writing in L2 English (Cont: p= .00 / Exp: p=.02).

The comparisons between pre and posttest scores on the total process time and number of bursts of L2 English writing process are seen below in table 33.

Table 33. Pre and Post Comparisons on L2 English Total Process Time, Number of Bursts

	Test	N	M	MD	sd	Sig.
Eng Cont Wri Total Process Time	Pre	14	1150.21	1109.79	360.71	0.002
	Post	14	2260.00		691.50	
Eng Exp Wri Total Process Time	Pre	14	1212.43	1693.57	702.60	0.001
	Post	14	2906.00		675.54	
Eng Cont Wri Number Bursts	Pre	14	52.64	93.29	24.09	0.001
	Post	14	145.93		48.78	
Eng Exp Wri Number Bursts	Pre	14	66.36	119.85	45.70	0.001
	Post	14	186.21		40.36	

The results show that there is a significant difference between pre test and post test scores for control and experiment group in the writing process regarding a) the total process time (Cont: p= .00 / Exp: p=.00) b) the number of the bursts (Cont: p= .00 / Exp: p=.00). This table reveals that subjects from both groups spent more time while writing in L2 English in the post test than the time they spent while writing in the pre test.

The results of the statistical analyses on pre and post comparisons on the total planning time, number of planning and mean planning time of L2 English writing process are given below in Table 34.

Table 34. Pre and Post Comparisons on L2 English Total Planning, Number of Planning, Mean Planning

	Test	N	M	MD	sd	Sig.
Eng Cont Wri Total Planning Time	Pre	14	453.79	576.86	328.29	0.004
	Post	14	1030.64		593.24	
Eng Exp Wri Total Planning Time	Pre	14	387.86	1035.14	281.28	0.002
	Post	14	1423.00		501.02	
Eng Cont Wri Number Planning	Pre	14	51.71	93.21	24.12	0.001
	Post	14	144.93		48.78	
Eng Exp Wri Number Planning	Pre	14	65.36	120.07	45.70	0.001
	Post	14	185.43		40.31	
Eng Cont Wri Mean Planning Time	Pre	14	8.29	-1.57	4.58	0.450
	Post	14	6.71		2.02	
Eng Exp Wri Mean Planning Time	Pre	14	5.64	1.71	1.74	0.007
	Post	14	7.36		1.82	

As shown in Table 34, there is a statistically significant difference between pre test and post test scores for both the experimental and the control group for a) total planning time (Cont: p= .00 / Exp: p=.00), b) the number of the planning (Cont: p= .00 / Exp: p=.00), c) the mean planning time for the experimental group (Exp: p=.00), but not a significant difference for the control group (Cont: p= .45).

Given below in Table 4.24 are the comparisons between pre and posttest scores on the active writing time, the number of editing and the number of revisions of L2 English writing process.

Table 35. Pre and Post Comparisons on L2 English Active Writing Time, Number of Editing, Number of Revisions

	Test	N	M	MD	sd	Sig.
Eng Cont Wri Active Wri Time	Pre	14	696.07	518.79	93.42	0.002
	Post	14	1214.86		382.72	
Eng Exp Wri Active Wri Time	Pre	14	826.64	655.79	458.71	0.001
	Post	14	1482.43		470.68	
Eng Cont Wri Number Editing	Pre	14	68.21	102.21	30.81	0.002
	Post	14	170.43		125.33	
Eng Exp Wri Number Editing	Pre	14	73.71	138.43	36.72	0.002
	Post	14	212.14		107.80	
Eng Cont Wri Number Revision	Pre	14	17.43	5.00	6.68	0.148
	Post	14	22.43		12.40	
Eng Exp Wri Number Revision	Pre	14	17.29	11.50	8.40	0.005
	Post	14	28.79		14.33	

As shown in Table 35, there is a statistically significant difference between pre test and post test scores for experimental and the control group for a) the active writing time (Cont: p= .00 / Exp: p=.00), b) the number of editing (Cont: p= .00 / Exp: p=.00), c) the number of revision for experimental group (Exp: p=.00) but no significant difference for the control group on d) the number of revision (Cont: p= .14). On the other hand, there is no significant difference between pre test and post test scores for experimental and the control group regarding c) the number of the characters produced.

These findings reveal that the subjects in both control and experimental groups had an increase regarding the active write time and number of editing during the training period in L1 Turkish. More precisely, the subjects spent more time on writing in the post test than the time they spent while writing in the pre tests, and they edited their text more in the post

test than they edited while writing in the pre tests. Moreover, the experimental group subjects had more revisions in the post test than they had in the pre test while writing in L2 English.

4.3.3.5. Comparisons of Writing Quality

The writing quality includes three separate scores. The first score reflects the grammatical accuracy of the writing. The second score shows the quality of the writing in terms of the content. The third score is the average of the scores for grammaticality and content. Comparisons through these writing quality scores were made between pre test and post tests and also between control and experimental groups.

The results show that there is not a statistically significant difference between control and experimental group regarding the writing quality scores for pre tests and post tests.

CHAPTER 5

DISCUSSION

5.1. Introduction

This chapter discusses the findings for a) the comparison of production span test with reading span tests b) the relationship between working memory capacity and writing processes in L1 Turkish and L2 English, c) the relationship between working memory capacity and writing quality in L1 Turkish and L2 English, and d) the effects of working memory training on working memory capacity, e) the difference between L1 Turkish and L2 English writing quality and process after the training period. The findings are discussed with their indications related to writing skill in L1 Turkish and L2 English respectively for each research question.

5.2. Development of a Production Span Test

For the study, as mentioned in the methodology section, a production span test was developed to measure working memory capacity specifically for writing in both Turkish and English. Then, factor analyses were run both reading span and production span to compare statistical power of each test to check the construct validity of the span tests.

The results in factor analyses showed that production span tests and reading span tests differ in terms of the factors they underlie. In other words, the production span tests in English and Turkish are seen to be loading on different factors than those on the reading span test. So, the findings indicate that production span test is a separate test construct to assess working memory capacity in terms of storage and operation. Although this test was the first to be developed both in Turkish and English, the findings of factor analyses provide convincing evidence that production span tests assess the working memory both in Turkish and English. As a result, one can assume that language ability is an effective factor in the

span tests leading to another underlying variable although the span tests are supposed to measure the same underlying factor independent of the language used. However, the findings of this study indicate that production span tests both in Turkish and English are under the same variable having the same underlying factor. Moreover, we can also see that the storage and the process aspect of working memory are listed on the same factor, which shows the construct validity of the span test by having two of them on the same factor load.

5.3. Research Question 1

The first research question in the second part in the study was asked to investigate the relationship between working memory capacity and L1 Turkish and L2 English online writing processes of EFL students. The findings showed significant relationship between writing process and working memory capacity in L1 Turkish for control group in terms of a) number of sentences produced and production span storage, b) writing total process time and operation span correct answers c) total planning time and operation span correct answers. These findings indicate that writing in L1 Turkish displays a positive significant relationship between working memory and a) length b) total process time and c) total planning time. First of all, the length and the process time are the two components having a significant positive correlation with working memory. This finding indicates that the higher working memory capacity may mean that any individual may write more and longer in a limited time. Moreover, working memory also correlates with time spent during writing. This finding shows that the higher working memory capacity may mean that any individual may spend more time in writing. The last positive correlation between working memory and writing components is seen on the total planning time. This finding shows that the individuals with higher working memory capacity may spend more time on planning during writing and the individuals with lower working memory capacity may spend less time on

planning while writing. This finding may also be interpreted as the independence and productivity of the individuals with higher working memory capacity during writing since this is also supported with the findings related to time. That is to say: the individuals with higher working memory capacity may spare more time on planning in writing in L1.

Similarly, the findings on relationship for the experimental group also show that the time spent while writing in L1 Turkish has a positive correlation with the working memory. This finding may be interpreted, like it is discussed above with the control group, as another indication of that any person with a higher working memory capacity may actively spend more time on writing in a limited time, or; any person with lower working memory may actively spend less time on writing in a limited time in L1.

When the findings are considered for L2 English, it is seen that there is a relationship between working memory capacity and writing process in L2 English for control group in terms of a) editing. This may be interpreted as the individuals with higher working memory capacity have more editing while writing, or, the individuals with lower working memory capacity may have less editing in L2 writing. In addition to these, the findings for experimental group show that there is a statistically significant correlation between working memory capacity and L2 English writing in a) the number of the sentences written, which refers to the length of the text. This finding reveals that any individual with higher working memory capacity may write more and longer in a limited time, or; any individual with lower working memory capacity may write less and shorter in any given time in L2.

To sum up, these findings on correlation show that the individuals with higher working memory may spend more time, write longer and plan more while writing in L1, or put it in other words, the individuals with lower working memory may spend less time, write shorter and plan less while writing in L1. Moreover, the findings reveal that the individuals

with higher working memory edit more and write longer in L2, or, the individuals with lower working memory edit less and write shorter in L2.

5.4. Research Question 2

In relation to the second research question investigating if there is a relationship between working memory capacity and writing quality, the findings for both control and experimental group show that there is not a significant correlation between L1 Turkish writing quality and working memory capacity. However, the findings show that there is a significant relation between L2 English writing and working memory capacity. Having no correlation between working memory capacity and the writing quality in L1 Turkish but having correlation in L2 English may be explained by the automaticity that the text writers have in L1 Turkish language when it is compared with L2 English. It is already known that text production in L1 and text production in L2 differ from each other since each of them may exploit the available cognitive sources in different ways, such as attention and memory and also each of them is fed by different linguistic sources. Not having automaticity in L2 may result in with reliance on the working memory as the retrieval of lexical knowledge, syntactical knowledge and also semantic knowledge during writing may have to function through the memory systems. That is to say; automaticity in L1 may compensate the load on working memory and the individuals while writing in L1 may not rely on the working memory capacity. From this sense, writing in L2 may make use of memory sources especially working memory more than it does in L1 and this distinction may result in and be reflected as the relationship between working memory and writing quality in L2. As a result, working memory capacity may be a determining factor for L2 writing quality considering the relationship observed through the findings in the current study.

5.5. Research Question 3

In relation to the third research question examining the effect of working memory training on working memory capacity of EFL learners, or in other words: in relation to the research question asking if the working memory training changed the working memory capacity, the findings were used to compare control and experimental groups and also to compare pre test and post test findings.

Regarding L1 Turkish, when experimental and control groups were compared through the L1 Turkish working memory span test scores, the findings on process scores in L1 Turkish show there is no significant difference for both the control group and experimental group. However, when the pre and posttests were compared for both control and experimental group in L1 Turkish, there is a statistical significant difference in working memory capacity scores in L1 Turkish for both control and experimental group.

Regarding L2 English, similarly, group comparisons in L2 English for pre and and post tests do not indicate a statistically significant difference between control and experimental group. On the other hand, pre and posttests comparison in L2 English for each group shows that there is statistical difference regarding the working memory capacity.

Having a statistical difference in the comparisons of pre test and post test but having no difference in the group comparisons can be explained in a couple of ways. First of all, the groups followed the same formal instruction during the study but experimental group had a training on working memory and control group had a training on attention. This may be a source of the difference between pre tests and post tests in both groups. As discussed in literature review, attention is a minor contributor of working memory capacity, that is to say: attention is one of the underlying factors of working memory capacity. So, the training on attention might have effected the working memory capacity during the study. Secondly, although with a light convincing evidence, when we examine the findings precisely, we can

see that control group shows difference between the pre tests and post tests in the reading span correct and operation reading span both correct answers. However, when we examine the findings from experimental group, we see that the difference is observed in the production span test in terms of process and storage. This has to be put into words in a correct way as the study had two span tests and different scores on these tests. The findings show the difference within production span test process aspect, the difference seen through this test may be quite acceptable compared to the difference seen through the reading span correct and operation reading span both correct answers by considering that production span test process reflect the core nature of the function of the working memory. In other words, considering the span tests showing significant difference, each group had a significant change between pre tests and post tests, but the difference observed in the experimental group, which received working memory training, reflects working memory capacity rather than the difference seen in the control group, which received attention training, within reading span test. To sum up, the difference observed regarding the working memory capacity in both experimental group and control group after the working memory training may be linked to the working memory training for the experimental group but to the attention training for the control group. On the other hand, although not on very strong basis, this difference may be linked to the contradictory findings coming different span tests used in the study as discussed in details above.

5.6. Research Question 4

The fourth research question asked if there is a difference in L1 Turkish and L2 English writing quality and process after the working memory training period.

The writing process was examined in L1 and L2 writing before and after the working memory training. The examination of the writing process included fourteen subcomponents;

1) number of characters, 2) number of words, 3) number of sentences uttered, 4) number of characters uttered, 5) number of words uttered, 6) total time for the writing process, 7) total number of the bursts, 8) total planning time, 9) total number of the planning, 10) mean planning time per each planning, 11) total active writing time, 12) total number of editing, 13) total number of revisions. When each language is considered individually, the findings are discussed in the sections below respectively for Turkish and English.

When L1 Turkish is considered, the experimental and control group comparisons in the pre and the post test results show that there is significant difference for the writing process only for bursts. However, the pre and post comparisons on in L1 Turkish writing process show that there is a statistically significant difference between the pre and posttests in terms of both control and the experimental group regarding a) the number of the characters used during writing process b) the number of words used c) the number of sentences, words and characters in the final output d) the number of the sentences produced e) the number of the characters produced f) the number of the words produced g) the total process time h) the number of the bursts i) the number of planning k) the active writing time l) the number of editing for both groups but m) mean planning time n) the number of revision for the control group but not for the experimental group.

When L2 English is considered, group comparisons for experimental and control group on writing process showed that there is a difference regarding a) length, b) time, c) bursts, d) planning. To be more precise, there is a significant difference regarding a) the number of sentences, words and characters b) the number of the sentences produced. The statistical findings show that there is a significant difference in the post writing process time between control and experimental group regarding c) the total process time in L2 English. However, there is not a significant difference between control and experiment group in the

pre writing process regarding the total process time in L2 English writing process. Moreover, a significant difference exists in the post writing process time between control and experimental group regarding d) the number of the bursts in L2 English. Furthermore, there exists a statistically significant difference between the control and the experimental group regarding e) the number of planning in the post writing process. As a result, the statistical analyses for the comparisons of control and experimental groups in terms of pre and posttests reveal that there is a statistically significant difference regarding a) the length of the text for the pretests and the time, b) the bursts and the planning for the posttests in L2 English. Regarding group comparisons, having no difference in L1 Turkish but having difference in L2 English may be interpreted only by considering the formal education that the participants had during the study on L2 English. As the working memory capacity did not show any improvement through the study, these changes may be interpreted as they may have resulted from the instruction on L2 English since the participants were still going on their formal instruction on L2 English.

In addition to group comparisons, when pre and posttest comparisons in L2 English writing process are made, the findings indicate that there is a significant difference between the pre and posttests for experimental group regarding a) the number of the characters used but no difference for the control group. Moreover, the findings how that there is a statistically significant difference between pre and posttests for both control and the experimental group regarding b) the number of words used, c) the number of the sentences produced, d) the number of the words produced, e) the total process time, f) the number of the bursts, g) total planning time, h) the number of the planning, and i) active writing time, and j) editing. However, there is a difference between pre tests and post tests on k) the mean planning time, and l) revision for the experimental group but not for the control. As a result, the findings

reveal statistically significant differences on the given writing components between the pre tests and post tests for the experimental and control group.

To sum up, the result of having significant difference in control and experimental group comparisons in pre test with the number of sentences produced, and yet, again, having significant difference in control and experemental group comparisons in post test with the process time, bursts and planning, on the other hand, having significant difference in the pre and post comparisons for both groups regarding every writing sub component other than revisions may be interpreted in two ways. First of all, the findings indicate that the working memory training did not make any change for experimental group to be significant enough to outstand when the experimental group was compared with the control group. Secondly, each group had a different training, experimental group received working memory training, whereas control group had the attention training. Seeing that each group had a significant difference between pre test and post test while they are both having different training for the study but the same instruction in their formal education, this may be interpreted as the working memory training and the attention training may have had the similar impact on control and experimental group. In other words, if there is an impact of the working memory training on the experimental group, a similar impact of attention training may exist on the control group.

The fourth research question investigated if any change in working memory capacity will lead to a change in L1 Turkish and L2 English writing quality of EFL students. The writing quality in L1 Turkish and L2 English was examined before and after the training period in the study. The texts composed were marked in terms of grammar and content in addition to overall writing quality.

It is seen that the comparisons of control and experimental groups on the writing quality in L1 Turkish and L2 English do not show any significant difference regarding a) grammar, b) content and c) writing quality. As a result, when the findings regarding the writing quality considered, there is not a statistically significant difference for L1 Turkish and L2 English regarding the control and experimental group comparisons, and also pre and posttest comparisons.

In addition to group comparisons, pre and posttest on L2 English writing quality were compared. Similarly, when L1 Turkish and L2 English are considered, pre test and post test comparisons from experimental and control groups on writing quality reveal that there is no significant difference for both control and experimental groups regarding a) grammar, b) content and c) writing quality.

To sum up, these findings, not having a significant difference both in pre tests and post tests comparisons and in experimental and control group comparisons regarding writing quality, may be explained in a couple of ways. First explanation may be that there may be improvement but this improvement may not be statistically significant, so it can not be observed in the statistical analysis. Second explanation may be that the training period which was equal to eight weeks may not be enough for the improvement to be seen in the statistical analysis.

CHAPTER 6

CONCLUSION

6.1. Introduction

This chapter gives an overall conclusion of the study by covering the outcomes from the findings and also by linking these findings to the available studies in the literature. Secondly, pedagogical implications are given in the light of the results. Finally, limitations are listed and recommendations for further research are given.

The current study aimed to shed light on issues associated with writing and working memory. The first aim was to develop a production span test. The second aim was to examine whether there is a relationship between working memory capacity and writing processes in L1 Turkish and L2 English. The third aim was to examine whether there is a relationship between working memory capacity and writing quality in L1 Turkish and L2 English. The fourth aim was to investigate whether working memory training leads to any effect on working memory. The final aim was to see if eight weeks training period effects L1 and L2 writing process and quality. In relation to the first aim of the study, the data collected through working memory span tests and keylog program was examined statistically. Working memory span tests provided the working memory capacity and the keylog program provided the statistical findings on the subcomponents of the writing process. The relationship between working memory and writing examined within L1 Turkish and L2 English writing processes individually.

In relation to the first research question, the study investigated if there is a relationship between working memory capacity and writing processes in L1 Turkish and L2 English. The examination of the writing process focused on thirteen subcomponents; 1) number of characters, 2) number of words, 3) number of sentences uttered, 4) number of

characters uttered, 5) number of words uttered, 6) total time for the writing process, 7) total number of the bursts, 8) total planning time, 9) total number of the planning, 10) mean planning time per each planning, 11) total active writing time, 12) total number of the editing, 13) total number of revisions.

The findings regarding the first research question of the study showed that each group has a relationship between the writing process and the working memory both for L1 Turkish and L2 English in few of the writing subcomponents. To be more precise, the findings for the control group indicate that writing in L1 Turkish displays a positive significant relationship between working memory and a) length b) total process time and c) total planning time. These findings can be explained in various ways. First of all, the findings show that the length and the process time are the two components having a significant positive correlation with working memory. The plausible explanation may be that the higher the working memory capacity, the more any person may write in a limited or given time, or; the lower working memory capacity, the less any person may write in a limited or given time. On the other hand, when the correlation between the working memory and the writing quality is examined, working memory and writing quality in L1 Turkish does not have a correlation. This may be interpreted as working memory may not individually and directly linked to writing process and the length of the writing may not guarantee the quality. Moreover, the findings for the experimental group indicate that the time spent while writing in English has positive correlation with the working memory. This finding is also seen with the control group writing. These findings may be interpreted as an indication of that the higher the working memory capacity, the more time any person can spend while writing, or; the lower working memory capacity, the less time any person can spend while writing.

First of all, regarding the findings on L1, these findings correlate with a number of studies, the results of which put forward that L1 writing components correlate either positively or negatively with the working memory capacity. Ransdell *et al*. (1996) concluded in their study by observing the impact of the attended and unattended irrelevant speech and memory load on the writing fluency. Simply put forward by Ransdell *et al.* (1996), the fluency in writing depends on the effective manipulation of the cognitive sources, such as attention and working memory. This proposal leads to the interpretation that any load on the cognitive sources affects the fluency in writing. Similarly, Tetroe (1984) observed the negative correlation between working memory capacity and constrains in L1 writing process through a study in which participants were asked to end a story. Tetro (1984) claimed that constraints in working memory lead to negative impact on L1 process, in other words, any load on the working memory may inhibit the production in writing. The overall interpretation of these findings may lead to think and conclude that working memory has a direct interaction with the writing. The findings of this study support the findings of the studies given since the findings in this study reveal the positive correlation between the working memory capacity and number of sentences, total process time, active writing time, and total planning time in L1 Turkish. The findings from Tetroe (1984) are contradicts with the findings of the present study since Tetroe (1984) put forward that there is negative correlation between memory span and the ending-sentence constraints in writing process, which may be considered as a reference to the number of sentences in this study. Parallel to the findings in the present study, Ransdell *et al.* (2001) put forward that the total number of planning were affected by the cognitive load during writing in L1, which shows any load on the cognitive sources would affect the writing process. In addition to these, Kellogg *et al.* (2007) highlighted the importance of working memory capacity in writing. As discussed

above, when the findings regarding the relationship between L1 writing process and working memory capacity in the present study are considered, it seems plausible to say that active writing time, total process time and the revisions correlate positively with the working memory capacity, all of which may show the higher working memory leads to longer process and active writing time. These findings may be explained in various ways. First of all, the reliance on the linguistic sources while writing in L1 may be lower than the reliance on the linguistic sources while writing in L2. Since L1 is already an acquaired language, the low dependence on linguistic sources may help to contribute to the already available cognitive sources, such as working memory. As a result, high working memory may contribute to the writing process interms of writing time spent and also the revisions. These two components may require both storage and process function of the working memory which may consequently result in with the higher working memory, the more writing time and revisions during text composing.

When the correlation findings for L2 English are examined, there are significant correlations between L2 writing process and working memory capacity. To be more precise, the findings on L2 English for the control group show that editing has a positive correlation,. This may be interpreted as higher working memory capacity may lead to more editing while writing, or, lower working memory capacity may lead to less editing. This is quite plausible since the ones with higher working memory capacity may rely on working memory and this advantage may give the writer more time to edit more during writing. In addition to that, the findings on L2 English for the experimental group indicate that there is a statistically significant correlation between working memory capacity and L2 writing in the number of the sentences written, which refers to the length. This finding indicates that any person with higher working memory may write longer or more sentences. This may be interpreted as that

the writers with higher working memory capacity can manipulate the working memory capacity, which may lead to longer sentences. Although there are only few studies focusing on the relationship between L2 and working memory, one of the rare studies but recent one comes from Lu (2010), in which she investigated the cognitive factors that may affect Chinese L2 learners of English while writing in English. The findings revealed no correlation between working memory and writing ability in L1 and L2. The findings of the present study contrast with the results of the study form Lu (2010) since there is a statistically significant relationship between working memory capacity and writing process in L2 English in the present one.

To sum up, the major findings regarding the relationship between writing process and the working memory capacity in L2 in the present study lie mostly in the quantity of the writing. That is to say: the statistically significant relationship between working memory capacity and writing process in L2 English explains that the higher the working memory capacity may lead to more characters, words and sentences in writing or the lower the working memory capacity may lead to fewer characters, words and sentences in writing. The relationship showing connection between the quantity and the process in L2 may be interpreted in two ways. First of all, the participants in the present study had the L2 language through formal instruction. That is to say: rather than acquiring, the participants learnt L2 English in a formal setting. Due to not being acquired, writing in L2, a productive process, may not be as automatized as writing in L1 for the participants. As a result, for not having automaticity in L2 writing, there may be a more reliance on the working memory during the text production. Second possible explanation may be the reliance on the planning since writing process is also fed by working memory capacity among other sources, such as linguistic and vocabulary knowledge. It is already clear that the sources used while

composing in L1 and L2 are totally distinct as it was proved by the study conducted by Ransdell *et al.* (2001), in which they compared the bilinguals and multi-linguals regarding the dependence on cognitive sources while writing in L1 and L2. Keeping in mind that the study from Lu (2010), in which she investigated the cognitive factors that may affect Chinese L2 learners of English while writing in English, revealed no correlation between working memory and writing ability in L1 and L2. In short, the relationship seen between working memory and writing process in L2 comes mostly from the quantity. The modest and simple way to explain this relationship may be the reference to the dependence on memory for longer text production in L2. In order to write longer, the individual may exploit the memory sources since the words and sentences uttered should be stored and processed during text composing. Due to this dependence on working memory, as the findings also confirm and highlight this relationship, the higher working memory may help to write longer texts, or put it in other words, the lower working memory may result in shorter texts in L2 English.

In relation to the second research question, the study investigated whether there is a relationship between working memory capacity and writing quality. The findings on the relationship between working memory capacity and writing quality in L1 Turkish showed that there is no relationship between working memory capacity and writing quality in L1 Turkish. However, the findings revealed that there is a relationship between writing quality in L2 and working memory capacity regarding the grammatical aspect of the writing, the content of the writing and also the overall quality of the writing. Although a number of studies conclude that working memory either directly or indirectly has a relationship with different processes related to writing, as discussed in previous sections, no study put forward the direct connection between working memory and writing quality in L1 (Tetroe, 1984; Fayol *et al.,* 1994; Swanson and Berninger, 1994; McCutchen *et al.,*1994; Lehto, 1996;

Swanson and Berninger, 1996b; Hoskyn and Swanson, 2003; Galbraith *et al.,* 2005; Kellog *et al.,* 2007, Olive *et al.,*2008). With the findings in the present study, it may not be possible to propose that the working memory capacity has a direct contribution or hindrance to the writing quality in L1 Turkish writing. However, the results related to L2 English surprisingly show a contradiction with the findings related to L1 Turkish. It is seen that there is a significant relationship between L2 English writing and working memory capacity. However, the literature has only rare studies examining working memory capacity and L2 writing relationship. Among these studies, Randsdell *et al.* (2001) precisely focused on L2 writing and working memory capacity and found that any irrelevant L1 speech distracting the writing process affected the writing quality in L2. The study confirmed the working memory and L2 writing quality relationship. In this sense, the present study also provided evidence on the relationship between working memory capacity and L2 writing quality in terms of the grammatical aspect of the writing, the content of the writing and also the overall quality of the writing. Regarding the writing process, Vandenberg and Swanson (2007) conducted a study categorizing the process into two as the macrostructure (e.g. planning, writing and revision) and microstructure (e.g. grammar, punctuation). The results of their study revealed that working memory capacity, especially central executive system of working memory, predicted both the macrostructure and microstructure components of writing process in L2. Similarly, the present study showed that the writing quality regarding grammar in L2 has a significant correlation with working memory capacity. The contradictory finding on having no correlation between working memory capacity and writing quality in L1 Turkish but having correlation in L2 English may be explained or justified by the automaticity in L1 Turkish language when it is compared with L2 English. Moreover, having a positive significant correlation between writing quality and working

memory capacity may refer to that the higher working memory capacity, the better writing quality. This finding may provide support for that writing quality may not only be linked with the working memory capacity but also the level of proficiency on its own may be dominant enough to explain and predict writing quality.

To sum up, working memory capacity correlated with writing quality and process in the present study in various ways. The differences in the relationship between working memory capacity and L1 Turkish and L2 English may be attributed to factors linked either directly or indirectly to the working memory, as discussed above. However, these assumptions and justifications may need to be investigated closely in a study in which these factors put forward are controlled and observed.

In relation to the third research question investigating if working memory training leads to a difference in the working memory capacity and subsequently to any difference in the writing process and quality, the findings indicate the experimental group shows a statistically significant difference between the pre test and the post test in terms of the production span tests in L1 and L2. However, the control group shows significant difference in terms of the reading span correct answers and of operation reading span both correct answers for only L2. These findings can be explained by referring to the training of each group. First of all, having significant difference with different span tests may explain the contradictory finding. The difference regarding the working memory is seen in L1 and L2 for the experimental group in the production span tests. Production span tests including process and storage reflect ultimately the function of working memory. However, the significant difference seen in L1 within control group regarding reading span tests, with its nature of retrieval of the knowledge, does not reflect the functional aspect of working memory but only the storage aspect. When these differences and contradictory findings are

considered, it may plausible to say that working memory training might have had an impact on the working memory capacity for experimental group but attention training may have had a similar impact on the working memory capacity for the control group.

In relation to the fourth research question examining the difference in L1 Turkish and L2 English writing process and writing quality after the training period, the findings show that there is a significant difference between pre tests and post tests both for control and experimental group.

The findings on the comparison for the writing process components reveal that two components out of thirteen do not have a statistically significant difference in L1 Turkish writing process for control and experimental groups, but the other writing process components have a statistically significant difference between pre tests and post tests for each group.

For the control group, total planning time and mean planning time in L1 Turkish writing process do not indicate a statistically significant difference; however, a) number of characters, b) number of words, c) number of sentences d) uttered, number of characters uttered, e) number of words uttered, f)total time for the writing process, g) total number of the bursts, h) total number of the planning, i) total active writing time, j) total number of the editing, k) total number of revisions have a statistically significant difference.

For the experimental group, total planning time and revisions in L1 Turkish writing process do not indicate a statistically significant difference, whereas a) number of characters, b) number of words, c) number of sentences uttered, d) number of characters uttered, e) number of words uttered, f) total time for the writing process, g) total number of the bursts, h) total number of the planning, i) mean planning time, j) total active writing time, k) total number of the editing have a statistically significant difference.

Regarding L2 English writing process, four components out of thirteen for the control group and one component out of thirteen for the experimental group do not have a statistically significant difference between pre and posttests.

For the control group, number of characters used, number of characters uttered, mean planning time and revisions in L2 English writing process do not indicate a statistically significant difference; however, a) number of words, b) number of sentences uttered, c) number of words uttered, d) total time for the writing process, e) total number of the bursts, f) total planning time, g) total number of the planning, h) total active writing time, i) total number of the editing, j) total number of revisions have a statistically significant difference. For the experimental group, only number of characters produced in L2 English writing process does not indicate a statistically significant difference, whereas a) number of characters, b) number of words, c) number of sentences uttered, d) number of words uttered, e) total time for the writing process, f) total number of the bursts, g) total planning time, h) total number of the planning, i) mean planning time, j) total active writing time, k) total number of revisions have a statistically significant difference. All of these findings may support the claims that working memory is independent of language, contributing to linguistic aspects of L1 and L2 at the same time.

These findings on the difference between L1 Turkish and L2 English writing process after the eight weeks training period may be discussed in two ways. First one is the group comparisons, the second one is the pre and posttest finding comparisons. The experimental and control group comparisons regarding the pre and the post test results in L1 Turkish show that there is not any significant difference for the writing process. However, the statistical analyses for the comparisons of control and experimental groups in terms of pre and posttests in L2 English reveal that there is a statistically significant difference regarding the length of

the text for the pretests and the time, the bursts and the planning for the posttests. Seeing that the working memory capacity did not have a significant change in the comparisons of control and experimental groups but there is statistically significant difference in the writing components in the comparisons of control and experimental groups in L2 English, it may be logical to accept that these differences may have resulted from the instruction in L2 English since the participants in each group were still going on their formal instruction on L2 English.

In addition to these, the findings on the pre and post comparisons on the writing components in L1 Turkish and L2 English reveal statistically significant differences between the pre tests and post tests for the experimental and control group. These findings can be explaining by considering the training and instruction that each group had during the study. First of all, the group members were assigned to each group considering their L2 English score in proficiency test and each group member, both in experimental and control group, received the same formal instruction during the study. The formal instruction during the study may have have contributed to both groups in the same way. This instruction may have been the source of the difference between pre test and post test for each group. Moreover, groups in the study received two different cognitive training packs during the study. Experimental group received online training on working memory capacity and control group received online training on the attention. Another logical explanation and justification can be done by considering the two different types of cognitive training given. Namely, the difference seen in the exprerimental group may have resulted from working memory training, whereas the difference seen in the control group may have resulted from the attention training given. In other words, the attention training and working memory training may have contributed to the study in a similar way to make a significant difference between pre tests and post tests. The latter explanation might have outweighed the earlier one since

the group members did not receive any formal instruction in L1 Turkish but the instruction was on English.

When the writing quality is considered, the findings revealed that there is no statistically significant difference between the control and the experimental group when they are compared in pre tests and post tests in L1 Turkish and L2 English. Moreover, there is no difference for each group during the training period. Regarding the distribution of the participants for control and experimental group members, as discussed in the methodology section, the members were assigned to each group considering their level of proficiency exam given at the beginning of the study. Considering this assignment procedure, not having statistically significant difference between the control and the experimental group in the comparisons done before and after the treatment in L2 English in terms of the writing quality may have resulted from the group member distribution. That is to say, since the participants come from the same pool of proficiency level and study in the same program, the findings regarding the writing quality may not be expected to have statistically changed during the study. However, having no difference between pre tests and post tests cannot be explained in the same way. This finding may indicate that there is not a significant change regarding the writing quality in eight weeks time training. In other words, the training given in eight weeks may not be sufficient and long enough to lead to a significant difference.

6.2. Pedagogical Implications

The present study has implications in relation to psycholinguistic aspects of the writing quality, writing process, working memory and working memory training.

First of all, seeing that the working memory and writing process relationship was in both L1 Turkish and in L2 English, it may be right to put forward that any consideration of working memory as an individual contributing factor on writing process in L1 and L2 may

need to have a sound basis. As proposed in literature, writing process depends on a number of cognitive sources, such as working memory and attention. That is to say, any improvement and development in any of the cognitive components may affect the writing process. So, writing process may be considered as a process which may be linked to and may be dependent on different linguistic sources and cognitive sources. Practitioners may stress and follow an integrated approach in which the sub components contributing to writing process are improved or developed. Among these improvements, working memory capacity may be considered as a support to both L1 and L2 writing process.

Moreover, as discussed in previous sections according to the findings, some results can only be explained by linking the difference in writing components and other variables ie, to both attention and working memory training. In the light of these, considering attention as a confounding factor acting as a contributor to the writing process like working memory may help to change the writing process and writing quality.

Secondly, seeing that there is a significant difference in terms of working memory capacity between the pretests and posttests, it is reasonable to claim that any working memory training in eight weeks may lead to change or increase in the working memory capacity. That means, any working memory training should be over eight weeks to be considered as a fruitful one in order to improve the working memory capacity.

In addition to these, the present study contributed to the field by a) developing a production span tests to measure working memory in L1 and L2, b) investigating the within group relationship between the working memory and L1 and L2 writing process, c) investigating the within group relationship between the working memory and L1 and L2 writing quality, d) investigating if the online working memory instruction will increase

working memory capacity, e) investigating if there is a possible impact of working memory capacity on the writing quality and the writing process components.

6.3. Limitations of the Study

The present study had several limitations. First of all, the study had limited number of the participants. Due to this limitation in findings, statistical findings of the study cannot be generalized.

Moreover, only eight weeks could be devoted to the treatment although longer period of time was necessary for this kind of study. Presumably, the findings could have been different if the treatment had been longer.

In addition, since there were some deficiencies of the Inputlog program, such as determining whether the pause time stands planning, revision or editing, it is difficult to precisely claim all pauses may be linked to planning. Therefore, close observation of the participants during the process of the writing was necessary through think aloud protocols. However, due to the limited scope of the study, this could not be done. As a result, this may have affected the findings in relation to writing process.

Moreover, since the study was conducted in a specific EFL context (L1 Turkish), the results cannot be generalized to other setting, and this may be considered as another limitation of the study.

In addition to these, attention could not be measured or controlled in the study. As a result, the comparative findings could not be linked directly to the impact of attention training.

Furthermore, the process of multitask data collection might have been considered as a time-consuming process by the participants; as a result, this might have demotivated the participants during the study.

6.4. Recommendations for Further Study

The present study has some recommendations for further research. First of all, another study can be conducted on the issues investigated in the study in a different context with a larger number of participants. Such a study could include observation of the participants during the writing process to overcome the deficiency of the online programs, such as Inputlog. Moreover, while investigating the relationship between working memory and writing process and quality, factors other than proficiency could be controlled, such as attention as a cognitive confounding factor. Furthermore, a comparative study can be conducted by using two different span tests; reading span test and production span test, to measure working memory capacity and to see which span test has the higher predictive power for reading skill, writing skill, listening skill and speaking skill. In addition to these, a comparative study examining the impact of individually working memory training and attention training may be conducted so that any reliable impact of these can be determined on writing process, writing quality and other cognitive sources, such as attention and working memory.

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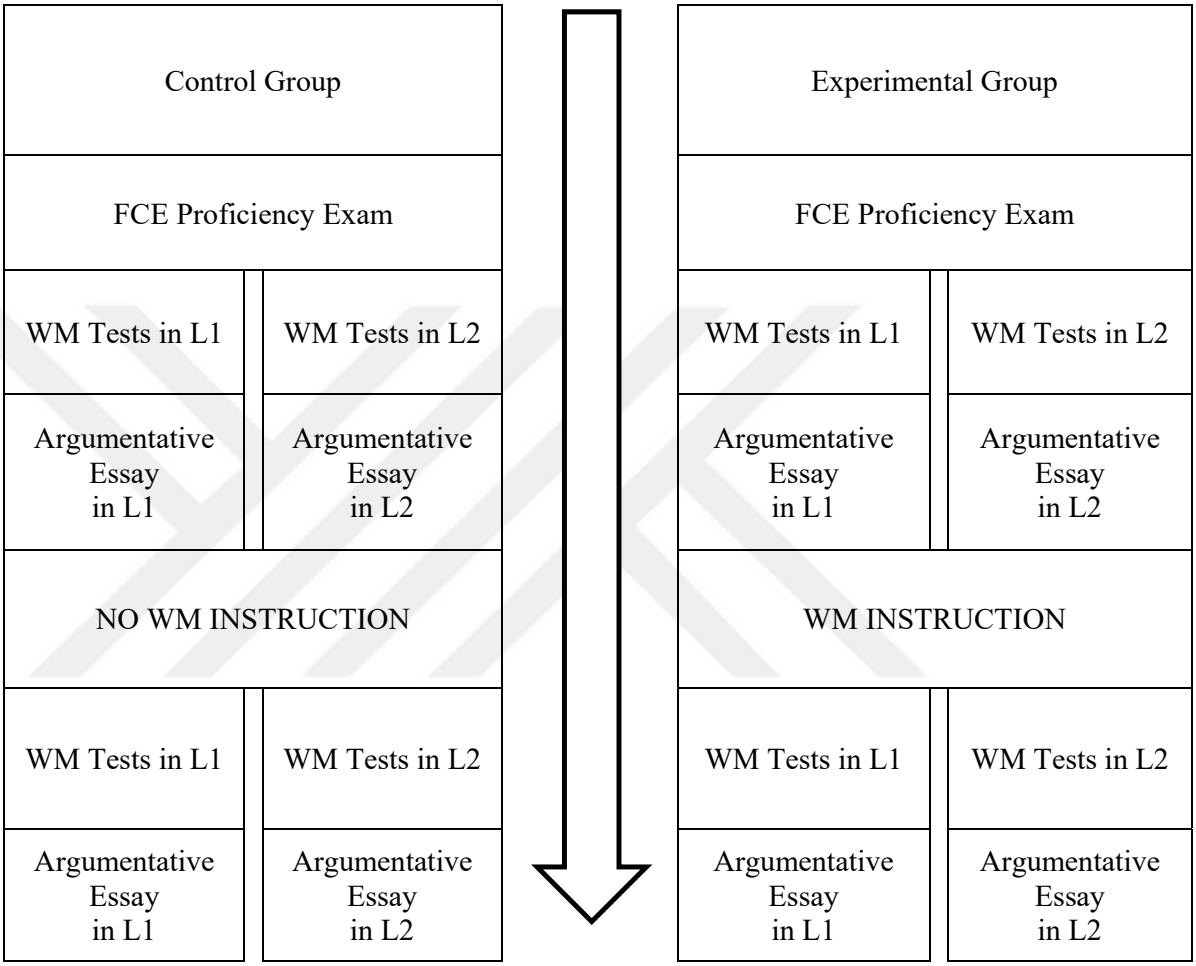
Appendices

Appendix A: Overall process of the study



Appendix B: Letter of Consent

PhD Dissertation by Orkun Canbay

Researcher: Orkun Canbay, +90 532 220 64 52, orkun.canbay@izmir.edu.tr
Supervisor: Prof.Dr.Ayse Akyel, +90 216 578 00 00, aakyel@yeditepe.edu.tr

Dear Participant;

You are invited to participate in a research study. The purpose of this research is to examine the psycholinguistic aspects of writing process. The study involves the tests on memory and writing process.

Dissertation committee members of the study at the Institution of Educational Sciences of Yeditepe University approved the study and its procedures. The study involves no foreseeable risks or harm to you. The procedure includes attending a training for eight weeks and taking the tests on memory and writing process.

You are free to ask any questions about the study or about being a participant by calling me at your phone number or by sending an e-mail.

Your participation in this study is voluntary; you are under no obligation to participate. You may withdraw at any time. Taking the tests and following the training imply consent for participating in the study.

The completed study will be reported in the aggregate. Confidentiality will be maintained. All data will be collected by Researcher's Name, stored in a secure place and will be destroyed after the completion of the study.

If your participation in my study has caused you to feel uncomfortable in any way, or if my study prompted you to consider personal matters about which you are concerned, I encourage you to report me any time for the discomfort and the privacy issues

I have read this informed letter and voluntarily consent to participate in this study.

.
Please sign and return the form as soon as possible if you agree to participate in the study.

Participant's name and surname:.....

Participant's approval (sign):.....

Consent Date:.....

Thank you

Appendix C: Production Span Test Items in Turkish

3A hava	6A kültür
3A savaş	6A halk
3A hayat	6A hafta
	6A yaşam
3B toprak	6A baba
3B mutlu	6A sonuç
3B işçi	
	6B sağlık
3C tarih	6B oyun
3C tarım	6B işaret
3C rekabet	6B sevgi
	6B barış
4A ceza	6B öğrenci
4A fikir	
4A nefes	6C tedavi
4A süreç	6C ilan
	6C güven
4B müşteri	6C demir
4B doğum	6C engel
4B usta	6C kurum
4B emek	
	7A davet
4C emeklilik	7A parça
4C mahkeme	7A işlem
4C teklif	7A duygu
4C kurtuluş	7A meclis
	7A kış
5A göç	7A ihracat
5A kelime	
5A kavram	7B deprem
5A süt	7B gençlik
5A kayıt	7B araba
	7B rüzgar
5B kavga	7B sahne
5B meyve	7B şeker
5B gün	7B zemin
5B ifade	
5B gece	7C inanç
	7C bebek
5C bilgi	7C uyku
5C durum	7C duvar
5C an	7C kulak

5C ülke 5C hizmet	7C tahta 7C toplantı

Appendix D: Production Span Test Items in English

3A egg 3A gift 3A bone 3B plate 3B chicken 3B map 3C pool 3C lip 3C farmer 4A poll 4A novel 4A affair 4A fruit 4B shadow 4B desert 4B bridge 4B loan 4C meal 4C chest 4C nose 4C bottle 5A dress 5A airport 5A snow 5A meat 5A bowl 5B mirror 5B nurse 5B dish 5B family 5B hand 5C place 5C question	6A friend 6A team 6A face 6A health 6A morning 6A food 6B education 6B death 6B decision 6B town 6B picture 6B movie 6C tree 6C window 6C culture 6C blood 6C career 6C loss 7A lawyer 7A dark 7A fear 7A skin 7A item 7A dinner 7A garden 7B speech 7B option 7B sky 7B plane 7B brain 7B solution 7B winter 7C flower 7C sugar 7C storm 7C silence 7C topic

5C number 5C water 5C job	7C ocean 7C stone

Appendix E: Topic Familiarity Test Items

1. Dieting makes people fat
2. Romantic love is a poor basis for marriage
3. The war on terror has contributed to the growing abuse of human rights.
4. All citizens should be required by law to vote.
5. All forms of government tax should be abolished.
6. People should have more holidays and longer vacations.
7. Participating in team sports helps to develop good character.
8. People have become overly dependent on technology.
9. Privacy is not the most important right.
10. University students should have complete freedom to choose their own courses.
11. The primary mission of universities should be preparing students for the workforce.
12. School uniforms should be mandatory in all schools
13. Mothers are better parents than fathers
14. Social media is ruining relationships
15. Our society depends too much on technology
16. Zoos should be shut down.
17. Any student caught cheating on an examination should be automatically dismissed from college.

461343 t/3 Sayılı yazıya istinaden tekrar taranmıştır. 30.01.2017

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