The Effect of Age on Working Memory Processing: Insights from Typing

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ABSTRACT

The role of memory in our lives is unquestionable. As age increases difference in our level of memory are known to exist. As a mental process important in guiding our behavior, memory has been studied extensively by psychologists. This study aims to explore the effect of working memory on typing performance, and how this effect changes with age. The sample consisted of 31 Turkish literate participants. The age of participants were divided into two groups, such that the younger group consisted of participants 44 years old and lower (n = 15) and the older group consisted of participants 45 years old and higher (n = 16). They were tested individually on their typing performance (accuracy, initiation time, IKI and trial duration) by using a typing paradigm with the MATLAB program. The three conditions important in the study were age, feedback and lexicality. Feedback condition was found to have an effect on accuracy, initiation time, IKI and trial duration. Findings also showed that feedback condition and age had an effect on accuracy and trial duration. Lexicality and age was also found to have a significant effect on accuracy and IKI. Older adults' performance was affected severely when they relied on tasks depending on the visuospatial sketchpad and was also severely affected when non-words were typed. Findings are discussed in line with the frontal lobe hypothesis of aging (West, 1996).

Keywords: Aging, Frontal Lobe, Typing, Visual Feedback

ÖZ

Belleğin hayatımızdaki rolü tartışılamaz. İlerleyen yaşla birlikte belleğimizde farklılıklar olduğu bilinmektedir. Davranışlarımızı yönlendirmede önemli bir zihinsel süreç olarak, bellek psikologlar tarafından yoğun olarak çalışılmakta olan bir alandır. Bu çalışmada bellek süreçlerinin klavye ile yazım performansı üzerine etkisi ve bu etkininyaşla nasıl değitiğini araştırmayı amaçlamaktadır. Çalışmada Türkçe okur yazar olan 31 katılımcı yer almıştır. Katılımcıların yaşı, daha genç yaş gurubunun 44 yaş ve daha düşük olan katılımcılardan oluştuğu (n = 15) ve yaşı daha büyük olan grubun 45 yaş ve üstü katılımcılardan oluştuğu (n = 16) şekide iki gruba ayrıldı. Veri toplama aracı olarak katılımcıların bireysel bir şekilde MATLAB bilgisayar programında, bir klavye çalışması (doğruluk, başlatma süresü, tuşlar arası basma süresi ve tamamlam süresi) kullanılmıştır. Yaş, geri bildirim ve sözdizimi faktörleri, çalışmada önemli olan üç koşuldu. Sonuç olarak geri bildirim koşulunun doğruluk, başlama süresi, tuşlar arası basma süresi ve tamamlama süresi üzerinde bir etkiye sahip olduğu bulunmuştur. Bulgular ayrıca geri bildirim durumu ve yaşın, doğruluk ve tamamlama süresi üzerinde bir etkisi olduğunu gösterdi. Kelime yapısı (sözdizimi) ve yaşın, doğruluk ve tuşlar arası basma süresi üzerinde de önemli bir etkiye sahip olduğu bulunmuştur. Yaşı daha büyük olan yetişkinlerin performansı, görsel mekansal eskizlere bağlı görevlere dayandığı zaman, cidi şekikde etkilenmiştir ve anlam taşımayan harf dizinleri yazıldığında da ciddi şekilde etkilenmiştir. Bulgular yaşlanmanın frontal lob hipotezine (West, 1996) göre tartışılmaktadır.

Anahtar Kelimeler: Frontal Lob, Görsel Geri Bildirim, Yaşlanma, klavye yazımı

To My Dear Family

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I would first like to thank my thesis supervisor Asst. Prof. Dr. Çığır Kalfaoğlu for his guidance and generous support, because he was always available when I needed help and continuously guided me through. I would not have been able to complete my thesis without his support and guidance.

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LIST OF ABBREVIATIONS AND SYMBOLS

ANOVA	Analysis of Variance
F	F Ratio
F	Feedback
Fig.	Figure
IKI	Inter-key-press Interval
M	Mean
Ms	Milliseconds
NW-F	Non-word-Feedback
NW-NF	Non-word-No Feedback
P	p value
S	Seconds
SD	Standard Deviation
W	Word
W-F	Word-Feedback
W-NF	Word-No Feedback
$\geq$	Greater than or Equal to
$<$	Smaller than
η^2	Eta Squared

Chapter 1

INTRODUCTION

Cognitive functions such as reasoning, language, attention and memory play an important role in the functioning of our daily lives. These may be cognitive functions that require automatic processing (attention is not required) for example tying your shoe, riding a bicycle and driving or tasks that require controlled processing (requiring attention), for example, learning how to drive a car / bicycle (Schneider & Shiffrin, 1977). As age increases throughout the lifespan a general decline in cognitive functions are observable (O’Sullivan et al., 2001; Perlmutter & Hall, 1992; Salthouse, 1996). Research has shown that of the many cognitive skills (e.g., language) that decline with age, attention and memory are the most affected functions during the development throughout the lifespan (Perlmutter & Hall, 1992). Since the general world population is living a longer life, worldwide there were 607 million people aged 60 years or over in 2000 and with an increase of 48 %, 901 million in 2015 (United Nations, 2015), and since attention and memory functions are crucial for daily activities (such as understanding a text being read, trying to memorise a given phone number or remembering to use medicine), the relation of age and cognitive functions are important to examine in order to provide a more valuable, healthy well-being of older persons. The general age increase in life, has led to an increase of an older retired population. (United States, Census Bureau, 2014). Improvement of technology (such as using e-mail for communication) has provided an increase in the use of computers even after retirement. Therefore investigating skills related to the work force such as typing and the effect of memory and aging on this skill has become inevitable. Research in the field of cognitive age-related decline is important in understanding and improving the lives of the growing adult population.

As a mental process, important in guiding behavior, memory has been studied extensively by psychologists (e.g., Atkinson, Atkinson, Smith, Bem & Hilgard, 1990; Baddeley, 1975; Perlmutter & Hall, 1992). One of the key concepts addressed in the current study, very broadly, is the effect of age on memory processes such as encoding, storage and retrieval. Encoding is the process of transforming a sensory input into a code that is able to be processed into the memory system (Atkinson et al., 1990). Storage is the maintenance of encoded information in memory over a period of time and retrieval is the recovering of stored information from memory or locating information in memory (Atkinson et al., 1990).

A number of theories (e.g., the modal model of Atkinson & Shiffrin (1968), working memory of Baddeley and Hitch (1974), and the processing speed hypothesis of Salthouse (1996) have been developed to explain how memories are formed and change as we age. The current study aims to explore the effect of working memory on typing performance, and how this effect changes with age. Three important theories that are central to the research question, on memory are the modal model of memory (Atkinson & Shiffrin, 1968), the multi-component model of the working memory (Baddeley & Hitch, 1974) and levels of processing (Craik & Lockhart, 1972). Additionally two important theories that are central to the research question on age-related decline are the processing speed hypothesis (Salthouse, 1996) and the frontal lobe hypothesis (West, 1996). In order to better understand their relation, additional research findings in the area of prefrontal cortex and memory have been included. In addition the hierarchical control of typing (Logan & Cramp, 2011) is presented with findings related to skilled typing, since this is the behavioral task that will be used to study working memory in this study.

1.1 Memory

James (1890, as cited in Hunt & Ellis, 2004) defined primary memory (short-term memory) as information in the active conscious state, and secondary memory (Long-term memory) as information in an inactive state. Later, Atkinson and Shiffrin (1968), Craik and Lockhart (1972) and Baddeley and Hitch (1974) introduced different theories of memory. The three fundamental theories regarding memory which are in favor of the research question are broadly presented after briefly explaining the distinction between the three memory processes; encoding, storage and retrieval in relation to short-term and long-term memory.

1.1.1 Memory Processes

Since people are selective to what they attend, short-term memory will contain only the selected information from the environment (Atkinson et al., 1990). Acoustic coding and visual coding are the two forms of encoding in short term memory. Acoustic coding is using sound for rehearsal. Rehearsing is repeating the sound over and over in our mind. The rehearsal strategy is generally used when the information consists of verbal items (digits, letters or words), whereas visual coding is remembering details of images and is generally used when nonverbal items must be stored (e.g., pictures) (Atkinson et al., 1990). In long term memory, encoding differs from short term memory such that the long term memory representation is based on the meaning of the item. This may be the meaning of a word or the meaning of a sentence (Atkinson et al., 1990). According to Atkinson et al. (1990) sometimes other aspects such as words may be coded when poems are memorized. Acoustic codes may also be used for the sound of a person, visual impressions, tastes and smells may also be coded in long term memory, although meaning may be the dominant way of representing verbal material in long term memory. Adding meaningful connections is a helpful way of encoding. Although items we have to remember are usually meaningful, the connections between them may not be, therefore it is useful to create real or artificial links between the items. Elaborating on the meaning, of material while encoding it, is one of the best ways to add connections. Elaboration, during encoding, later makes retrieval easier (Atkinson et al., 1990).

Storage in short term-term memory, as mentioned earlier, has a limited capacity. Although it is known that people differ in their memory abilities (Atkinson et al., 1990), short term memory is known to have a capacity of an average of seven items, where some people can only store up to five and others at the most store up to nine items (Miller, 1956). In their study, Yu et al. (1985) has stated that this average limit of seven is also true in non-Western cultures. On the other hand, storage in long term memory does not have a limited capacity like short term memory, but it still may encounter forgetting. Although some forgetting is due to retrieval failures not all are so (Loftus & Loftus, 1980). According to Loftus and Loftus (1980) some information may be lost from storage in long term memory.

Retrieval in short term memory is active in consciousness. According to Sternberg (1966) as the number of items in short term memory increase, retrieval time is shown to decrease, indicating that the more items stored in short term memory the slower retrieval will occur. When items are letters, words, auditory tones or pictures of people's faces, the same results are found (Sternberg, 1975). In long term memory as mentioned above, elaborating on meaning during the encoding process latter makes the retrieval process easier. This is true because the more connections made between items, the more retrieval possibilities occur. The retrieval process is also easier when information is organized at the time of encoding, therefore as long as information is organized, it is possible to store and retrieve a large amount of it.

1.1.2 The Modal Model of Memory

In their model, Atkinson and Shiffrin (1968, as cited in Hunt & Ellis, 2004) concentrate on the relationship between sensory storage, short-term storage and long-term storage. Incoming information, the input, first passes through the sensory store and is controlled by attention. Only attended information passes to the short term store where it will either be rehearsed and transferred to the long term store or will be lost (Hunt & Ellis, 2004). This relation has been visually shown in figure 1.

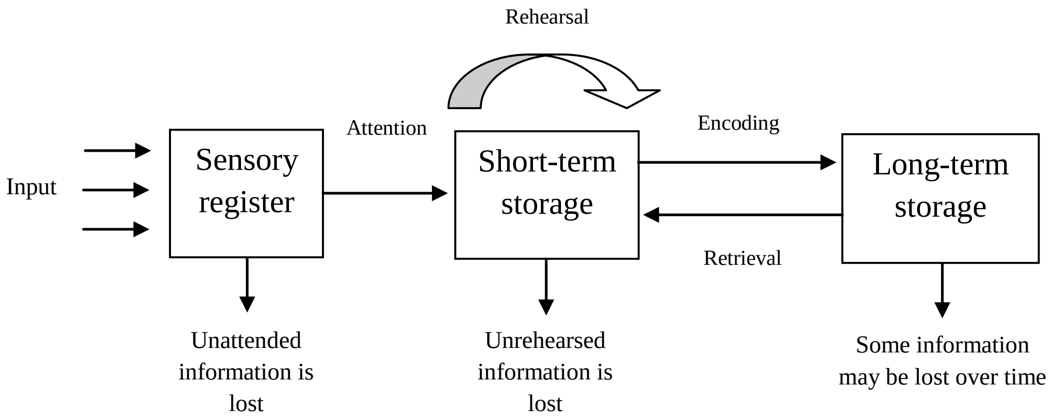

Figure 1: Atkinson and Shiffrin (1968) Memory Model.

According to the model, short term memory has three basic characteristics which distinguishes it from long-term memory, these are; rapid decay of the trace (rapid forgetting occurs over a very short time), capacity of short term memory (an average of seven items) and kind of information stored in the memory trace (stored as sound patterns or in other words, phonetically coded) (Hunt & Ellis, 2004). Long term memory on the other hand is the relatively permanent component of the memory system. It may involve recent information, such as a comment made a few minutes ago, or it may involve a memory from an adult's childhood (Atkinson et al., 1990).

1.1.3 Multi-component Model of the Working Memory

According to Baddeley (2012), a short-term memory system involved in tasks that require a combination of storage and manipulation of information is the Working memory. Presented by Baddeley and Hitch in 1974, the initial model proposes working memory with the existence of three functional components, the central executive, visuo-spatial sketchpad and phonological loop, is named the multi-component model of working memory. The relation of the three components has been illustrated in figure 2.

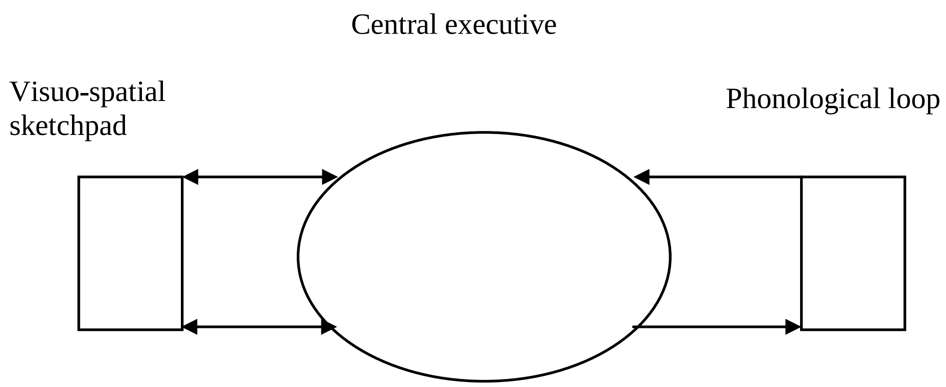

Figure 2: The three component model of working memory by Baddeley and Hitch, originally proposed in 1974 (Baddeley & Hitch, 1974).

First of these components, the central executive, is visualized as a control system of limited attentional capacity and has two main responsibilities. First, it is responsible for focusing and switching attention and activating representations within long term memory. Second, it is responsible for controlling the two subsidiary systems known as the phonological loop and the visuospatial sketchpad. The storage and maintenance of information in an auditory form was assumed to be the responsibility of the phonological loop, whereas the maintenance of visual and spatial information was assumed to be the responsibility of the visuospatial sketchpad. Based on a number of empirical findings the episodic buffer was later added to the model (Baddeley, 2000). It is assumed as being a limited-capacity system with a temporary storage. The episodic buffer is capable of multi-dimensional coding. The relation of the episodic buffer with the central executive, phonological loop and visuospatial sketchpad is illustrated in figure 3.

Literature in regards of working memory (e.g., Baddeley, 2003; Sims & Hegarty, 1997; Wang & Bellugi, 1994) has shown that a number of brain regions are important for working memory processes and its three basic components. Baddeley (2003) has stated that lesion studies involving the left temporo-parietal region has indicated the anatomical localization of the phonological loop, and similarly studies (Sims & Hegarty, 1997; Wang & Bellugi, 1994) involving the right hemisphere have indicated that visuospatial working memory is primarily in this region. In their study, Sims and Hegarty (1997) used a mental animation of a pulley system as interference. The mental animation interfered with memory for a concurrent visuospatial array more than with memory for a list of letters, indicating dissociation between the visuospatial sketchpad and the phonological loop. Similarly by examining Williams

Syndrome and Down Syndrome, each with a specific brain morphology and also with a specific neuropsychological profile, Wang and Bellugi (1994) evidence dissociation between the phonological loop and the visuospatial sketchpad of the Working Memory.

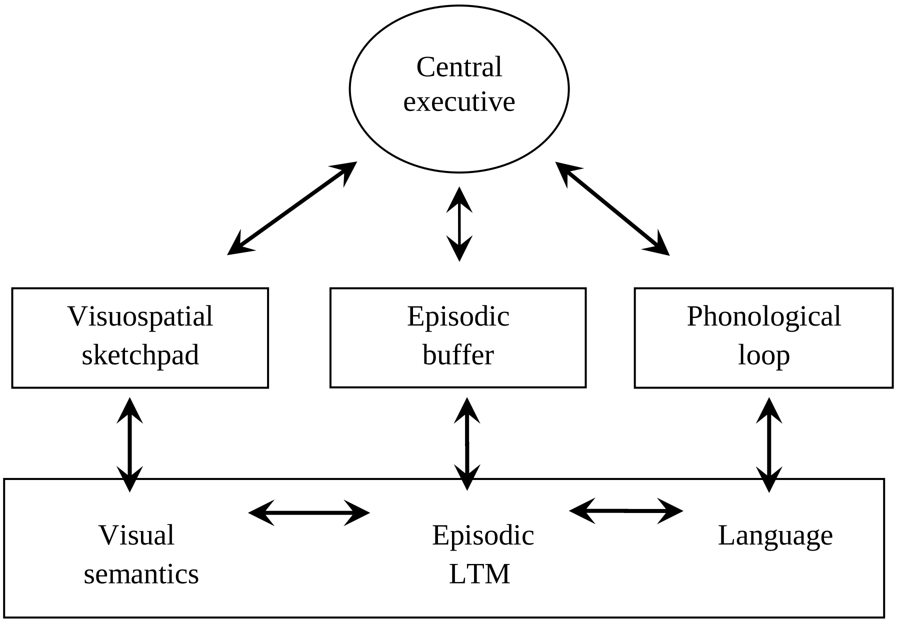

Figure 3: Baddeley's (2000) current version of the multi-component working memory model.

1.1.4 Levels of Processing

The previously presented two models of human memory have been explained by the concept of stores and the transfer of information between them. Different from these models, level of processing emphasizes memory as more of a continuum rather than divided stores. Craik and Lockhart (1972) provide a conceptual framework of memory. According to levels of processing, the memory trace is a byproduct of perceptual analysis and comprehension, and the depth of the analyses of the stimulus leads to a persistence of the trace. The more meaning given to a perceived stimulus will affect its encoding in a deeper sense, therefore the things you attain more will be the things you remember, and more meaning given to this attained stimulus will affect the duration of retention.

According to Craik and Lockhart (1972), when something is processed semantically it is going through deep processing, and when something is processed non-semantically it is going through shallow processing. The reason underling better memory of semantic processing is that, semantic traces last longer than non-semantic traces. When stimuli are highly familiar and meaningful they link with previous cognitive structures more easily. This kind of stimuli (e.g., sentences, pictures and words) will be processed more rapidly to a deep level when compared with less meaningful stimuli and they will be well retained. Therefore according to Craik and Lockhart (1972), retention is not necessarily predicted by speed of analysis rather it is a function of depth. The function of depth depends on different factors such as the amount of attention given to a stimulus, its relation with structures being analyzed and the time available for processing. In their framework, Craik and Lockhart (1972) think of memory as tied to levels of perceptual processing. This processing is seen as a continuum of analyzing sensory input to a product of semantic-associative operations. They also believe that a second way in which stimuli can be retained is by keeping information at one level of processing and names this operation as primary memory.

Different studies have been conducted in order to confirm the existence of the levels of processing model introduced by Craik and Lockhart (1972). Rose, Myerson, Roediger, and Hale (2010) reported the influence of levels of processing on a novel span task. The task consisted of a to be remembered word with one of two "matching" words that were presented just after the target word. It was possible to match the target word according to its font color (shallow, orthographic), whether it rhymed in relation with the target word (medium, phonological), or with the meaning of the target word (deep, semantic). Participants were expected to recall the target words in serial order, immediately after processing between different trial lengths of each target match per trial. Results demonstrated no effect of levels of processing on immediate recall, in any case of trial length. On the other hand results indicated that on a later recognition test, levels of processing influence were found. According to findings, items processed semantically were better recognized when compared with items processed phonologically and orthographically. Additionally findings also indicated that items processed phonologically were better recognized when compared with orthographically processed items.

In their study, Daselaar, Veltman, Rombouts, Raaijmakers and Jonker, (2003) examined whether or not older adults were able to perform specific cognitive operations under deep processing conditions, and further examined related brain regions. In order to compare brain activity patterns, Daselaar et al. (2003) tested both younger and older adults during a deep and shallow classification task and used functional magnetic resonance imaging for the examination of related brain regions. The deep processing consisted of the classification of whether a word represented a living vs nonliving word and the shallow processing consisted of the classification between uppercase and lowercase words. Results indicate that in regards of the deep and shallow processing tasks, both younger and older groups performed similarly. When response times were analyzed, whether the processing was deep or shallow was important. However the group effect of age was not found to be of any significance. In addition, during deep relative to shallow classification, younger adults showed significantly more activity in the left anterior hippocampus when compared with older adults.

1.1.5 From Processing to Typing

In line with the work of Atkinson and Shiffrin, (1968), Repovs and Baddeley (2006), and Craik and Lockhart (1972), it is possible to state that visual working memory related with perception, and spatial working memory related with attention, have an important role in the process of typing. During the copy-typing process, perceptual and attentional demands are needed to be coordinated (Wallot & Grabowski, 2013). This coordination is especially true in the application of the eye-finger span, which is the time elapsed between a person looking at a letter and typing it. The process is prominently dependent on perception and attention components related with the visuospatial sketchpad. One needs to hold in memory either a visual or phonological form of the letters or words read until the fingers press the keys corresponding to these letters or words. Therefore, in relation with the current study, words are expected to be analyzed at a deeper level and therefore make greater use of past knowledge and also retain more information (Craik& Lockhart, 1972), when compared with non-words which are expected to be analyzed at a more shallow level.

1.2 Age and Cognition

Mental testing of adults has a long history and has documented the relation between age and cognition (e.g., Foster & Taylor, 1920; Jones & Conrad, 1933). The two theories the processing-speed hypothesis (Salthouse, 1996) and frontal lobe hypothesis of aging (West, 1996) are first briefly explained and next related with memory.

1.2.1 The Processing-Speed Hypothesis

The processing-speed hypothesis developed by Salthouse (1996) explains that a decline in performance is due to age-related reductions in the speed of sensory or motor processes. Within the processing speed theory are two resulting mechanisms that relate directly to functional problems. The first is the limited time mechanism, which explains that, within a cognitive task, there is less time available for performing later operations because of the excess time spent on earlier operations, and the second is the simultaneity mechanism which explains that when a mental operation requires simultaneous integration of one concept in working memory with another that was figured out several moments before, people with abnormally slow processing speeds may have spent so long figuring out the second idea that they are no longer able to access the first one (Salthouse, 1996).

The limited time mechanism and simultaneity mechanism are the two distinct mechanisms assumed to be responsible for the relation between speed and cognition. According to the limited mechanism, when performance is slowed, and a sequence of operations are needed to be performed, the slowing down of the performance limits the following operation since a large section of the present time is engaged by the execution of earlier operations. Basically when speed of processing is faster, the opportunity to accomplish a larger amount of processing is greater, compared to when the processing is slower (Salthouse, 1996). According to the simultaneity mechanism, by the time that later processing is completed, the products of early processing may be lost. If this becomes the case, the extent of the process may result in loss of information when it is in need and the process may not be completed due to missing information (Salthouse, 1996). An example related with memory, a critical aspect of this study, may be age-related declines in important operations such as encoding, rehearsal, or retrieval (Salthouse& Babcock, 1991). This is an important aspect in the current study since the typing performance which has been measured requires both sensory (feedback from the screen) and motor (the movement of the fingers) processes.

1.2.2 Frontal Lobe Hypothesis of Aging

Another theory highly relevant to the effect of age on cognitive functions supported by the prefrontal cortex is the frontal lobe hypothesis of West (1996). According to West's theory, prefrontal cortex functions such as memory should reveal a decline at an earlier age than those supported by other brain regions. Thus, frontal lobe hypothesis suggests that as age increases adults are more disadvantaged when tasks depend on cognitive processes relying on the prefrontal areas of the brain, such as memory and executive control (West, 1996).

An anatomical study that strongly supports the frontal lobe theory of aging was conducted by Haug and Eggers (1991). According to Haug and Eggers (1991) there is a significant general decline in gross brain volume in the 7^{th} decade of life (ages 60-69). The brain has a weight which is different in males and females called gross brain volume (Higashiyama, Takeda, Someya, Kuroiwa, & Tanaka, 2015). As human beings get older there is a reduction in volume and this general reduction shows differences across the cortex, such that the degree of reduction in the parietal, occipital and the temporal cortices was predicted to account for only about 1% of the decline in brain volume. In contrast, decline of frontal cortex was predicted to account for about 10%-17% of volume. In the frontal cortex, cells begin to shrink earlier, and the shrinkage appears to be more severe when compared with other brain regions. Haug and Eggers (1991) stated that, in all regions measured in the cortex, cell size showed little reduction before the age of 45. When the extrapyramidal cells of the prefrontal cortex were measured, the contraction of cortical neurons became visible during the 5^{th} (ages 40-49) to 7^{th} (ages 60-69) decades of life and was greater (22%) in comparison with the parietal (6%), orbital prefrontal (3%), and primary visual cortex (9%). Haug and Eggers (1991) also reported that in all regions, the decline in cell size became more noticeable above the age of 65. Additionally, at the age 65, cell shrinkage in prefrontal regions continued to be dominant such that 43% measured in the extrapyramidal prefrontal, 11% in parietal, 25% in orbital prefrontal, and 13% in primary visual regions.

1.2.3 The Relationship between Frontal Lobe Structures and Memory

Many studies (e.g., Gabrieli et al., 1996; Kapur et al., 1994), including behavioral and neuroimaging designs have shown a correlation between memory encoding and the frontal lobes. Studies (Oscar-Berman, 2012; Shimamura, Jurica, Mangels, Gershberg, & Knight, 1995) related with Korsakoff's Syndrome also support this relationship. The processes by which an experience is transformed into an enduring memory trace, is memory encoding (Wagner et al., 1998). In a study conducted by Kapur et al. (1994) participants were tested on shallow and deeper processes, where participants in the shallow process task studied whether the word contained the letter "a" and participants in the deeper processes studied whether the word was a living or non-living one. The first, with shallow processing was an analysis of orthographic (a letter in the word) so it was more perceptual and the second, with deeper processing was an analysis of semantics (the meaning of the word). Results of the positron emission tomography scans indicated that when participants carried out deeper processing compared to shallow processing operations on the same verbal stimuli, the deeper encoding operations showed increased neural activity in the left inferior prefrontal cortex (Kapur et al., 1994). Similarly, by using functional magnetic resonance imaging Gabrieli et al. (1996) examined frontal lobe activation during semantic memory performance and found that left inferior prefrontal cortex was more activated for semantic than for perceptual encoding of words. Indicating that prefrontal cortex is involved in encoding processes.

Studies of Korsakoff’s syndrome have also provided evidence of the relation between memory encoding and the prefrontal lobes (Oscar-Berman, 2012; Shimamura, Jurica, Mangels, Gershberg, & Knight, 1995). For example, patients with Korsakoff's Syndrome show symptoms such as anterograde amnesia (inability to acquire new factual information) related with frontal lobe damage (Oscar-Berman, 2012). In a study conducted by Ratti, Bo, Giardini and Soragna (2002), the pattern of executive function (cognitive control) impairment in chronic Alcohol Use Disorder was examined by using hospitalized Alcohol Use Disorder patients and a control group, in order to shed light on possible differences between specific functions related to the prefrontal lobe. Results of this study showed that performance on neuropsychological tests of the Alcohol Use Disorder patients were worse when compared with performance of control subjects, indicating that the frontal lobe has been linked with executive functions (Ratti et al., 2002), which are important in working memory.

These findings are added in order to provide evidence for the relationship between the prefrontal cortex and memory. It is important to link prefrontal cortex with memory since, in the current study, the effect of working memory on typing performance and how this effect changes with age will be measured.

1.3 The Typing Paradigm

In accordance with technological change, computers have become an important tool in both our work and social lives. Especially due to its importance in our daily working lives, typing has become a key skill for most jobs. Today it is possible to find computers in most homes, schools, and businesses. The changing environmental factors have made the computer one of the most important tools in our daily lives and by doing so the importance of typing performance has come to its peak. In this section, first the Hierarchical Control Theory of typing (Logan & Crump, 2011) will be introduced and following findings of Butsch (1932) and Shaffer and Hardwick (1968) on variables affecting typing will be introduced.

1.3.1 The Two-Loop Theory of Typing

Typing is a complex activity when compared with other tasks studied in cognitive neuroscience and cognitive science (Logan & Crump, 2011). In their model of typewriting, Logan and Crump (2009) divided processes into the inner loop and the outer loop. The outer loop starts with language comprehension or generation and finishes with a series of words to be typed. On the other hand, the inner loop starts with a word to be typed, and finishes with a series of keystrokes.

Logan and Crump (2011) distinguishes the outer loop from the inner loop, by examining response times (initiation times) and interkeystroke intervals (IKI). Response time (initiation time) is the time between the appearance of the word on the screen and the first keystroke to be registered. According to Logan and Crump (2011) response time measures both, the outer loop, by defining and sending the present word to the inner loop, and also measures the inner loop, since it is the duration which prepares and executes the first keystroke. Interkeystroke interval, on the other hand, is the time elapse between each successive keystroke. They differ from reaction time since they may have overlapping processes (Logan & Crump, 2011). Therefore in Logan and Crump's theory interkeystroke interval measures the inner loop.

In order to distinguish the two loops Logan and Zbrodoff (1998) conducted a stroop task by using a keyboard in evaluating responses. Findings indicated that the color of the text matched with the word to be typed affected response time, but did not affect interkeystroke interval. Results indicate that the color word match affects the selection of type of the word, which is the duty of the outer loop, but does not affect the execution of keystrokes, which is the duty of the inner loop.

In his study Logan (2003) found a similar result by having typist type words either existing on the left or the right side of a fixation point. Results suggested interference for words that were typed only with one of the hands. The harmony between the stimulus and the location of the hands had an effect on response time but did not have an effect on interkeystroke interval, indicating that harmony affects the preference of the word to type but does not affect the execution of keystrokes.

The two loops also communicate with each other at the word level and not with sentences or keystrokes (Logan & Crump, 2011). A series of words to be typed are generated by the outer loop then they are passed to the inner loop, were the words are put into letters and letters into a series of keystrokes, and then are executed one by one on the keyboard. The theory indicates that there is a hierarchical relationship between the two loops since a word in the outer loop corresponds to a lot of letters in the inner loop (Logan & Crump, 2011).

Since the typing process needs to be conducted fast and appropriate, speed and accuracy are two variables that affect the typing process. On the other hand since in the current study the input, the word to be typed, will be available from the screen, reaction time (initiation time) and interkeystroke intervals of the typed words are also two other important variables affecting the typing performance in the current study.

1.3.2 Additional Variables Affecting the Typing Performance

According to a classical study proposed by Butsch (1932) eye-finger span, is one important variable in typing. Typists, who are experts, are able to read four or five words ahead of the written text. Eye-finger span is the time elapsed between a person looking at a letter and typing it. In his study, Salthouse (1986) defined the eye-finger span as “the amount of material intervening between the character receiving the attention of the eyes and the character whose key is currently being pressed” (p. 310).

In his study, Butsch (1932) used participants with different levels of typing skill and found that the average span per participant varied between 3.24 and 7.60 letters. In his study, one observation of Butsch (1932) was that, the average eye-finger span commonly covers an amount of material that can be transcribed in about a second (Butsch, 1932). Similar to findings of Butsch (1932), Salthouse (1986) reported that for average to excellent typists the eye-finger span ranges between three and seven characters. Therefore, Working Memory is an important factor in determining a typists eye-finger span. The more characters the typist is able to store in working memory, the less the typist will rely on the feedback and thus the faster will be the typing process.

In order to determine eye finger-span Salthouse (1984) used both unfamiliar or meaningless material and normal text. Results indicated that, in contrast with normal text having an average eye-finger span of 3.45 characters, unfamiliar or meaningless material had an average eye-finger span of only 1.75 characters. These results indicate that, the eye-finger span for normal text is larger than the eye-finger span of unfamiliar or meaningless material. This suggests that familiar words are easier to keep in mind compared to unfamiliar words.

In their experiment, Shaffer and Hardwick (1968), used qualified touch typists (ability of using the fingers without the sense of sight in finding keys) and analyzed mean response time per symbol in dissimilar circumstances (prose and random letters strings) indicating that in typing performance, word structure and word length are effective variables and that these effects are additive. The authors also stated that, typing performance is also affected by familiar and meaningful material. Results suggests that familiar and meaningful material is typed faster than unfamiliar and nonsense material.

As stated above, literature has indicated that different variables affect the performance of typing. Eye-finger span indicates that, word viewing span and word typing time is highly correlated (Butsch, 1932; Salthouse, 1986) and has significant effects on typing performance. In addition, word structure and word length have additive effect on typing speed (Shaffer & Hardwick, 1968). In the current study, eye-finger span and word length was limited with only one word with five letters, for both of the two different word structures (word and non-word condition).

1.4 The Current Study

In the current study, typing performance of participants is measured under 4 different conditions. Feedback duration (constant and absent) and lexicality of the text to be typed (word vs. non-words) have been manipulated within participants, and typing performance of older and younger participants under these conditions are compared. When there is no feedback, participants have to store the briefly presented words in working memory. As stated above, memory is a cognitive process that relies on prefrontal areas of the brain, where age-related changes start as early as the 5^{th} decade (West, 1996). Since typing performance relies on memory (especially when feedback is absent), it is expected to be affected by the age of the participant under the feedback absent condition.

In the current study, as stated earlier, typing performance is measured under a second condition lexicality, also with two levels (word or non-word). It is believed that since words can be phonologically coded, they may be stored both by the phonological loop and the visuospatial sketchpad. In regards of retrieval, words may be retrieved both through working memory and also through long term memory processing (feedback is absent and a word is required to be typed, e.g., pembe, hayal). On the other hand, since non-words (a letter string with only consonants) are very difficult to code phonologically and have no meaning, they are expected to be stored primarily by the visuospatial sketchpad component of working memory (e.g., ptcvn, kncyf).

In regards of Logan and Crump's (2011) theory, it is useful to state that, in the current study the encoding process of words is a part of the outer loop, indicating that processes of the outer loop can be affected by memory failure during both the encoding and storage process' in the non-word – no feedback condition, were non-words presented have no meaning. Since non-words have no meaning, they will be able to be neither coded phonologically nor be able to go through deep processing.

Based on the literature reviewed so far, it can be stated that, 1) there is a strong relationship between the shrinkage of brain cells in the prefrontal cortex and aging; 2) impairments in the prefrontal cortex affect memory; and 3) working memory is an important factor affecting typing performance. Therefore, since the effect of age on the prefrontal cortex has an earlier onset than other parts of the brain (Haug & Eggers, 1991), it is hypothesized that it will also affect memory processes, especially storage. Copy typing involves retaining information perceived by the eyes in memory until fingers execute the necessary actions to type it (i.e. eye-finger span). It is believed that holding visual information in memory, especially without feedback, requires input of the visuospatial sketchpad. The current study aims to explore the effect of working memory on typing performance, and how this effect changes with age. Therefore, the following are hypothesized;

Hypothesis 1: When there is continuous feedback (i.e., when the effort on working memory is less) typing performance will be better on accuracy, initiation time, IKI and trial duration than when there is feedback for only one second.

Hypothesis 2: As age increases, the detrimental effect of no-feedback condition on typing performance (accuracy, initiation time, IKI and trial duration) is expected to increase.

Hypothesis 3: As age increases, the detrimental effect of lexicality condition on typing performance (accuracy, initiation time, IKI and trial duration) is expected to increase.

Chapter 2

METHOD

2.1 Participants

By using snowballing technique, 45 individuals were recruited to participate in the experiment. Only 31 of the participants' data were analyzed. Nine of the participants' data were excluded because they could not reach 50% accuracy in the word vs. feedback condition and the other 5 were excluded due to technical problems. The age of participants were divided into two groups, using the age 45 as the cutoff point in relation with the study of Haug and Eggers (1991), such that the younger group consisted of participants 44 years old and lower (n = 15) and the older group consisted of participants 45 years old and higher (n = 16). The age range of younger participants were between 18 and 43 (M = 31.00, SD = 7.97) and the age range of older participants were between 45 and 64 (M = 56.63, SD= 5.92). Twenty five of the participants were females and 6 were males. None of the participants were professional touch typist. Each participant performed the procedure in individual sessions. It took each participant approximately 20 minutes to complete the procedure. All of the participants had normal or corrected-to-normal vision and were literate in the Turkish language.

2.2 Design

There were three independent variables; age (< 45 and > 45); feedback condition (feedback present vs. feedback absent); and lexicality (word vs. non-word). There were four dependent variables which were accuracy (number of trials in which words were typed correctly / total number trials), initiation time (the time elapsed between the appearance of each word on the screen and the first key press), Inter-Key-press Interval (the time elapsed between each successive keystroke) and trial duration (time elapsed between the presentation of the rectangle and the last letter typed in the trial). All conditions were presented in these condition blocks: Word-Feedback (W-F), Word - No Feedback (W-NF), Non-Word - Feedback (NW-F) and Non-Word - No Feedback (NW-NF). Order of conditions were counterbalanced and presented in one of 4 orders: W-F, NW-F, W-NF, NW-NF / NW-F, W-F, NW-NF, W-NF / W-NF, NW-NF, W-F, NW-F and NW-NF, W-NF, NW-F, W-F. There were 30 trials in each block. The lists of words and non-words are presented in appendix B.

2.3 Instrument (Apparatus)

The participants were tested individually under fluorescent lighting in a computer laboratory within the Eastern Mediterranean University Faculty of Arts and Sciences building, on a desktop computer running windows 7 with a 15.6 inch monitor and a standard QWERTY keyboard. MATLAB© 2014 (Mathworks Inc.) was used to present the stimuli and record the time of every key-press. Participants were asked to adjust their distance from the computer so that they could type comfortably. The stimuli were five-letter words which were randomly selected from the first three chapters of the Turkish translation of the book "Alice in Wonderland" (Carroll, 2010). Words and non-words were presented in black on a white screen, with 45 fonts in Courier New typeface.

2.4 Procedure and Task

Upon receiving the letter of approval given by the Psychology Department Ethics and Research Committee, (see appendix A) participants were called by phone and appointments were arranged. After the participants were welcomed, they were first asked to read and sign the consent form and second they were given the instructions on how to carry out the experiment. After the instructions were orally stated participants were asked if they had any related questions. In order to make sure that participants were feeling comfortable enough to start the experiment, additional time was given for the adjustment of their monitor, keyboard or seat if needed. The experiment began with a practice session lasting one minute, where the participant typed a short paragraph. All participants typed the same paragraph by using the website of http://turkegitim.net/fklavye/KlavyeSuratTesti.aspx?metinNo=36510. After the practice session participants began the real experiment. At the beginning of the experiment, using the MATLAB© program, demographic information (i.e., age, handedness, being a touch typist or not, and vision) was recorded and the presentation and timing of the stimuli, and recording of key-presses were accomplished using MATLAB©.

Next, task instructions were presented on the computer screen. The participants were instructed to start the experiment by pressing the spacebar when ready. Each trial started with the presentation of the stimulus to be typed on the upper half of the screen for one second. After one second, a rectangle appeared in the lower half of the screen. The letters that the participant typed echoed (visually) in this rectangle. Participants were told that letters typed before the appearance of the rectangle were not recorded. Participants were also told that in order to start the next trial, they had to press the button with the plus symbol ("+") on the number pad.

As mentioned in the design section, the experimenter manipulated the availability of visual feedback on the screen. In the feedback condition, the letters to be typed were presented on the screen from the beginning of the trial until the end (participants could see the word they were supposed to type on the screen throughout the trial). In the no feedback condition, the word to be typed was presented for only the first second before the rectangle appeared. As soon as the rectangle appeared, letters typed started being recorded and the stimulus to be typed disappeared from the screen. The participant was expected to type the target word as fast and as accurately as possible. Lexicality of the word was also manipulated: the target stimulus was either a meaningful word (e.g., pembe, hayal) or a non-word made up of consonants, which were difficult to pronounce (e.g., ptcvn, kncyf), in order to minimize the use of the phonological loop and maximize the dependency on visuospatial sketchpad in working memory.

As mentioned in the design section four within subject conditions, one for each combination of feedback (present vs. absent) and lexicality (word vs. non-word) was created. Each condition consisted of 30 trials. The same 30 words were used under W-F and W-NF conditions, and the same 30 non-words were used in the NW-F and NW-NF conditions. At the beginning of every condition, each participant was informed on the screen with additional instructions with regards to the present condition. After the participant completed all four conditions, he/she was thanked and debriefed.

2.5 Analysis

Data only from correctly typed trials were included in the analysis of IKI, trial duration, and initiation time. Trials which lasted more than 30 seconds and IKIs larger than 3 seconds were excluded because they were outliers. For each trial, trial duration, initiation time and the mean IKI of all key-presses were extracted. For the across condition comparisons of IKI, trial duration and initiation time, each participant contributed one data point for each condition. This data point is the average value (across $\leq$ 30 trials) of IKIs, trial durations and initiation times under each condition. Additionally for the across condition comparisons of accuracy, each participant contributed one data point calculated by dividing the total number of correctly completed trials by 30 (total number of trials per condition). All statistical analyses were conducted using three-way (2x2x2) analysis of variance (ANOVA) for each of the four dependent variables; accuracy, initiation time, interkeystroke intervals and trial duration.

Chapter 3

RESULTS

To test each of the hypotheses, four separate three way 2 (age: young vs. old) x 2 (lexicality: word vs. non-word) x 2 (feedback: feedback vs. no feedback) mixed analysis of variance, with repeated measures on the latter factors was conducted.

3.1 Hypothesis 1

When there is continuous feedback (i.e., when the effort on working memory is less) typing performance will be better on accuracy, initiation time, IKI and trial duration than when there is feedback for only one second. In order to test Hypothesis 1; the mean accuracy, initiation time, IKI, and trial duration, during the feedback condition were compared to those during the no feedback condition. It was found that there was a significant main effect of feedback on accuracy, $F(1,29) = 38.14$, $p < 0.001$, $\eta^2 = .57$. Participants typed more accurately when feedback was present, compared to when it was absent (see Table 1 for the means). In addition, feedback was found to have an effect on initiation time, $F(1,28) = 123.87$, $p < 0.001$, $\eta^2 = .82$, such that it took participants longer to begin to type when feedback was absent, compared to when feedback was present. Similarly, there was a significant effect of feedback on IKI, $F(1,29) = 23.58$, $p < 0.001$, $\eta^2 = .45$, it took participants longer to press each letter when feedback was present and shorter when feedback was absent. Additionally feedback also had a significant effect on trial duration, $F(1,29) = 13.78$, $p = 0.001$, $\eta^2 = .32$, such that, it took participants longer to complete trials when feedback was present, and shorter to complete trials when feedback was absent. The mean accuracy, initiation time, IKI, and trial durations are summarized in Table 1.

Table 1. *Main effects* Table showing the overall average values in each condition for each of the dependent variable. Numbers in brackets show the standard error.

	Accuracy (%)	*Initiation time (s)*	*IKI (ms)*	*Trial Duration(s)*
Feedback				
Present	80.40 (3.07)	1.65 (0.05)	594.75(47.11)	3.97(0.18)
None	62.05 (2.60)	1.98 (0.04)	522.79(35.52)	3.62 (0.11)
Lexicality				
Word	80.24 (2.52)	1.54 (0.05)	354.92 (31.33)	3.04 (0.15)
Non-word	62.21 (3.91)	2.10 (0.05)	762.62 (52.07)	4.55 (0.16)
Age				
<45	73.39 (3.48)	1.76 (0.06)	423.81 (58.99)	3.42 (0.20)
≥45	69.06 (3.37)	1.88 (0.06)	693.73 (57.12)	4.17 (0.20)

3.2 Hypothesis 2

As age increases, the detrimental effect of no-feedback condition on typing performance is expected to increase. The mean accuracy, initiation time, IKI, and trial duration, for younger adults were compared to older adults. It was found that, there was a significant main effect of age on IKI, $F(1,29) = 10.81, p = 0.003$, $\eta^2 = .27$, it took older participants longer to press each letter when compared with younger participants. Similarly age had a significant main effect on trial duration, $F(1,29) = 7.04$, $p = 0.013$, $\eta^2 = .20$, such that, it took older participants longer when compared with younger participants to complete trials. There was no significant main effect of age on accuracy $F(1,29) = .80$, $p = 0.38$, and initiation time $F(1,28) = 1.98$, $p = 0.17$, $\eta^2 =.07$. In order to test hypothesis 2 it was checked whether there was a significant interaction between age and feedback on all four dependent variables. There was a statistically significant interaction between age and feedback on accuracy $F(1, 29) = 9.91$, $p = 0.004$, $\eta^2 = 0.26$ and on trial duration $F(1, 29) = 4.62$, $p = 0.040$, $\eta^2 = 0.14$, but not on initiation time $F(1, 28) = 0.39$, $p = 0.54$ and IKI $F(1, 29) = 1.64$, $p = 0.21$. Simple effect analysis indicates that the effect of feedback on accuracy depends on age, such that the effect of feedback on accuracy with younger participants were smaller (mean difference between feedback & no feedback 9.00%), $p = 0.04$, than its effect with older participants, (mean difference between feedback & no feedback 27.71%), $p < 0.001$ (see fig.4).

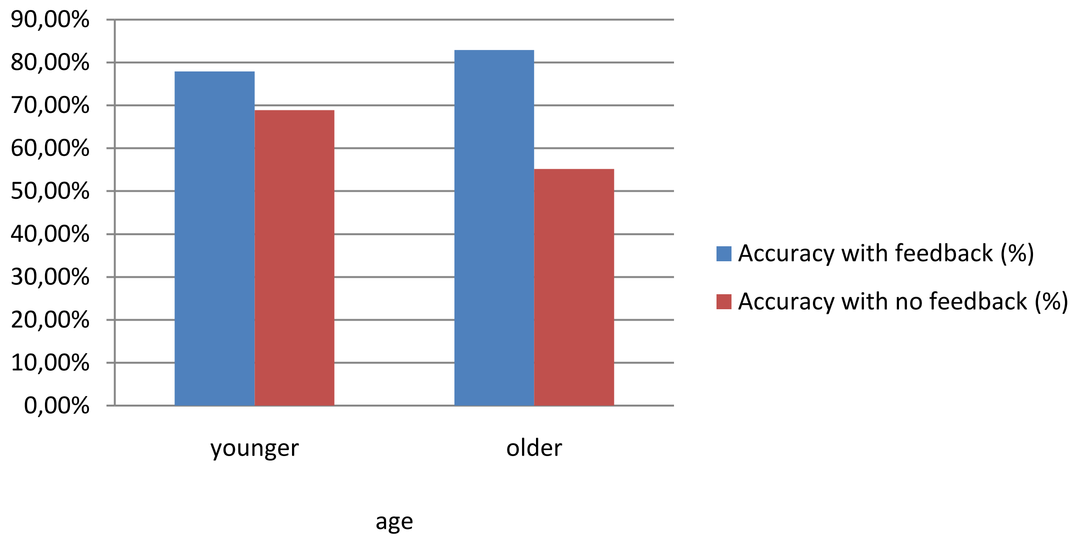

Figure 4: Interaction effect of feedback and age on accuracy.

Similarly, the effect of feedback on trial duration depends on age. Feedback only affected the trial duration of older participants (mean difference between feedback & no feedback 0.57), $p < 0.001$, and did not affect the trial duration of younger participants (mean difference between feedback & no feedback 0.15), $p = 0.286$ (see fig. 5).

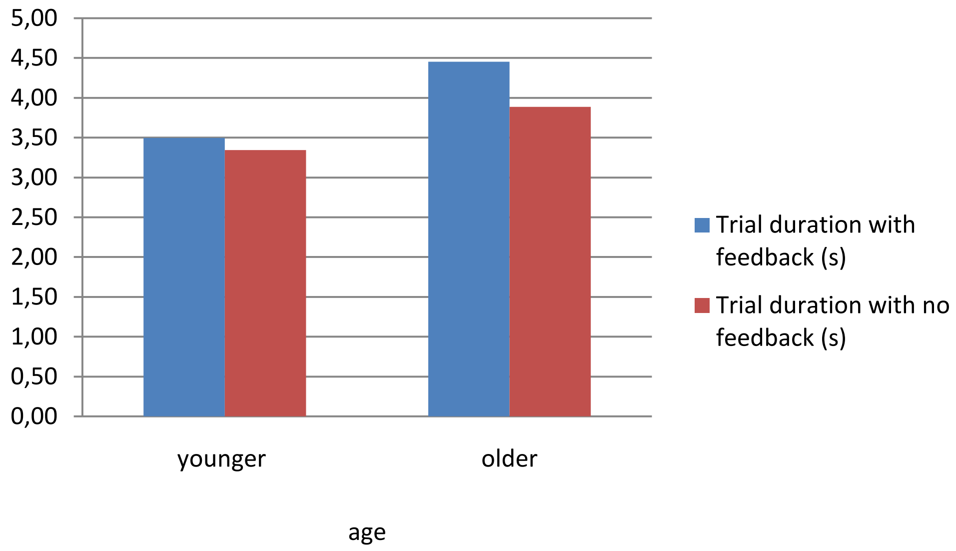

Figure5: Interaction effect of feedback and age on trial duration.

3.3 Hypothesis 3

As age increases, the detrimental effect of lexicality condition on typing performance is expected to increase. The mean accuracy, initiation time, IKI, and trial duration, during the word condition were compared to those during the non-word condition. It was found that there was a significant main effect of lexicality on accuracy, $F(1,29) = 16.41$, $p < 0.001$, $\eta^2 = .36$. Participants typed words more accurately when compared to non-words. In addition, lexicality was found to have an effect on initiation time, $F(1,28) = 131.74$, $p < 0.001$, $\eta^2 = .83$, such that it took participants longer to begin to type non-words, when compared to words. Similarly, there was a significant effect of lexicality on IKI, $F(1,29) = 258.47$, $p < 0.001$, $\eta^2 = .90$, it took participants longer to press each letter when non-words were typed and shorter when words were typed. Additionally lexicality had a significant effect on trial duration,

$F(1,29) = 202.13$, $p < 0.001$, $\eta^2 = .88$, such that, it took participants longer to complete trials when non-words, and shorter when words were typed. In order to test this hypothesis it was checked whether there was a significant interaction between lexicality and age on all four dependent variables; there was a statistically significant interaction between age and lexicality on accuracy $F(1, 29)= 19.14$, $p < 0.001$, $\eta^2= 0.40$ and on IKI $F(1, 29) =11.69$, $p = 0.002$, $\eta^2= 0.29$, but not on initiation time $F(1, 28)= 2.09$, $p = 0.16$ and trial duration $F(1, 29) = 1.30$, $p = 0.26$. Simple effect analysis showed that, age affected the accuracy both when words (mean difference between young & old =15.15%), $p = 0.005$, and non-words were typed (mean difference between young & old =23.80%), $p = 0.005$, such that, words were typed more accurately by older participants and non-words were typed more accurately by younger participants (see fig. 6).

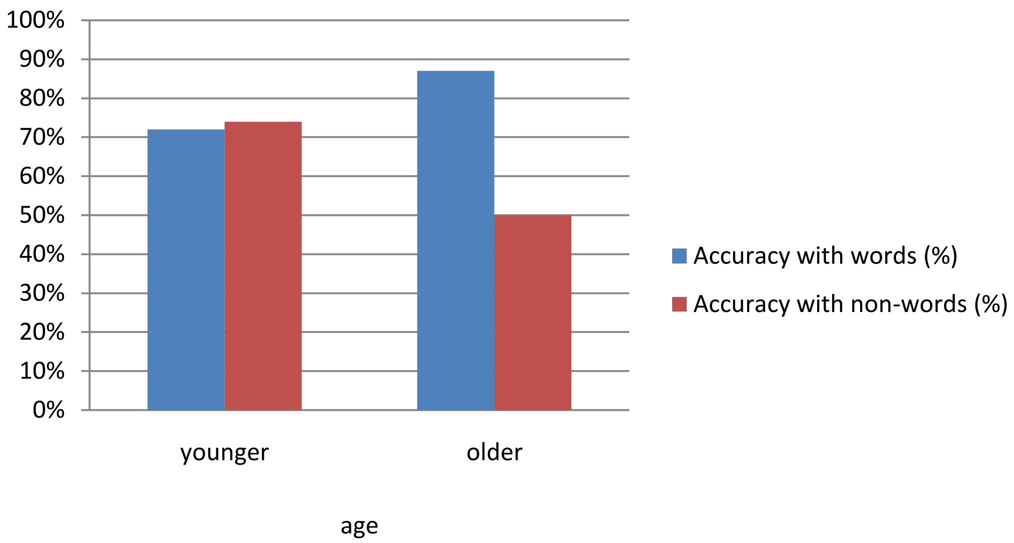

Figure 6: Interaction effect of lexicality and age on accuracy.

Similarly, age affected the IKI both when typing each letter of words (mean difference between young & old =183.22ms), $p = 0.007$, and non-words (mean difference between young & old =356.62ms), p = 0.002, such that, both word and non-word letters were typed slower by older participants (see fig.7.).

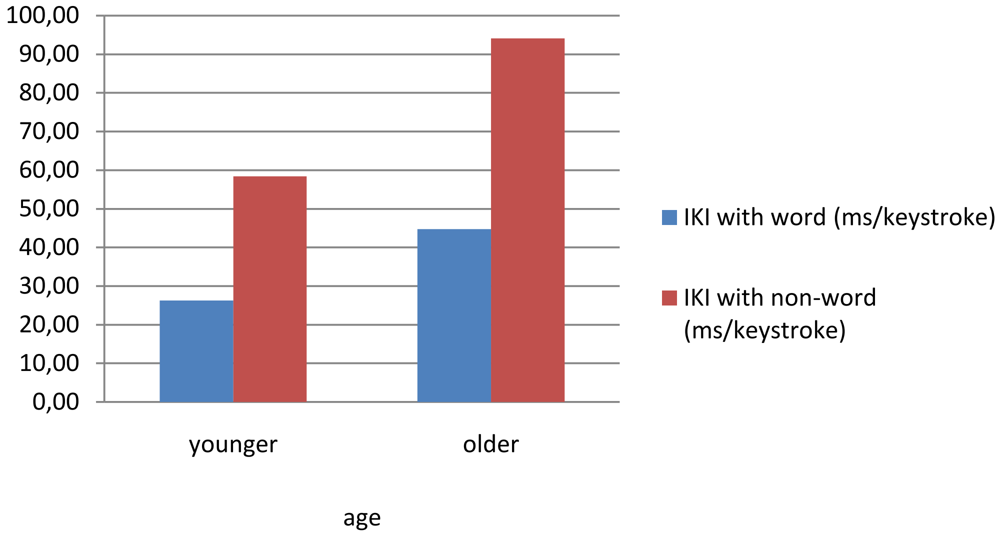

Figure 7: Interaction effect of lexicality and age on IKI

Chapter 4

DISCUSSION

The primary aim of the current study was to explore the effect of working memory on typing performance and how this effect changes with age. The current study first investigated how the availability of visual feedback from the screen affected typing performance (i.e., hypothesis 1). Results showed that as expected, when feedback was present (word viewing time was unlimited) participants typed more accurately, and it took them shorter time to begin to type after viewing the target (initiation time), and these results are in line with the literature (Butsch, 1932; Inhoff, Chiu & Wang, 1990). However, it was found that participants' IKIs were longer when feedback was present (it took longer to press each letter) compared to when it was absent. Consistent with this observation, it also took participants longer to complete trials (type each word).

Although participants started typing (initiation time) faster in the feedback condition (when feedback was present), in order for them to be able to type accurately their IKI slowed, resulting in longer IKIs. This reduction of speed in feedback compared to no feedback conditions is possibly due to the fact that participants were not relying on their working memory and therefore started typing as soon as they saw the first letter, but slowed as they referred to the present word on the screen. In other words, the IKIs slowed down in the feedback condition possibly because participants kept looking back and forth to the screen in the feedback condition, but not in the no feedback condition. During the study, participants knew which condition they were in thus when feedback was present they knew they did not have to rely on their memory and knew they had time to refer to the present feedback (word presented).

The current study also investigated how the availability of visual feedback from the screen affected typing performance with an increase in age. As expected, results showed that the effect of feedback on accuracy was larger with the older than younger group of participants, indicating that when there was no feedback, older participants were affected more severely compared with younger participants. This finding is consistent with West's (1996) frontal lobe hypothesis of aging which indicates that prefrontal cortex functions such as memory should reveal a decline at an earlier age than those supported by other brain regions.

Findings of the experiment indicate that the effect of feedback on accuracy depends onage. Effect of feedback on accuracy was larger in older participants than younger participants, indicating that in line with hypothesis 1, feedback condition affected accuracy more as age increased, confirming that the detrimental effect of the absence of feedback for only one second increases with age. Participants in the current experiment, especially in the “no feedback” - “non-word” condition, heavily relied on their visuospatial sketchpad of working memory (Baddeley, 2012). Age only affected the accuracy of the target word when feedback was absent, supporting West's (1996) frontal lobe hypothesis of aging, which indicates that working memory functions rely heavily on structures in the prefrontal cortex of the brain and had no effect on accuracy while feedback was present (i.e. when participant didn’t have to hold information in memory but could look at the monitor as they needed). As difficulty increased (feedback was absent), especially in the “non-word-no feedback condition”, where difficulty of retaining information in memory was at its peak, difference in performance (accuracy) came to an importance.

Effect of feedback on trial duration was also dependent on age. Dissimilar to accuracy, in regards of trial duration only participants in the older group were affected, indicating that the increase in age is of considerable importance. This finding also supports hypothesis 2 (As age increases, the detrimental effect of no-feedback condition on typing performance is expected to increase) and is in line with West’s (1996) frontal lobe hypothesis of aging which proposes that declines in the frontal areas (such as memory) starts becoming observable as early as mid-40s.

Findings indicate an accuracy, trial duration tradeoff in older participants such that, when feedback was present, older participants typed more accurately yet they spent longer time completing trials. In addition, when feedback was absent, older participants completed trials faster yet typed less accurately. Derived from the information stated above, when feedback was present, participants in the older group needed more time to be able to type accurately. Although speed is an important factor in copy typing, unless the typed word is correct, speed loses its importance. Therefore when feedback was absent and the participant could not spend as much as time desired to look back at the target word/non-word, difficulty (participants relied on memory) of the task was important and affected accuracy. When participants had to rely exclusively on their visuospatial sketchpad, accuracy decreased because in older adults a decline of prefrontal cortex has been reported to begin at an age as earlier as 45 (Haug& Egger, 1991). Therefore, memory mainly a function of prefrontal cortex is impaired with the absence of visual feedback. These results are in line with the work of Haug and Egger (1991) which indicated that contractions of cortical neurons become visible during the 5th to 7th decades of life.

Feedback did not significantly affect the younger group on accuracy, initiation time, IKI and trial duration. This may be due to several factors. For example, participants in the younger group may be using the computer more often than participants in the older group. This practice effect helps their fingers to correspond to the right letter faster and makes them rely less on their visuospatial sketchpad.

One pattern of results worth discussing is the significant effect of age on IKI and trial duration but not on accuracy or initiation time. This may be a result of the speed accuracy trade off. In addition the current study also investigated how lexicality condition affected typing performance with an increase in age. Results showed that the effect of lexicality on accuracy and IKI depends on age. Age affected the accuracy when both words and non-words were typed. Older participants typed words more accurately when compared with younger participants. In order to discuss reasons, other individual variables must be taken into account. For example, participants in the younger group may have been more focused on speed rather than on accuracy, so while trying to type as fast as possible, assuming that the participants in the younger group had more experience (uses the computer for more purposes), they may have made more typo errors due to their speed. Likewise, older participants may have been more focused on accuracy and less on speed, assuming that older participants had less experience (uses the computer for fewer purposes or has not used it for a long time), they may have made less typo errors. On the other hand, the situation was opposite for non-words. Non-words were typed more accurately by younger participants when compared with older participants. This is especially true in the non-word no feedback condition, where participants highly depended on their working memory. Even if participants in the older age group focused more on accuracy, their memory may have failed them during the storage and therefore retrieval process. When age and feedback factors are taken into account these findings are in line with Haug and Eggers (1991) study. When the lexicality factor is taken into account, findings are in line with studies of Salthouse (1986) and Shaffer and Hardwick (1968).

Age also affected the IKI when both words and non-words were typed. When compared with younger participants, participants in the older group typed letters of both word and non-word condition slower. According to processing-speed hypothesis (Salthouse, 1996) age-related reductions in speed of sensory and motor processes, result in decline in performance. Indicating that, older participants may have different typing skills when compared to younger participants.

In the feedback condition participants did not have to rely on the limited capacity of visuospatial sketchpad. Similarly, when feedback was absent and words were to be typed, as a result of previous deep processing (Craik& Lockhart, 1972) participants were able to use long term memory for the retrieval of words. This was not the case when non-words were typed and feedback was absent. Therefore, it was the only condition when non-words were typed and feedback was absent that, participants had to rely on the limited capacity of visuospatial sketchpad. In order to better understand limitations of visuospatial sketchpad, studies using only non-words in a similar setting with different time intervals may be conducted.

Participants both knew the fact that they had to rely on their working memory, and also knew that they may forget the words read from the screen in front of them, this awareness may have forced them to increase both their attention and speed, therefore affected IKI. Again, in order to justify this argument, further experimental research should be conducted by using only non-words, in order to decrease the possibility of using the phonological loop (Baddeley, 1974) and also the retention of information from long term memory. By doing so, the awareness will be manipulated and the affect on IKI will be better understood. The same argument may be made for trial duration, since it is acceptable to note that as IKI is longer, this will affect the duration to complete each trial.

One other explanation for these results may be the fact that participants were not formally educated to be touch typists, therefore further investigation in this field may be done with touch typists and the difference between formally educated and informally educated typists may be analyzed bearing in mind that feedback may affect the two groups differently.

There were several limitations regarding the experiment, first, participants were not tested for any kind of neurological, psychiatric, or cognitive disorder. Therefore, if participants especially in the older age group had any kind of neurological, psychiatric, or cognitive disorder this may have affected the results. Second, education of participants and their professions were not controlled for. Although words used in the word list were selected as frequently used ones, the education of participants may still have had an effect on their performance. Similarly, some of the participants may have been required to use typing in their professions or daily lives whereas others may not have. This also may have an effect on the results due to practice effect. Additionally, participants in the study were not touch typists. This may or may not have an effect on the typing performance, since the aim of the study was to investigate effects of working memory on the typing performance. Future studies should control for the limitations stated above.

It is important to investigate within the same experimental condition with touch typist and compare results with typist with no typing experience. By doing so the effect of memory processes on the typing performance will be understood whether they are effects of skilled typing or effects of individual memory processing.

In order to more fine-grained look in to the effect of age on memory, a similar experiment should be conducted, but this time the age groups should be divided into a larger number of groups and span a larger range of participant age. This would provide more information regarding older age. This study only showed effects regarding differences in the two age groups, but does not apply to older age in regards of the aging literature and this point must be confirmed with future investigation.

The current study aimed to explore the effect of working memory on typing performance, and how this effect changes with age. Older adults' performance was affected severely when they relied on tasks depending on the visuospatial sketchpad. Older adults' performance was also severely affected when non-words were typed.

With an increase of age the detrimental effect of visual feedback on performance is clearly seen. With an aging population (United Nations, 2015) in order to provide a better life standard for the community, it is important to consider changes in possible environmental settings. For example, governmental policies may be changed in favor of stating the importance of visual feedback in public environments. Nursing homes should provide environmental setting with rich visual feedback, such that daily responsibilities and leisure activities especially planed for older adults should be announced with visual feedback and with clear statements. This rich environment should also be adapted to home and public settings. The importance of visual feedback should also be considered in technological improvements in order to provide older adults with easier guides or instructions. Importance of the speed accuracy trade off is also important to consider in environmental settings. Within settings which need accuracy, older adults should be given adequate time for the completion of tasks.

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http://turkegitim.net/fklavye/KlavyeSuratTesti.aspx?metinNo=36510 website

APPENDICES

Appendix A: Eastern Mediterranean University Psychology Department Ethics and Research Committee Approval Letter

Eastern Mediterranean University

Famagusta, Turkish Republic of Northern Cyprus

The Department of Psychology
Eastern Mediterranean University
Research & Ethics Committee
SenelHusnu Raman-Chairperson

Tel: +(90) 392 630 1389
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Ref Code: 15/05-30

Date: 20.05.2015

Dear LeylaYorganciogluUsta,

Thank you for submitting your revised application entitled *The effect of age on working memory processing: insights from typing.* Your application has now been *approved* by the Research & Ethics Committee on 20.05.2015.

If any changes to the study described in the application or supporting documentation is necessary, you must notify the committee and may be required to make a resubmission of the application. This approval is valid for one year.

Yours sincerely,

Assoc. Prof. Dr. Senel Husnu Raman
On Behalf of the Research & Ethics Committee
Psychology Department
Eastern Mediterranean University

Appendix B: List of Words and Non-Words

List of words		List of non-words	
pembe	hayal	ybkfn	pbnlv
ancak	anlam	mhvtd	cvdmg
armut	bazen	tdcph	trdkv
bebek	kepek	kpzfs	jchfy
beyaz	keten	tbpsy	zgypc
duygu	merak	dptbf	zbcfp
hemen	salon	tgryz	ftrvg
kadar	saman	zntcv	rjgcy
senet	sepet	vzbmg	cpvbk
sonra	tabak	rlkcf	bmvyh
topuk	turta	bhszm	lybdp
pasta	ramak	zdypt	skjlp
yarar	temas	gjyhs	jcknf
yemek	zaman	snryd	rzmgj
zaten	ekmek	cvtzr	gfrvc