EFFECTS OF KIND AND AMOUNT OF COGNITIVE LOAD AND DURATION ON PROSPECTIVE TIME ESTIMATION

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EFFECTS OF KIND AND AMOUNT OF COGNITIVE LOAD AND DURATION ON PROSPECTIVE TIME ESTIMATION

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ABSTRACT

EFFECTS OF KIND AND AMOUNT OF COGNITIVE LOAD AND DURATION ON PROSPECTIVE TIME ESTIMATION

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The estimation of temporal intervals is influenced by characteristics of a secondary task carried out during those intervals. Different kinds of cognitive load (e.g., memory load, attentional demand) and different amounts of load (low, high) of the secondary tasks modulate time estimation. Increase in the amount of cognitive load decreases time estimation. According to the Attentional Gate Model this is because the more attention is allocated to the secondary task, the less attention is left for the primary task – time estimation. Furthermore, amount of load may interact with length of the estimated interval such that people underestimate longer durations more than shorter durations under conditions of high but not low load. This may be due to the non-linear nature of the time scale underlying subjective time estimation. The present study aims to explore the effects of different kinds of cognitive load (memory load, executive load) and different amounts of load (low load, high load) for various time durations (short, medium, long) by using the prospective paradigm. It is expected that time estimation varies according to kind of load, amount of load, and duration. Furthermore, it was predicted that time estimation ratios (between objective durations and subjective, reproduced durations) get smaller with longer durations for high memory and executive loads. Two experiments were carried out and three duration lengths (12, 24 and 36 sec) were used in those experiments. Simon Task was used as a secondary executive task in the first experiment. In the second experiment, Memory Search Task was executed as a secondary task. The effects of duration and different amount of load were found. However, time estimation ratios changed across duration and different amount of load depending on types of cognitive load.

Keywords: attention, executive load, memory load, Attentional Gate Model, task difficulty

ÖZ

BİLİŞSEL YÜK ÇEŞİDİ VE MİKTARININ VE SÜRENİN İLERİYE DÖNÜK ZAMAN TAHMİNİ ÜZERİNE ETKİSİ

Bıyık Sarı, Fatma
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Birincil görev olarak zaman aralıklarının tahmini, bu zaman aralıklarında yapılan ikincil bir görevin özelliklerinden etkilenmektedir. İleriye dönük paradigmada, denekler maruz kaldıkları aralıkları tekrar üretmek zorunda oldukları konusunda bilgilendirilir. İkincil görevlerin farklı bilişsel yüke (hafıza veya yönetimsel talebi gibi) ve farklı miktarda yüke (az veya fazla) sahip olması, zaman tahmini değiştirmektedir. Bilişsel yük miktarındaki artış, eksik tahmin etmeye yol açmaktadır. Attentional Gate Modeline göre, bunun nedeni ikincil görevin daha fazla dikkat tahsis ederken birincil göreve daha az dikkat ayırabilmesidir. Ayrıca, yükün miktarı ile tahmin edilen aralığın uzunluğu etkileşim içinde olabilir; öyle ki, yük miktarının fazla olması durumunda, insanlar uzun zaman aralıklarını kısa zaman aralıklarına oranla daha düşük tahmin etmektedir. Bunun sebebi öznel zaman tahminin temelinde yatan, doğrusal olmayan zaman ölçeği olabilir. Bu çalışmanın amacı, ileriye dönük paradigma kullanarak, farklı miktardaki yüklerden (az, fazla) kaynaklanan farklı çeşit bilişsel yükün (hafıza yükü, yönetimsel yükü) çeşitli zaman aralıkları (kısa,orta, uzun) üzerindeki etkisini incelemektir. Zaman tahmin aralığının, yük çeşidine ve miktarına bağlı olarak değişkenlik göstermesi tahmin edilmektedir. Ayrıca, zaman tahmin oranlarının fazla hafıza ve yürütme yükü gerektirdiği durumlarda uzun zaman aralıklarında gittikçe azalması beklenmektedir. Bu çalışmada deneylerde üç farklı zaman aralığı (12, 24 ve 36 saniye) kullanıldı. İlk deneyde Simon görevi iki farklı yük miktarı ile ikincil görev olarak kullanıldı. Uzun zaman aralığının kısa ve orta zaman aralığa oranla zaman tahmin aralığı oranı daha fazla düşük tahmin edildiği sonucuna bulunmuştur. Farklı yük miktarlarının zaman aralığı tahminini etkilemediği gözlemlense de, zaman tahmin oranının yük miktarına bağlı olarak zaman aralıkları arasında değiştiği gözlemlenmiştir. İkinci deneyde ise iki farklı yük miktarı ile hafıza arama görevi ikincil görev olarak uygulandı. Uzun zaman aralığı, kısa ve orta zaman aralıklarına göre daha fazla düşük oranla tahmin edilmiştir. Artan yük miktarına bağlı olarak azalan zaman aralığı üretimi gözlemlenmiştir. Kısacası; zaman tahmin oranları fazla yönetici yükü gerektirdiği durumlarda uzun zaman aralıklarında gittikçe azaldığı gözlemlenirken zaman tahmin oranlarının hafıza yükünün artmasına bağlı olarak zaman aralıkları arasında bir fark olmadığı sonucu bulunmuştur.

Anahtar Kelimeler: Dikkat, hafıza, yönetimsel yük, Skalar zamanlama, Attentional Gate Modeli.

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LIST OF ABBREVIATIONS

BOUN	Boğaziçi University
METU	Middle East Technical University
AGM	Attentional Gate Model
SET	Scalar Expectancy Theory
CV	Coefficient of Variation

CHAPTER 1

INTRODUCTION

Time is crucial for all living creatures. Due to its nature, time cannot be stored or accumulated (Hayden, 1987). According to the Newtonian view, it is independent of any events and a continuous process from past to future. Therefore, everyone experiences the same amount of time in a day (Benabou, 1999). However, the significance of psychological effects on time perception of people was emphasized. He states that time perception of people is predisposed to diverge from objective time depending on what they were busy with during particular period of time (Buhusi & Meck, 2009). Time seemingly passes faster when people have a good time whereas time seemingly drags when they are bored. To investigate under which circumstances people misestimate a certain time interval, the concept of "time perception" has been introduced (Fraisse, 1984). It implies the subjectivity of time depending on human perception.

The role of psychological time in human life is so important that it has been intensely investigated by researchers. It has been tried to explain how people perceive time differently from objective timing (Block, 1990). Many studies on time perception focus on duration which is the representation of present and recent past events. Although humans have no particular sensory organ for timing, it is asserted that cognitive and biological processes explain time perception of human beings. The reason is that attention and memory related to cognitive processes are essential to estimate a given duration (Block & Zakay, 1996).

How attention influences time perception of humans has been investigated with the “dual-task”- paradigm. It is assumed that people perceive the passage of time as shorter if they perform a secondary task during a given duration and pay attention to stimuli in the task instead of time signals (Stelmach & Herdman, 1991). According to internal clock models, the accumulator mechanism takes from the pulses generated in the pacemaker mechanism and stores them. These pulses provide information about time. The number of pulses is positively associated with perceived duration (Treisman, 1963). The number of generated pulses decreases when people attend to a secondary task. Therefore, people perceive duration shorter than actual duration (Thomas & Weaver, 1975).

Characteristics of the secondary task are crucial to understand how it affects perceived duration such that it appears shorter (Block, Hancock & Zakay, 2010). For example, if the secondary task is difficult and it requires higher attentional resources to perform, it shortens perceived duration. Conversely, if the secondary task is not required more efforts to perform, people perceive the passage of time as being longer (Brown, 2008). Therefore, it is stated that time perception is under the influence of characteristics of the secondary task (Block et al., 2010). Besides amount of cognitive load, numerous other factors such as type of load, or emotion, modulate time estimation. Types of cognitive load (e.g. memory load and executive demand) and amounts of load (low and high) of the secondary tasks play an important role in the estimation of interval length (Block et al., 2010).In this study, how types of cognitive load (executive demand or memory demand), amount of load (low or high) and durations (short, medium or long) influence time perception are investigated. Therefore, two experiments are carried out to test these effects.

An executive demand task requires conflict resolution, coordination and integration of information (Block, 2008). Previously, the Stroop task (Zakay & Block, 2004), the counting task (Duke, 2005) and the Simon task (Duzcu & Hohenberger, 2014), all requiring executive function, were used as a secondary task. These studies showed that tasks demanding executive functions lead to underestimation of time (Brown, 2006). In the present study the Simon task is used to explore the effects of executive demands on time estimation in the first experiment. In the classic Simon task, two different colors of geometric objects, e.g., red and green, are used and each color is coded as either requiring a left or right response. Stimuli are presented on either the left or right side of the screen. Participants are required to press the left or right button depending on the relevant stimulus dimension (color) as stated in the rule while ignoring the irrelevant stimulus dimension (location on the screen). If the response location as defined by the color code and the stimulus location are the same, this condition is called "congruent". However, if they are different, this condition is called "incongruent". It is typically found that subjects' reaction in congruent trials is faster than in incongruent trials (Feng, 2009). Another rule can be added to the Simon Task in order to increase the amount of task load. The classic Simon Task is used in the low-load condition in the executive demand task. For the high-load condition of the Simon task, a shape is presented at the beginning of each trial, indicating the response mapping with respect to this shape. If a circle is presented, the mapping rule is to press right arrow for blue square and left arrow for red square. If a rectangle is presented, the mapping rule is reversed; i.e., left arrow for blue square and right arrow for red square. The high-load condition of the Simon task is supposed to require even more attention than the low-load classic Simon task and therefore shorten subjective time perception even more.

Probing a different type of cognitive load, a memory search task is used to study whether memory demand task affects time perception in the second experiment. The memory search task needs to keep information in memory and recall it when necessary (Smith & Jonides, 1999). Also the memory demand of the secondary task influences duration judgment. According to internal clock models, an increase in attentional demand by the secondary memory task causes decrease in number of pulses stored in accumulator mechanism which leads to underestimation of time (Fortin & Neath, 2005). The memory search task proceeds as follows: participants see items with different memory set size in a 3x3 grid for a specific duration, then a target item is presented on the screen. Participants are required to report if the target had been present in the memory set or not. To increase the amount of task load, two different of memory set sizes are used: a set of two for the low-load condition and six for the high-load condition.

The Simon Task and the Memory Search Task have different requirements on working memory. The Memory Search Task is about storing and retrieving information whereas the Simon Task requires conflict resolution and task switching. These are different processes in working memory (Baddeley & Logie,1999). The results of both tasks are compared to each other to find out whether the type of cognitive load has a significant role in time perception and whether its influence changes depending on amount of load and duration length.

In this thesis, Chapter 2 provides a review of time perception and factors influencing time perception. Furthermore, duration judgment paradigms and duration judgment methods used in time perception studies will be explained. The differences between duration judgment paradigms will be discussed briefly. Which duration judgment methods are preferred to be used in the present study will be explained. To clarify how people perceive time, time perception models will be introduced. Then, each factor investigated in the present study will be presented. Additionally, studies based on these factors will be presented and discussed.

In Chapter 3, methods and results of two behavioral experiments will be presented and specific discussions of those experiments will be provided. A general discussion and conclusions will be provided in Chapters 4 and 5.

CHAPTER 2

LITERATURE REVIEW ON TIME PERCEPTION

Time perception, also called "psychological time", plays a crucial role in daily activities of humans (Matell & Meck, 2000). For example, walking across a crowded street (Wittmann & Paulus, 2007), communicating with other people (Hoffman, 2009) and dancing (Brown & Parsons, 2008) require accurate time estimation. Furthermore, it plays a crucial role in different cognitive processes such as planning and decision making when people want to attain a goals or complete an activity on time (Lakein, 1973). However, people tend to fail in accurate time estimation. According to Vierordt's law, the perceived duration tends to be shorter when the actual duration is long. On the other hand, a short duration can be perceived as longer (Block & Gruber, 2013). This law has been a controversial issue because time estimation is under the influence of different factors such as task demands (Casini & Macar, 1997), task difficulty (Block, 1992), and duration length (Zakay, 1993). Therefore, these factors lead to some distortions in duration judgment such as overestimation or underestimation (Flaherty, 1999).

How each factor influences time perception will be explained in the next sections. Before that, the following sections will review the duration judgment paradigm used in time perception studies and time estimation methods. Additionally, models of time perception will be presented to understand how people estimate time.

2.1. Duration Judgment Paradigms

Time estimation is under the impact of attention and memory processes. Different duration judgment paradigms in terms of prospective and retrospective paradigms have been used in time estimation studies. Prospective duration paradigm requires people to inform that they will estimate the time interval subsequently. Therefore, they experience a time interval and gather information about how much time passes. On the other hand, people are not forewarned until they have experienced the time interval in the retrospective duration paradigm. In that case, people do not have the opportunity to focus on the time interval; they can use memory resources instead of attentional resources for time estimation (Zakay & Block, 1997). Therefore, it has been concluded that attention has a key role in prospective time estimation whereas retrospective time estimation is under influence of memory processes (Zakay & Block, 1996). To clarify the distinction between the two paradigms, time experience in the prospective judgment can be called "experienced duration" whereas retrospective judgment is related to "remembered duration" (Block, 1990). Another, practically relevant distinction between the two paradigms is that the prospective paradigm has the advantage to allow multiple interval judgments, whereas retrospective time estimation can be done only once per subject. In this study, the prospective time estimation paradigm has been used.

Prospective Duration Judgment

Time estimation with prior knowledge is the main distinctive property of prospective duration judgments compared with retrospective paradigm. Awareness that they will have to reproduce the time interval later guides people to attend the passage of time. Therefore, attention plays a crucial role in this form of duration judgment (Zakay & Block, 1997). Besides prior knowledge, temporal uncertainty and temporal relevance determine which mechanism starts the timing of the duration of the task. How important perfect timing is to reach optimal behavior determines the amount of temporal relevance. On the other hand, temporal uncertainty is related to whether people have information about when the task will finish. In a situation in which temporal relevance and temporal uncertainty are high, more attention is devoted to timing and the process of prospective duration judgment starts working during the task. However, allocated attention resources about timing is low in the situation in which temporal relevance and temporal uncertainty are low. For example, people are asked to estimate the past time interval. If they do not expect this question, attention dedicated to time will be low. Therefore, retrospective duration judgment starts working (Block & Zakay, 2006)

Devoted attention to time has been discussed by many researchers. When people require performing two tasks at once, they have to divide their attention between them. Thus, allocated attention for each task is likely to differ from each other: sometimes one task is attended; sometimes the other. To explain the division of attentional resources between two different tasks in terms of a timing task and a secondary task, a technique was developed by Thomas and Weaver (1975). In this technique, attentional resources are kept in the common pool of mental capacity. Depending on the characteristics of the secondary task, the distribution of attention between primary and secondary tasks changes. To clarify, if a non-temporal task such as a difficult, novel or complex task requires more attentional resources to be performed, less attention is left for the temporal task (Pouthas & Perbal, 2004). This means that increase in the need of attention to perform secondary task leads to underestimation of time (Zakay& Block, 1997; Macar, Grondin & Casini, 1994). The temporal interval is judged shorter because less attention could be allocated to the timing of the interval. Its subjective duration therefore shrinks. In addition to task demand, the duration length also has effects on prospective duration judgment. Estimated duration tends to get smaller in long intervals compared to short intervals (Block & Zakay, 2006).

2.2. Duration Judgment Methods

Different estimation methods such as verbal estimation, production, reproduction and comparison have been used in time estimation studies (Block, 2003; Grondin, 2010; Lejeune &Wearden, 2009). In verbal estimation, people state how many seconds or milliseconds the given duration lasted after experiencing it, for example, people report that the interval was 450 ms. Although estimations can be specific; there is a problem about reporting clock units. For example, people tend to use more typical numbers such as 450 and 475 instead of 458. However, the interval can be 458 ms. Therefore; it is likely to result in larger variance (Wearden, 2014).

People have to produce a time interval in the production method. Participants determine the start and end of duration via pressing a button. However, the speed of the pacemaker influences duration judgment. The pacemaker is the component in timing models that determines the rate at which temporal pulses are emitted, see subsequent section. Therefore, it may not be appropriate for shorter durations. For example, a shorter interval such as 250 ms can be hard for people to produce. As a result, it is proposed that this method can provide reliable results only for longer duration such as seconds and minutes (Gil & Droit-Volet, 2011).

In the reproduction method, participants reproduce the target duration immediately after they have experienced it. It is possible to compare target duration and reproduced duration in this method. Unlike verbal estimation and production methods, this method has no disadvantages in respect to clock units and duration length (Droit-Volet, 2010). Alternatively, the capacity of working memory modulates the variance in reproduced duration (Baudouin, Vanneste, Isingrini, & Pouthas, 2006). Therefore, the reproduction method is preferred in this study.

2.3. Model of Time Perception

Differences in time estimation of people are explained by hypothesizing an internal clock. In accordance with the hypothesized timing model, there is a mechanism called pacemaker-accumulator similar to the mechanism in a clock. The pacemaker system generates regular pulses and the accumulator system is responsible for counting them. The information about how many impulses are accumulated is kept in memory. When estimating the given duration, people retrieve the information about the length of the duration from memory. Depending on the stored number of impulses, correct or incorrect, people are likely to judge the time interval correctly, or else overestimate or underestimate time, respectively (Grondin, 2001).

2.3.1. Scalar Expectancy Theory (SET) Model: Gibbon (1977) introduced the Scalar Expectancy Theory to explain time estimation in animals. There are three processes in the model in terms of clock, memory and decision, see Figure 1. The clock process functions similar to the pacemaker and accumulator system in the internal clock model. There is a switch between pacemaker and accumulator system. The switch is responsible for transmitting pulses produced by the pacemaker to the accumulator system. Working memory obtains the accumulated information and then sends it to long term memory. In the decision process, the information is retrieved from memory by a comparator. Having compared them, the comparator decides whether the estimated duration is equivalent to the actual duration (Gibbon, Church & Meck, 1984).

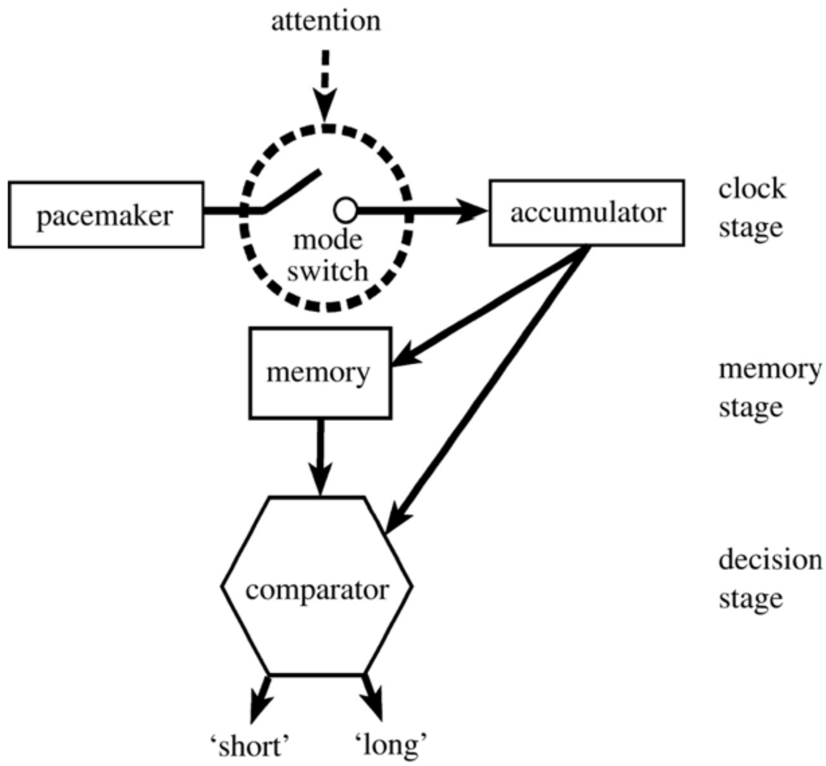

Figure 1. SET Model. Droit-Volet & Gil, 2009, pp. 1944.

Despite its significant contributions to the learning about timing in animals and humans, it has been criticized as ruling out the effects of cognitive factors in humans (Block, 1990). Cognitive factors such as attention and memory, as well as their possible interactions with physiological factors such as arousal are likely to alter the speed of the internal clock which causes changes in the number of pulses produced by the pacemaker. Therefore, people might overestimate or underestimate the given duration (Droit-Volet&

Gil, 2015). For example, dopaminergic drugs have different effects on time perception depending on their type (Cevik, 2003). If people take dopamine agonists, they tend to experience time faster (Maricq, Roberts & Church, 1981). However, people are prone to perceive time passing slowly when they takes dopamine antagonists (Rammsayer, 1989). In addition to drugs, environmental factors can modulate time perception of humans. Zakay and Block (1997) propose that attention has a significant role in transferring information to the accumulator. If people are busy with something and pay less attention to time, the number of accumulated pulses decreases which leads to underestimated time.

2.3.2. Attentional Gate Model (AGM): This model has been constructed by adding an attention mechanism to SET and provides explanations for prospective time perception. The model functions as follows, see Figure 2:

I. The rate of produced pulses by accumulator is constant. Their speed might change depending on the arousal level.

II. Pulses dedicated to timing arrive at an attentional gate. Depending on the amount of attentional resources, the gate opens and permits more pulses to reach the accumulator system.

III. The switch between the gate and the accumulator opens with a start cue. A cue is presented to inform people about the beginning of the time interval. Until the second, stop cue is given, the accumulator continues to receive pulses.

IV. After the second cue, the switch closes and information processing stops. Then, information about the number of pulses passes through to working memory. If this information is to be retrieved later, information in working memory sends to long term memory.

V. When a given duration is required to be (re-)produced, the pacemaker starts to generate pulses and transfer them to the accumulator. The number of accumulated pulses is compared with the number of pulses stored in long term memory. When there is a match between them, the switch closes and the process ends (Block &Zakay, 2006).

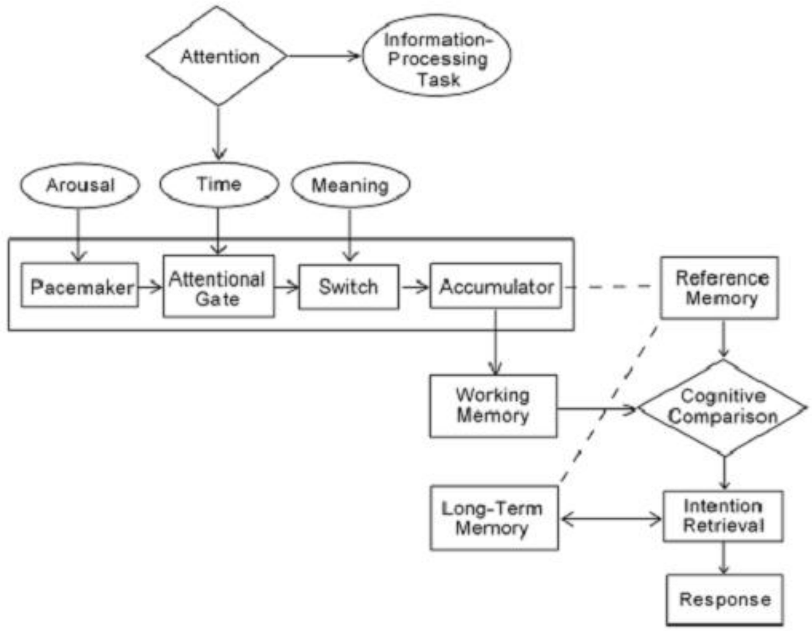

Figure 2. Attentional Gate Model. Block & Zakay, 2006 pp.32

a.

Recent studies have pointed out that accuracy in time estimation is positively associated with attentional resources devoted to timing (Block, Zakay, & Hancock, 1999; Chaston & Kingstone, 2004). In the prospective time duration judgment, attention plays a significant role. People have to pay attention to both timing (primary) task and secondary task. Depending on attentional resources for timing, people can either time the interval correctly, or underestimate or overestimate it. This model explains in particular how people misestimate time in the prospective duration judgment paradigm (Block & Zakay, 2006).

2.4. Types of Cognitive Load and Time Perception

Time perception studies force participants to pay less attention to timing by manipulating the tasks' cognitive load (Thomas & Weaver, 1975). Participants are asked to perform both temporal (timing task) and non-temporal task simultaneously, which renders this setting a dual-task paradigm. Both tasks require attention to be completed. Due to limited attention resources, both tasks are in a competition (Pouthas & Perbal, 2004). Therefore, increase in demand of one of the tasks leads to a decrease in performance in the remaining task (Fortin, Rousseau, Bourque, & Kirouac, 1993). Typically, it is the timing task that suffers more because participants consciously focus their attention on the task given to them. The degree of attention devoted to time varies depending on how much the secondary task requires attention to be performed. If cognitive load of the secondary task increases, it requires more attentional resources. Thereby, the degree of attention allocated to the primary timing task is decreased (Block & Zakay, 2006).

The dual-task paradigm has been applied in many time perception studies (Brown, 2006). Memory tasks (Brown, 1985), arithmetic tasks (Brown, 2006), the Stroop task (Zakay, 1993), the card sorting task (Zakay& Shub,1998), word recognition, letter identification and manual tracking (Brown & West, 1990) have been employed as non-temporal secondary tasks.

Numerous factors such as cognitive load and amount of load modulate time estimation. Types of cognitive load (e.g., memory load, attentional demand) and amounts of load (low, high) of the secondary tasks influences time perception of people (Block et al., 2010).

Cognitive load is about information processing demands consisting of attentional, executive and working memory resources. It is defined as "the amount of information-processing (especially attentional or working-memory) demands during a specified time period"; that is, the amount of mental effort demanded by a primary task (Block et al. 2010, 331).Cognitive load has different effects on time estimation depending on which duration judgment paradigm is applied to the experiment. For example, executive demand of a task significantly influences time estimation in the prospective paradigm whereas memory demand of a task has important effects on time estimation in the retrospective paradigm (Block et al., 2010).

2.4.1. Executive Demands

The importance of attentional resources on time perception has been investigated by several researchers (Block et al., 2010; Ogden, Salominaite, Jones, Fisk & Montgomery, 2011). When higher order processing takes place in the secondary task or people fail in switching attention between primary and secondary tasks, less attention is left for the primary task. Therefore, the accuracy of time estimates drops and the temporal interval is underestimated (Ogden et al., 2011; Brown, 2006).

Secondary tasks with executive function requirements need more attentional resources to be performed (Ogden et al., 2011). Executive function has a significant role in the various cognitive processes such as planning, decision making, and reasoning (Baddeley, 1986). Working memory is just one well-known example to explain the role of executive function (Baddeley, 1992). The central executive, a part of working memory, is in charge of the integration of information, coordination, and inhibition of inappropriate automatic responses. Therefore, executive tasks consume more attention (Brown, 2006). On the other hand, the resources prospective time duration uses are also linked to the central executive. Therefore, it is postulated that executive function demanding tasks influence prospective duration judgment. Both executive and timing tasks consume attention and the division of attention varies depending on which task requires more attention. Due to this dependency on attention, people are prone to misestimate time (Zakay & Block, 2004).

Several experiments have been carried out to investigate the effects of executive function demands on timing (Odgen et al., 2011). For example, Zakay and Block (2004) used Stroop tasks as an executive secondary task. The Stroop task involves two important cognitive processes in the central executive: inhibition and switching. Participants were required to switch between naming of the colors in which color words were printed and reading color words. The result revealed that performance for both tasks declined and the reproduced duration was shorter compared to the actual duration. The degree of underestimation varied depending on task difficulty. In the Stroop task, naming of the colors that do not match with the meaning of the color words is a harder task than simply reading the color words (and ignoring the color in which they are printed.)

Dutke (2005) carried out a time perception experiment by using a counting task which requires coordination. A list of numbers was presented for a while and people were instructed to verbalize target numbers after every third presentation of that number. It was found that performing this counting task resulted in underestimation of time.

Duzcu and Hohenberger (2014) employed a Simon task as an executive demanding task in prospective time estimation. The Simon task involves response selection processes and inhibition of inappropriate automatic responses. The procedure of the task is as follows: stimuli – colored rectangles – are presented in one side of screen: left or right. Participants give responds by pressing a left or right button according to the color of the stimulus regardless of its spatial location on the screen. When there is a match between response location according to the rule and spatial location, participants give response faster. However, there is no match between response location and spatial location of stimulus, interference arises during the response selection process and response times increase. The difference in response times between congruent and incongruent trials is known as the "Simon effect". This task decreased the degree of attention devoted to timing due to the need of more attentional resources. Therefore, time intervals of 15, 30, and 45 s were considerably underestimated in the study of Duzcu and Hohenberger (2014).

The present study uses the Simon Task as an executive demanding task. The Simon task is an executive task because in case of incompatibility of stimulus and response location, the participant has to inhibit her natural tendency to respond towards the location of the stimulus on the screen (i.e., on the right side) (Simon, 1969; Hommel, 2011).

2.4.2. Memory Demands

In addition to executive demanding tasks, memory demanding tasks have been employed as a secondary task in time perception studies. As stated before, prospective duration judgment is related to attention whereas memory processes play a significant role in retrospective duration judgments. Therefore, Fortin and Rousseau (1997) claim that secondary tasks with memory demands may not cause variation such as underestimation and overestimation in time reproduction when prospective duration judgment is used.

Zakay (1990) emphasizes the importance of short term memory in time estimation tasks. It is well known that information about timing is stored in short term memory and recalled in the production period (Gibbon, Church & Meck, 1984). Thus, short term memory tasks have been started to use as a secondary task to investigate their effects on time estimation. For instance, Fortin and Rousseau (1987) conducted time estimation studies by using a memory search task as a secondary task. In the memory search task, participants saw a series of numbers for a while simultaneously. Then, a target item was presented on the screen when time interval begins. Participants were required to report whether the target item was presented in the memory set or not. Before giving their response, they had to produce two seconds. To terminate the production, they pressed the left or right button. Type of response button changed depending on the response for memory search task. It was found that production of time interval is more overestimated when memory set size increased.

The studies investigating the effects of memory processing on duration judgment differ from each other in terms of encoding and reproduction phases. For example, Fortin and Rousseau (1998) used different paradigms in their experiments. In the first experiment, a series of numbers was shown simultaneously and then a target item was presented. The target item was on the screen during the time interval. This is called "encoding phase". After the end of the time interval, the reproduction phase started. When participants decided that enough time had passed, they terminated the reproduction by pressing the left or right button. The left button was for the absence of the target item in the memory set whereas the right button was for the presence of the target item in the memory set. In another experiment, the target item was shown in the reproduction phase instead of the encoding phase. In the reproduction phase, participants waited until the interval time elapsed. Then, the target item was presented and participants reproduced the time interval. They terminated the reproduction by giving response to the memory task. Both experiments involve different memory set sizes. Results revealed that time was underestimated and increase in memory set size led time production to shorten more when the target item was shown in the encoding phase. On the other hand, time was overestimated and overestimation was increased when memory set size increased when the target item was presented in the reproduction phase. They suggest that the effects of memory on time estimation changed depending on when short term memory processing takes place. If the target item was presented during the encoding phase, short term memory was active during that phase. Therefore, accumulated pulses about timing decreased and people underestimated time. On the other hand, memory process was active during the reproduction phase if the target item was shown in the reproduction phase. In that case, participants paid more attention to time and devoted attentional resources to secondary task left less. Therefore, participants overestimated time.

In the present study, two different tasks varying in terms of executive function and memory load are planned to be used as secondary tasks: the Simon Task and the Memory Search Task. The Memory search task differs from the Simon task in terms of process demands. The memory search task is related to holding information and remembering it later (Smith &Jonides, 1999) whereas the Simon task requires response selection and inhibition of inappropriate responses (Duzcu & Hohenberger, 2014). In contrast to time perception studies using the memory search task as in Fortin and Rousseau (1998), our participants perform the memory search task during the experienced time interval. When the time interval has elapsed, participants reproduce that interval.

2.5. Amount of Load and Time Estimation

As pointed out above the characteristics of the secondary task influences time estimation differently depending on duration paradigms. Time intervals filled with a difficult secondary task are experienced as shorter compared to the same interval filled with an easy secondary task in the prospective duration judgment paradigm (Block, 1989). The reason is that a difficult task needs more attentional resources to perform and leaves less attention to timing (Zakay, 1993). On the other hand, in the retrospective duration judgment, the relationship between task difficulty and time estimation is positive. This means that increase in task difficulty makes people reproduce a longer interval (Zakay & Block, 2004; Eagleman, 2008).

Smith (1969) examined whether task difficulty influenced time perception of humans. He used analogy problems with three levels: easy, moderate and hard problems. Results revealed that task difficulty and duration judgment are inversely correlated, i.e., the harder the secondary task, the shorter the reproduced time.

Block (1992) tested this hypothesis by using both prospective and retrospective paradigms. The experiment had two levels in terms of easy and hard. In the easy condition, participants just paid attention to words. However, participants were instructed to assign an action to the word in the hard condition. He found that task difficulty influenced only prospective duration judgments. Participants underestimated time more in the hard condition compared to the easy condition.

Khan, Sharma and Dixit (2006) also investigated the relationship between amount of load and time perception for both duration judgment paradigms. Words were selected from the category of animals and fruits. Participants were required to observe the words (low load), or categorize the word as animal or fruit (medium load) or memorize them (high load). Results showed that accuracy of the timing task dropped more when load increased in the prospective duration judgment, as expected. Additionally, the error in time estimation was higher in the prospective duration judgment than in the retrospective duration judgment.

Studies based on amount of load and time estimation support attention models of timing. Due to our limited attentional capacity, increase in task difficulty leaves less attention to timing in the prospective duration paradigm. Therefore, people tend to underestimate time more (Khan et al., 2006).

2.5. Duration Lengths and Time Perception

Another manipulation in time estimation studies concerns duration length. Several experiments reveal that people are better in estimating shorter durations compared to longer durations in prospective time estimation (Block &Zakay, 2006). For example, Brown (1985) carried out an experiment by manipulating task difficulty and using different interval lengths. People completed a pencil figure tracking task with two difficulty levels for each duration lengths (16 sec and 32 sec). It was observed that longer duration was underestimated more when the task was more difficult.

Zakay (1993) also examined the effects of duration range and task difficulty on time production. People performed Stroop tasks during some time interval (12 sec or 22 sec). Participants either reported the font color (difficult condition) or read the written color name regardless of the color of its ink (easy condition). The results showed that productions of longer durations were shortened more than productions of shorter durations in the difficult condition.

CHAPTER 3

METHODOLOGY AND RESULTS

The present study aims to investigate the effects of different amounts of cognitive load (low, high) and different types of load (memory load, executive load) for various time durations (short, medium, long) by using the prospective paradigm. To investigate these effects, the "dual task" paradigm is used. In the dual task paradigm, the time estimation is called "primary task" whereas the task carried out in those intervals is called "secondary task". In the present study, there are two different secondary tasks: an executive task and a memory task, respectively. The Simon task is used as executive demand task whereas a memory search task is used as memory demand task. Each secondary task has two different amounts of loads: low and high. In the Simon Task, participants have to respond to a stimulus appearing on the screen by pressing a button. Two different rules are used for defining stimulus and response relations. In the low-load condition, participants press right arrow for blue square and left arrow for red square regardless of the location of the stimulus in the screen (left or right). The low-load condition was employing a “fixed mapping” since there was only a single rule determining the S-R mapping. On the other hand, the stimulus-response relations in the high-load condition are firstly determined by a shape as indicator of a certain mapping rule. The high-load condition was employing a “random mapping” since the appearance of either triangle or circle indicating either rule was random. A triangle indicates that participants should press left arrow for red square and right arrow for blue square. If a circle is shown, the response is vice versa. The amount of load in the memory search task is determined by the memory set size. Two items are used for the low load condition of the memory task while six items are used for the high load condition of the memory task. Multi-seconds scales (12-24-36 sec) are selected for durations and the reproduction method is used as estimation method.

Two different experiments are carried out between participants. In the first experiment, participants perform the executive demand task as secondary task during the interval. In the second experiment, the memory search task is used during the intervals. The results of two experiments are also planned to be compared. Both have same within subjects' variables (the amount of load and different duration lengths).

Hypotheses in the study:

I. It is expected that time estimation varies according to kind of load (executive or memory), amount of load (low or high), and duration (short, medium or long).
II. Relying on the Attentional Gate Model, it is expected that time is underestimated more when secondary task demand increases.
III. It is predicted that increase in duration length is associated with smaller time estimates ratios (between objective durations and subjective, reproduced durations).
IV. Furthermore, it is expected that time estimation ratios get smaller with longer durations for high memory and executive loads.
V. It is predicted that coefficient of variation (to be explained below) is stable for all possible conditions.

3.1. Experiment 1: The effects of the executive demand task with two different loads (low vs. high) on time duration estimates

The present experiment aims to examine the effect of a secondary executive task on time reproductions. The Simon task is used as an executive task. Since it requires conflict resolution, participants need more attention to perform it properly. Therefore, it is expected that less attention is left for timing and participants perceive the passage of time fast. Therefore, they will underestimate temporal intervals.

In this experiment, participants are enforced to perform both temporal and non-temporal tasks concurrently. Therefore, they have to divide their attention between the two tasks. According to the Attentional Gate Model, the degree of attention devoted to the timing task varies depending on how much attention the secondary task needs to be performed (Block & Zakay, 2006). Furthermore, increase in task difficulty (i.e., high load) makes people underestimate time more (Zakay, 1993). Duzcu and Hohenberger (2014) found out that time estimates ratios are smaller in long durations compared to medium and short durations. Thus, it is expected to observe a decreasing trend in time estimates with increasing durations and increasing amount of load of the secondary task.

3.1.1. Method

Participants

18 subjects (14 females, 4 males) participated voluntarily in the experiment. Mean age was 25.77 years (SD= 3.78). They had normal or corrected-to-normal vision.

Stimuli

The stimuli were shown on a personal computer running special design software, Java, (providing 1366x768 resolutions). Stimuli appeared in the centre of the screen against a grey background. The screen was viewed from a distance of approximately 30 cm. Responses were measured by pressing left and right arrows on the keyboard. Participants used their right hand.

The stimuli in the executive task consisted of colored squares (red and blue) with a size of approximately 6 cm height and 6 cm length, which were target stimuli. Additionally, a circle and a triangle were presented, which were indicators of a mapping rule either for "fixed mapping" or "random mapping" (see procedure).

Procedure

The study was approved by the university’s Ethics Committee. Following their regulations, participants signed an informed consent form before they started the study. Before the real experiment, a demonstration trial was shown to participants. How to initiate the task and give a response was explained. After the demonstration trial, they completed a practice phase with three different durations (8-20-30 sec) for each cognitive load condition. Same stimuli as in the test phase were used in the practice phase; however, the durations were different. Having completed the practice section, participants started the real experiment.

There are three different durations used in the experiment: 12, 24, and 36 seconds. Participants performed the Simon Task with two different amounts of load (corresponding to the fixed vs. random mapping condition) during a randomly assigned duration. The set-up of the experiment in the low cognitive load of the experiment (fixed mapping) was as follows: a cross was presented for 200 ms in the centre of the screen followed by a blank screen for 300 ms. Then, a colored square was displayed for 500 ms on either the left or right side of the screen, followed by a blank screen for 1000 ms. In the high cognitive load of the experiment (random mapping), a shape appeared for 200 ms in the centre of screen followed by a blank screen for 300 ms. Then, a colored square appeared for 500 ms on either left or right side of screen followed by a blank screen for 1000 ms. Participants were required to respond within 1.5 seconds. Each trial lasted two seconds. The total numbers of trials for durations were 6, 12 and 24, respectively. At the end of each duration, participants were required to reproduce their estimates of the duration as follows: A black square was presented in the centre of the screen immediately after the given duration had elapsed. Participants were expected to wait for a certain amount of time, corresponding to their estimate of the duration, and then they needed to press space bar to indicate the end of their estimation. Each duration for each type of load was presented five times, in random order. In total there were 30 trials.

In the low-load condition of the Simon task (which is tantamount to the classical Simon task), a colored square (red or blue) is presented on either the left or right side of the screen. Participants are instructed to press left arrow when the red square is presented and right arrow when the blue square is presented regardless of the spatial location of squares (see Figure 3).

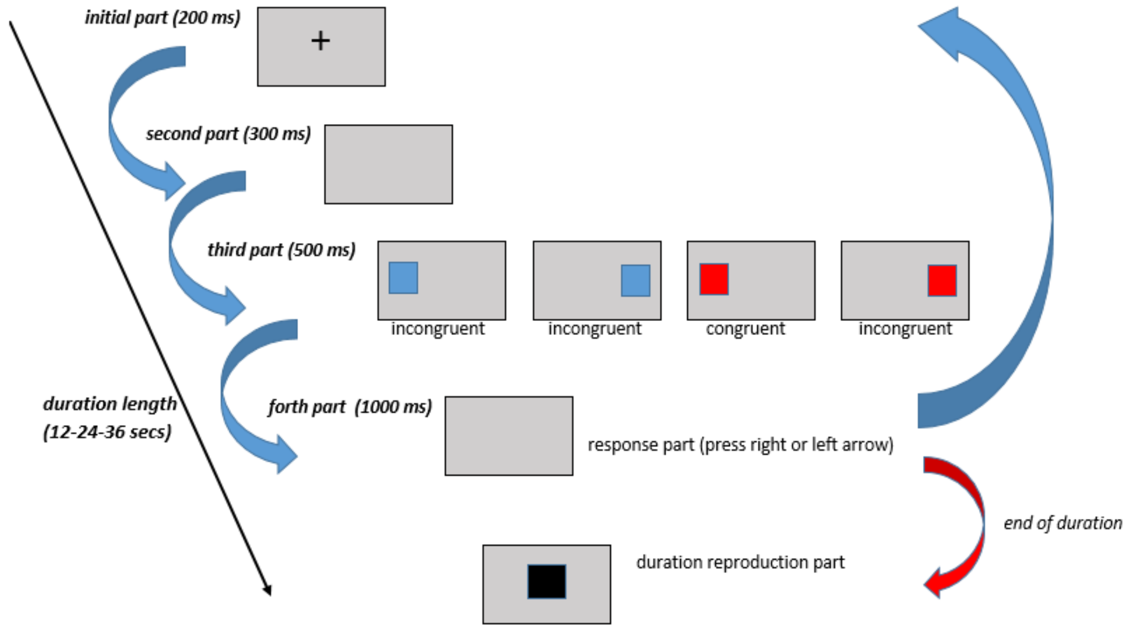

Figure 3. Illustration of the experimental design in the fixed mapping

For the high load condition of the Simon task, a shape is presented at the beginning of each trial, indicating the response mapping with respect to this shape. If a circle is presented, the mapping rule is to press right arrow for blue square and left arrow for red square. If a rectangle is presented, the mapping rule is reversed; i.e. left arrow for blue square and right arrow for red square (see Figure 4, indicating the rule for the circle condition).

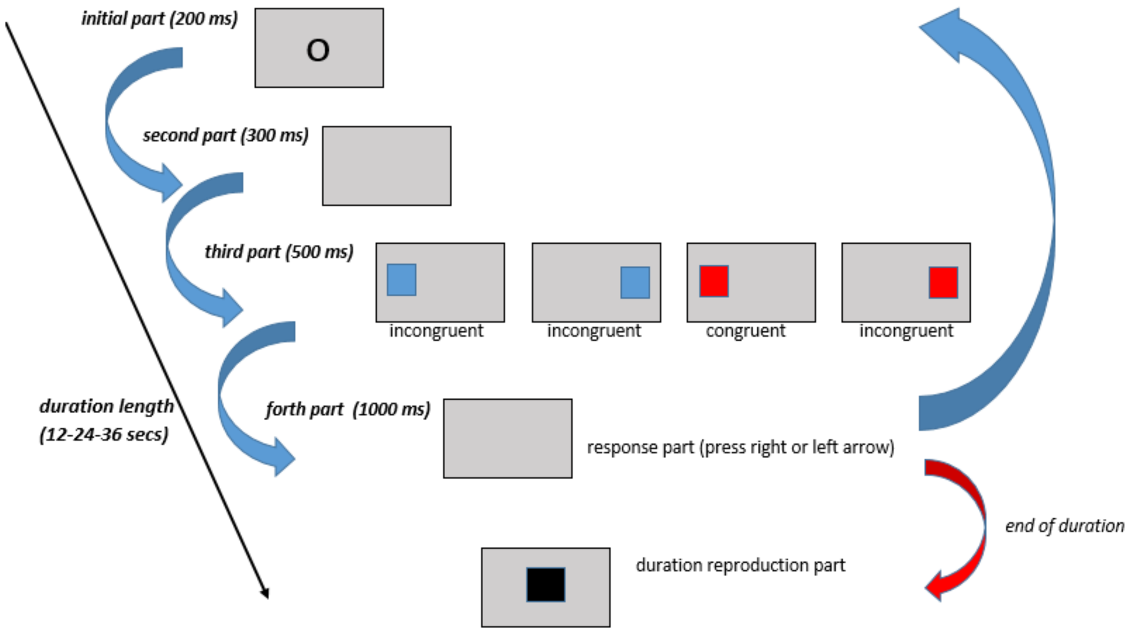

Figure 4. Illustration of the experimental design in the random mapping

3.1.3. Results

Three dependent measures were calculated and analyzed: Ration (Estimates/Actual Duration), Absolute Error/Actual Duration and Coefficient of Variation (SD/Mean).

<u>Duration judgments</u>

A 2 (load: low vs. high) x 3(durations: short, medium vs. long) Repeated Measures ANOVA was carried out to find out whether the amount of load and various in duration have any effects on time estimation with a secondary executive task .

Table 1. Judgments for each type of load across duration lengths in time estimation with an executive secondary task

	Low			High		
	Durations					
	12 sec	**24 sec**	**36 sec**	**12 sec**	**24 sec**	**36 sec**
Raw Estimates in sec (SE)	8.58 (.69)	14.95 (.97)	19.54 (1.25)	8.87 (.75)	14.06 (1.13)	16.25 (1.12)
Difference Score in sec	3.42	9.05	16.46	3.12	9.94	19.75
Ratio (Estimates/Actual Duration)	.72	.62	.54	.74	.59	.45
Absolute Errors in sec	4.11	9.47	16.67	4.61	10.92	19.75
Absolute Error/Actual Duration	.34	.39	.46	.39	.46	.55
Coefficient of Variation (SD/Mean)	.21	.21	.22	.23	.24	.21

Various measures were computed from participants' raw reproduction times (see Table 1 for descriptive statistics). In the first analysis, the ratio score was used. It was calculated by dividing estimated duration by actual duration. A 2 (load: low vs. high) x 3(durations: short, medium vs. long) Repeated Measures ANOVA was carried out to find out whether amount of load and the variation in duration have any effects on time estimation with a secondary executive task. The main effect of duration was statistically significant (F (2, 34) =33.5, p<.001, η_p^2 = .66). Simple contrast revealed that the long duration (M=.50, SE=.04) was underestimated more compared to moderate (M=.60, SE=.05) (F (1, 17) =38.34, p<.001, η_p^2= .69) and short durations (M=.73, SE=.06) (F (1, 17) =37.37, p<.001, η_p^2= .69). The amount of load had no significant effect on duration judgment (F (1, 17) =3.81, p=.079). The estimated time ratio was similar in both low (M=.63, SE=.04) and high load (M=.59, SE=.05). The interaction effect of type of load and duration was statistically significant (F (2, 34) =4.61, p=.017, η_p^2 = .21). Simple contrasts were carried out for further analysis. These revealed a significant interaction when comparing low load to high load for both long duration and short durations (F (1, 17) =7.66, p=.013, η_p^2 = .31). This effect reflected that the longer duration was more underestimated in the high load (*M*=.45, *SE*=.03) compared to low load condition (*M*=.54, *SE*=.04) whereas time estimate in the short duration was similar in low load (*M*=.72, *SE*=.06) and high load (*M*=.74, *SE*=.08). However, there was no significant interaction when comparing low load to high load for both long duration and medium duration ($F(1,17)=1.92$, $p>.05$).Ratio scores in the long duration were lower than in the medium duration for both low load and high load conditions (see Figure 5).

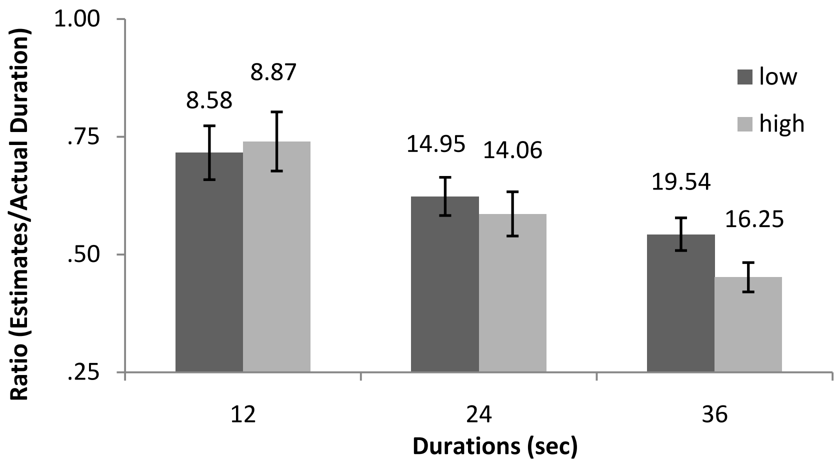

Figure 5. Mean Ratio Score across durations for each amount of load. Error bars shows SE and estimated duration was on the bars

In the second analysis, the average absolute errors and subsequently the ratio between absolute errors/actual duration were calculated. For that purpose, each reproduced duration was subtracted from its actual duration by ignoring the sign of the duration, i.e., whether the reproduced time was shorter or longer. . Then, the mean score was divided by its related actual duration. The reason was that increase in duration length obstructs getting reliable results when a comparison between durations only in terms of absolute error score was done. The ratio takes care of the effect of duration length and thus provides a more reliable measure. A two way Repeated Measure ANOVA revealed that the amount of load had a significant effect on absolute errors/actual duration (F (1, 17) =13.45, $p<.001$, η_p^2 = .44). Inaccuracy in high load (*M*=.46, *SE*=.03) was higher than inaccuracy in low load (*M*=.40, *SE*=.03). The main effect of duration length was statistically significant (F (2, 34) =17.58, $p<.001$, η_p^2 = .51). Accuracy dropped more in the long duration (*M*=.51, *SE*=.03) compared to medium duration (*M*=.36, *SE*=.03) (F (1, 17) =21.71, p<.001, η_p^2 = .56) and short duration (*M*=.42, *SE*=.03) (F (1, 17) =39.51, $p<.001$, η_p^2 = .70). The interaction effect of duration length and amount of load was not significant (F (2, 34) = 1.25, $p>.05$). Errors did not vary across duration length depending on amount of load (see Figure 6).

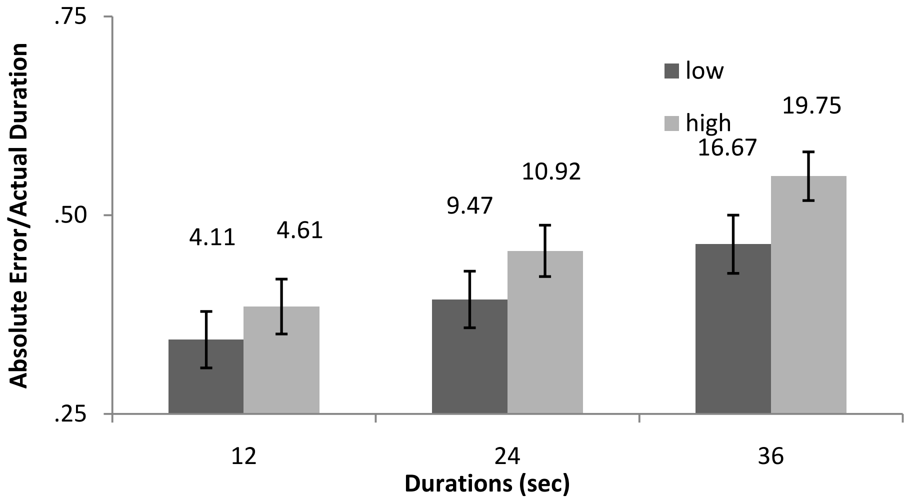

Figure 6. Mean Absolute Error/Absolute Duration score across durations for each amount of load. Error bars show SE and absolute error score was on the bar

Finally, in the third analysis, a Repeated Measure ANOVA was conducted by using the Coefficient of Variation (CV). CV was calculated by dividing standard deviation by mean estimated durations. The CV is considered as the crucial variable in Scalar Expectancy Theory since it indicates the scalar invariance of time estimation across different temporal intervals (Church, 2003, among many others). A 2 (load: low vs. high) x 3(durations: short, medium vs. long) Repeated Measures ANOVA was carried out. The main effect of duration length on time estimation was not significant (F (2, 34) =.11, p>.05). This means that all duration lengths had similar CVs. The amount of load had no effect on time estimation (F (1, 17) =.30, p>.05). CVs were stable for both low load and high load conditions. The interaction effect of amount of load and duration length revealed no significant effect either (F (2, 34) =.45, p>.05). CVs did not change across duration lengths depending on amount of load (see Figure 7).

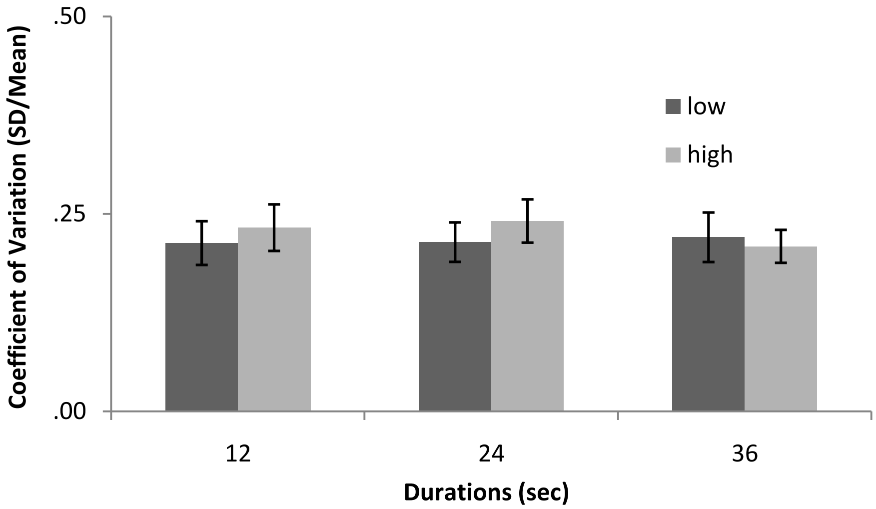

Figure 7. Mean CV across durations for each amount of load. Error bars show SE.

<u>Simon Task</u>

Figure 8 shows mean reaction time for each mapping across congruent and incongruent condition. It seems that reaction time in random mapping is higher than reaction time in fixed mapping. Additionally, it can be observed that there is a difference between congruent and incongruent trials in the fixed mapping whereas reaction time for both conditions is similar in random mapping. A 2(types of mapping: fixed vs. random) x 2(congruency: congruent vs. incongruent) Repeated Measures ANOVA revealed that the main effect of mapping type was statistically significant (F (1, 17) =71.16, $p< .001$, $\eta_p^2=.81$). Reaction time in random mapping (*M*=865.99, *SE*=33.75) was significantly higher compared to fixed mapping (*M*=695.73, *SE*=20.94). The main effect of congruency was not statistically significant (F (1, 17) = 1.49, $p=.24$). Participants had similar reaction time for both congruent (*M*=776.40, *SE*=25.76) and incongruent (*M*=785.33, *SE*=27.14) condition. The interaction effect of mapping type and congruency was statistically significant (F (1, 17) =10.24, $p=.005$, $\eta_p^2=.38$). Participants gave faster responses for congruent condition (*M*=683.57, *SE*=21.88) compared to incongruent condition (*M*=707.90, *SE*=20.62) in fixed mapping. However, reaction time in congruent condition (*M*=869.24, *SE*=33.01) was similar to reaction time in incongruent condition (*M*=862.76, *SE*=35.19) in random mapping.

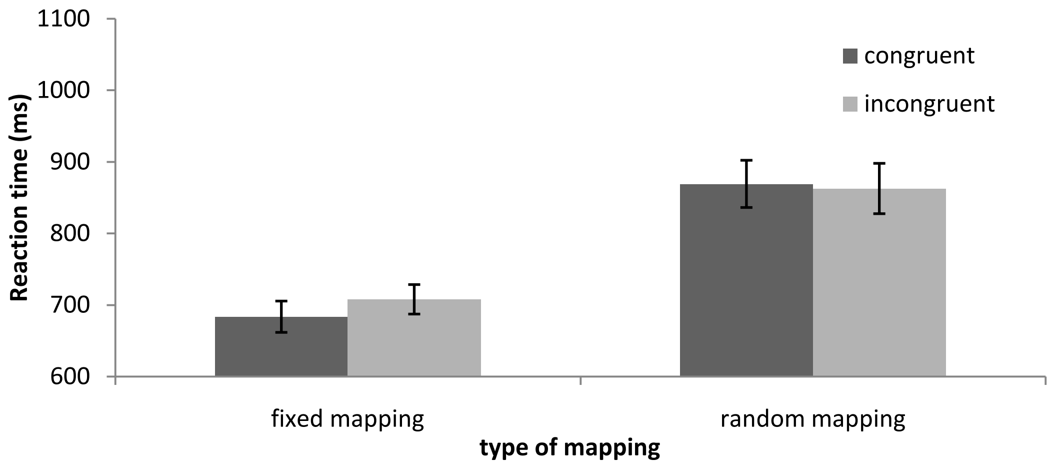

Figure 8. Mean reaction time for each mapping across congruent and incongruent condition. Error bars show SE.

A paired samples *t*-test was carried out to compare congruent and incongruent condition in the fixed mapping. It revealed that reaction time in the congruent condition was significantly faster than reaction times in the incongruent condition (t (17) =3.32, p=.004, r=.63)

3.1.4. Discussion

The aim of the first experiment was to explore the effects of executive function with different amounts of load and various duration lengths on time perception. Participants performed a time estimation task involving high and low executive demand tasks. In the experiment, ratios of estimated duration and absolute duration, ratios of absolute errors and actual duration and coefficient of variance scores for each duration length (12-24-36 sec) were calculated and used in the analysis.

The results of the first experiment demonstrated that there was a significant effect of duration length on time estimation. Time estimation ratios decreased more when duration length increased. It means that participants underestimated time more in the long duration compared to short and medium durations. Further, increase in the amount of task load was associated with lower time estimates ratios, however, not generally but only with respect to temporal durations, as revealed by a significant interaction between load and duration. As expected, a decreasing trend in time estimates with increasing durations and amount of load of secondary task was observed. Time estimates ratios in the short duration was similar for both low and high amount of task load while underestimations in medium and long durations were more profound for high amount of task load compared to low amount of load. These results were expected and actually found. Also Duzcu and Hohenberger (2014) had found an effect of duration length on time estimation by using the Simon Task as a secondary task. Additionally, they state that this effect was stronger when duration was longer. In the present experiment, the Simon task was also used as the secondary task. In addition to the study of Duzcu and Hohenberger, two different mapping rules were implicated in the Simon Task in order to increase its difficulty. It was found that the effect of duration length was more profound when the task was more difficult. Thus, the present finding replicates and extends the previous findings of Duzcu and Hohenberger (2014).

Absolute error is used to evaluate accuracy in time estimation overall (Brown, 1985). If absolute error is nearly zero, it means that performance of participants in time estimation is perfect. It was expected that accuracy in time estimation varies depending on task difficulty and duration lengths. The analysis of absolute error/actual duration ratios revealed significant effects of duration length and task load on time estimation. Accuracy in time estimates dropped more when duration length increased. This result is consisted with the study of Duzcu and Hohenberger (2014). Additionally, error scores in the high-load condition were higher than error scores in the low-load condition. This finding supports previous ones (Brown, 1985; Fortin & Rousseau, 1987). However, accuracy for each duration did not change depending on task difficulty.

According to scalar timing theory, timing is achieved through counting pulses, which are emitted by the pacemaker, in the accumulator. The number of pulses increases when the time interval increases. This implies that variance likewise increases due to increase in durations. However, when variance is divided by mean estimated duration, CV remains constant (Penton-Voak, Edwards, Percival & Wearden, 1996). Consequently, it was expected that CV did not show changes depending on the amount of load and duration lengths. The results conformed to this expectation and therefore support scalar timing theory.

The result of the secondary task was also analyzed. It was important since it provides information about whether participants responded to the secondary task randomly or seriously. Additionally, the comparison between fixed mapping and random mapping condition would report whether the levels of difficulty were manipulated in the intended way. The results indicated that participants responded faster for fixed mapping condition than random mapping condition. This means that random mapping was more difficult than fixed mapping. Furthermore, the interaction between congruency and task showed that the congruency effect only held for the fixed condition but not for the random mapping condition. It may be due to reaction times. Fixed mapping condition had shorter reaction times compared to random mapping condition. Additionally, participants actually completed the regular Simon Task in the fixed mapping. Therefore, the advantage in the congruent condition manifests itself. In the random mapping, reaction times increased since participants needed more time to respond according to the rule and this might have cancelled out the early response advantage due to the overlap between stimulus and response location. Wiegand and Wascher (2007a) also conducted an experiment about the Simon effect with fixed and random mapping. In this perspective, their study was similar to the present study. The results of their study indicated that reaction time in random mapping was higher than in fixed mapping. Additionally, increase in reaction time led Simon effect fade away. Although the present study was comparable to the study of Wiegand and Wascher (2007a), reaction times for both conditions in the present study were longer than reactions times in their studies. Therefore, it may be concluded that the primary task also influenced performance of the secondary task.

3.2. Experiment 2: The effects of the memory demand task with two different loads (low vs. high) on time duration estimates

The aim of the present study is to reveal the effect of a secondary memory task on time estimation, as compared to an executive secondary task. A Memory Search Task was used as memory task. It requires storing and recalling information when it is necessary. Therefore, it is different from a secondary executive task like the Simon task we used in Experiment 1.

As in the previous experiment, the memory task has two difficulty levels. It is predicted that time reproduction in the difficult condition (high-load) is shorter than reproduction in the easy condition (low-load). Furthermore, an effect of duration length on time reproduction is expected. Long duration will be underestimated more compared to short and medium durations. Finally, it is expected that time reproduction varies across duration length depending on task difficulty.

3.2.1. Method

Participants

19 subjects (15 females, 4 males) participated voluntarily in the experiment. Mean age was 26.53 years (SD= 2.25). They had normal or corrected-to-normal vision.

Stimuli

The stimuli were shown on a personal computer running special design software, Java, (providing 1366x768 resolutions). Stimuli appeared in the centre of the screen against a grey background. The screen was viewed from a distance of approximately 30 cm. The responses were measured by pressing left and right arrows on the keyboard. Participants used right hand.

The stimuli in the memory task consisted of digits between one and nine. Each digit in the set appeared in one of the squares in a 3-by-3 grid randomly. There were two types of memory sets: two and six numbers (see procedure).

Procedure

The study was approved by the university's Ethics Committee. Following their regulations, participants signed an informed consent form before they started the study. Before the real experiment, a demonstration trial was shown to participants. How to initiate the task and give a response was explained. After the demonstration trial, they completed a practice phase with three different durations (8-20-30 sec) for each cognitive load. Same stimuli as in the test phase were used in the practice phase. Having completed the practice section, participants started the real experiment.

There are three different durations used in the experiment: 12, 24, and 36 seconds. Participants performed a memory search task with two different amount of load during a randomly assigned duration. In the memory search task, the stimuli consisted of digits in the range of 0-9. They were presented in a 3x3 grid in the centre of the screen. Each digit in the memory set appeared in one of the squares in the grid randomly. The number of digits presented in the grid changed depending on the type of cognitive load. The memory set in the low cognitive load condition had two digits whereas the memory set in the high cognitive load condition had six digits. The procedure of task was as follows: In the real experiment, the memory sets were presented in the centre of screen for 500 ms followed by a blank interval for 500 ms. Then, the target item was presented in the screen for 500 ms followed by a blank interval for 1300ms. During this interval, participants had to indicate "Yes" or "No" by pressing the right and left arrow respectively. The target item had either been present in the memory set or not. Participants were required to press right arrow for presence of target item and left arrow for absence of target item in the memory set. The total number of trials in each duration was 4, 8 and 12, respectively. At the end of each duration, participants were required to reproduce their estimates of the duration as follows: A black square was presented in the centre of the screen immediately after the given duration had elapsed (see Figure 9). Participants were expected to wait for a certain amount of time, corresponding to their estimate of the duration, and then they needed to press space bar to indicate the end of their estimation. Each duration for each type of load was presented five times, in random order. The total number of trials was 30.

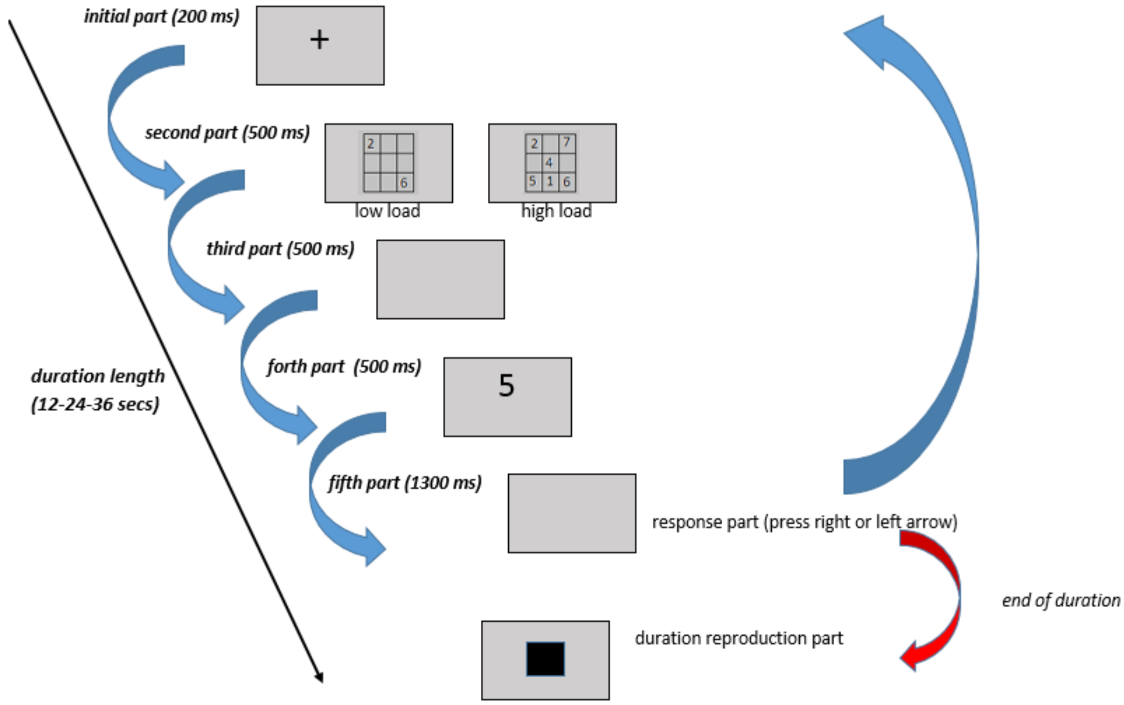

Figure 9. Illustration of the experimental design in the memory search task

3.2.2. Results

The same dependent variables as in first experiment were computed and analyzed. Table 2 provides the descriptive statistics.

Duration Judgment

A 2 (load: low vs. high) x 3(durations: short, medium vs. long) Repeated Measures ANOVA was carried out to find out whether the amount of load and the variation in duration have any effects on time estimation with a secondary memory task.

Table 2. Judgments for each type of load across duration lengths in time estimation with a secondary memory task

	Low			High		
	Durations					
	12 sec	24 sec	36 sec	12 sec	24 sec	36 sec
Raw Estimates in sec (SD)	8.39 (.67)	14.32 (.95)	16.70 (1.22)	8.09 (.73)	13.05 (1.10)	15.86 (1.09)
Difference Score in sec	3.61	9.68	19.30	3.91	10.95	20.14
Ratio (Estimates/Actual Duration)	.70	.60	.46	.67	.54	.44
Absolute Errors in sec	4.52	10.07	18.46	4.56	11.33	20.22
Absolute Errors /Absolute duration	.38	.42	.51	.38	.47	.56
Coefficient of Variation (SD/Mean)	.21	.19	.18	.25	.21	.20

In the first analysis, ratio scores were analyzed. A 2 (load: low vs. high) x 3(durations: short, medium vs. long) Repeated Measures ANOVA was carried out. The main effect of duration was statistically significant (F (2, 34) =40.11, p<.001, η_p^2 = .69). Simple contrast revealed that the long duration (M=.45, SE=.03) was more underestimated compared to medium (M=.57, SE=.04) (F (1, 18) =63.15, p<.001, η_p^2 =.78) and short durations (M=.69, SE=.05) (F (1, 18) =46.96, p<.001, η_p^2 = .72). The amount of load had a significant effect on duration judgments (F (1, 17) =4.72, p=.043, η_p^2 = .21). Estimated time was shorter in high load (M=.55, SE=.04) compared to low-load (M=.59, SE=.04). The interaction effect of load and duration was not statistically significant (F (2, 34) =.80, p>.05). Estimated time did not change across duration lengths depending on amount of load (see Figure 10).

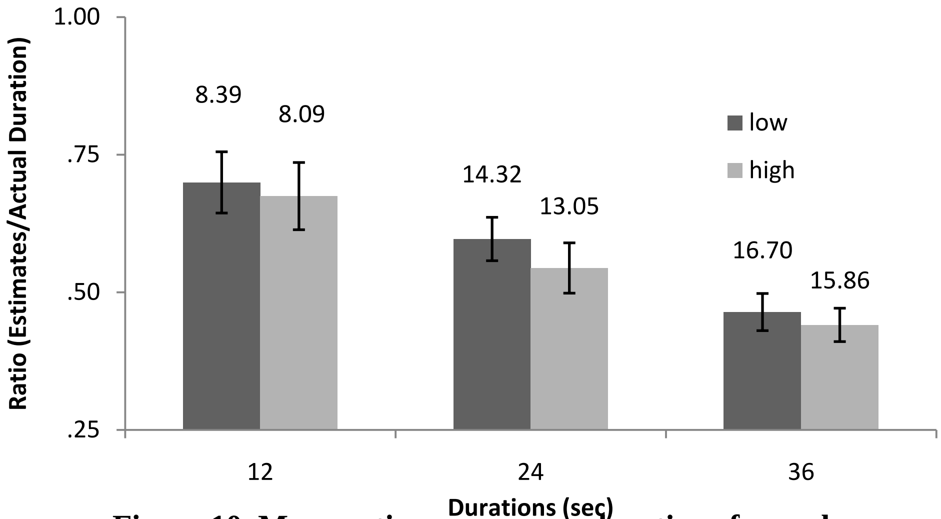

Figure 10. Mean ratio score across durations for each amount of load. Error bars show SE and estimated duration was on the bar.

In the second analysis, absolute error/actual duration ratios were submitted to a two-ways Repeated Measure ANOVA. It revealed that duration length had a significant effect on duration judgment (F (1, 18) =9.15, p<.001, η_p^2 = .34). Simple contrast revealed that accuracy dropped more in the long duration (M=.54, SE=.03) compared to short (M=.38, SE=.04) (F (1, 18) =53.06, p<.001, η_p^2 = .75) and medium durations (M=.45, SE=.03) (F (1, 18) =72.43, p<.001, η_p^2 = .80). The main effect of amount of load was statistically significant (F (2, 36) =43.44, p<.001, η_p^2 = .71). Errors in the high load condition (M=.47, SE=.03) were higher than errors in the low load condition (M=.44, SE=.03). The interaction effect of duration length and amount of load was significant (F (2, 36) = 4.08, p=.025, η_p^2 = .19). Inaccuracy in time estimation varied across duration lengths depending on the amount of load. This was revealed in a significant interaction when comparing low load to high load for both long duration and short duration (F (1, 17) =7.66, p=.013, η_p^2 =.31). Simple contrasts were carried out for further analyses. The contrast approached significance when comparing the low-load condition to the high-load condition for short versus long duration (F (1, 18) =4.18, p=.056). Inaccuracy in the long duration was numerically higher for high-load (M=.56, SE=.03) compared to low-load (M=.51, SE=.04), whereas error scores in the short duration was similar in low load (M=.38, SE=.03) and high load (M=.38, SE=.03). However, there was no significant interaction when comparing low load to high load for both long duration and medium duration (F (1, 18) =.06, p>.05). Accuracy dropped more in the long duration compared to the medium duration for both low load and high load conditions (see Figure 11).

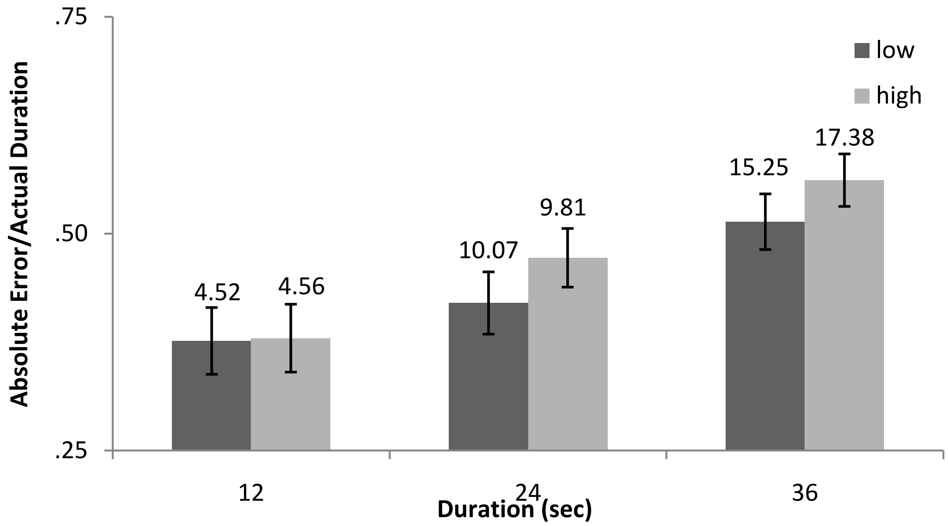

Figure 11. Mean Absolute error/actual duration score across durations for each amount of load. Error bars show SE and absolute error score was on the bars.

In the third analysis, a 2 (load: low vs. high) x 3(durations: short, medium vs. long) Repeated Measures ANOVA was conducted by using the Coefficient of Variation (CV) (see Figure 12). The main effect of duration length on time estimation was not significant (F (2, 36) =1.14, p>.05). This means that all duration lengths had similar CVs. The amount of load had no effect on time estimation either (F (1, 18) =1.84, p>.05). CVs were stable for both low-load and high-load conditions. The interaction between amount of load and duration lengths revealed no significant effect either (F (2, 36) =.08, p>.05). CVs did not change across duration lengths depending on amount of load.

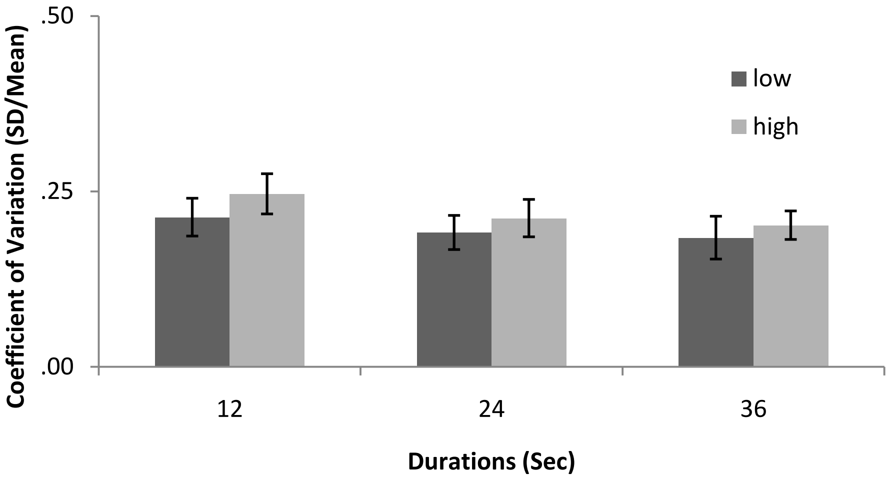

Figure 12. Mean CV across durations for each amount of load. Error bars show SE

Memory Search Task

In the following, the results for the secondary memory task are reported, in terms of correct responses and response times. Figure 13 shows correct responses for each memory set in percent, for the easy and hard condition. It seems that participants tend to give more correct responses in the two digits memory set compared to the six digits memory set. On average, participants' performance was better in the smaller memory set size with two digits (*M*=95.79, *SE*=1.09) compared to the larger memory set size with six digits (*M*=79.78, *SE*=2.26), as expected. This difference was statistically significant ($t\ (18) = 7.65$, $p<.001$, $r=.87$).

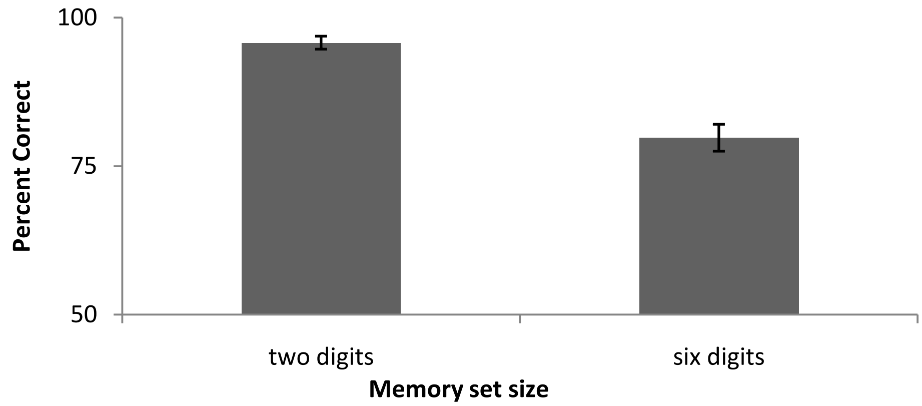

Figure 13. Percent correct response for each memory set size. Error bars show SE.

Figure 14 shows mean reaction times for each memory set. It seems that participants tend to respond faster in the two digits memory set compared to the memory set size with six digits. Reaction times in the memory set with six digits (*M*=979.13, *SE*=137.28) was slower than reaction times in the memory set with four digits (*M*=912.79, *SE*=138.05). The difference was statistically significant (t (18) =4.76, p<.001, r=.75).

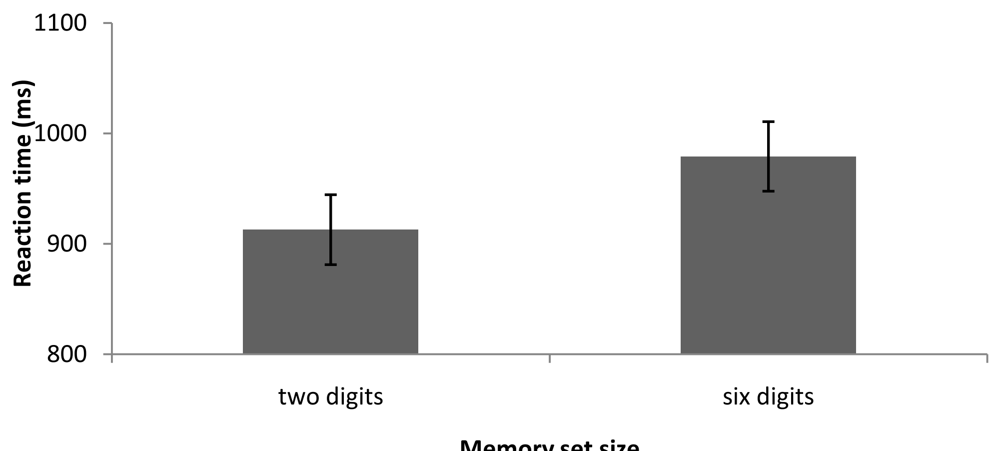

Figure 14. Mean reaction time across memory set sizes. Error bars show SE.

3.2.3. Discussion

Experiment 2 investigated the effect of memory on time perception for different durations and different amounts of task load. As it was expected, high amount of task load shortened time perceptions more compared to low amount of task load. Additionally, long durations were underestimated more than medium and short durations. Contrasting with the first experiment, time perception did not differ across duration length depending on the amount of task load. i.e., the interaction between these two factors was not significant. It was found that long duration were shortened more than other durations and high amount of load caused participants to underestimate time more compared to low amount of task load. When comparing low amount of task load to high amount of task load for each duration length, it was observed that the long duration was underestimated more than the others for both low and high amount of loads. These findings supported a previous experiment by Fortin and Rousseau (1998).

The findings from the absolute error score analysis and coefficient of variation analysis were similar to the first experiment. There were no significant findings in the analysis of the coefficient of variation. Inaccuracy, in terms of absolute error/actual duration, increased more for the long duration than for the others. Increase in amount of task load made participants underestimate time more. When comparing high amount of load to low amount of load for each duration, accuracy dropped more in the long duration with high amount of load compared to low amount of load. However, the error score in short duration was similar for both amounts of loads.

The result of the secondary task was also analyzed. It is important since it provides information about whether participants responded to the secondary task randomly or seriously. Additionally, the comparison between the memory set size with two digits and the memory set size with six digits would report whether the levels of difficulty were manipulated in the intended way. The results indicated that percent correct responses in the memory set size with two digits were higher than percent correct responses in the memory set size with six digits. Additionally, reaction times were faster for the memory set size with two digits than the memory set size with six digits. Therefore, it can be said that the load manipulation in the memory search task was successful. It was observed that the primary timing task was influenced by the secondary memory task. To find out whether the secondary task was affected by the primary task, reaction times in the present experiments were compared to reaction times in the memory search experiments without a duration judgment task, as provided in the literature. In the present study, reaction times for two digits and six digits conditions were 912.79 ms and 979.13 ms respectively. In the study of Corbin and Marquer (2009), reaction times for two digits and six digits conditions were around 720 and 910 ms, respectively. Sternberg (1966) also carried out a memory search experiments with different set size. In the results of his study, reaction times for two and six digits were at around 450 ms and 650 ms. Although it seems that in the present study, the secondary task also suffered from the primary task, the difference may be due to different digit presentation procedures. In the memory search studies investigated in the literature, digits were presented sequentially. On the other hand, in the memory search task in the present study, digits were presented simultaneously. The methodological difference may cause higher reaction times. For this reason, the question whether in our present study, the secondary task was affected by primary task cannot be answered conclusively.

3.3. Comparison of Experiment 1 and Experiment 2

In order to find out whether Exp-1 and Exp-2 differed from each other, an overall analysis was conducted with “group” as a between-subject factor. Thus, we are able to address the question whether the kind of load – executive vs. memory – has an impact on time estimation, in terms of ratio score, inaccuracy, and coefficient of variation and whether it interacts with the other factors, load and duration. CV was not used for the comparison of the two experiments because none of Exp-1 or Exp-2 had shown any effect.

In the first analysis, ratio scores were used for comparison of the two experiments. A 2 (group: memory vs. executive) x 2 (load: low vs. high) x 3 (durations: short, moderate vs. long) mixed ANOVA was conducted. A significant main effect of amount of load was found (F (1, 35) =8.04, p<.001, η_p^2=.19). Participants underestimated time more in the high-load condition (M=.57, SE=.03) compared to the low-load condition (M=.61, SE=.03). The main effect of duration was significant (F (2, 70) =73.28, p<.001, η_p^2=.68). Simple contrast analysis revealed that the long duration (M=.47, SE=.02) was underestimated more severely than the medium duration (M=.59, SE=.03; F (1, 35) =96.77, p<.001, r=.73) and the short duration (M=.71, SE=.04; F (1, 35) =84.84, p<.001, r=.71). There was no main effect of group (F (1, 35) =.46, p>.05). The ratio in the executive group (M=.61, SE=.04) was similar to the ratio in the memory group (M=.57, SE=.04). The interaction effect of amount of load and group was not significant (F (1, 35) =.003, p>.05). The ratio did not change across low and high load depending on the group. The interaction effect of duration and group was not significant (F (2, 70) =.04, p>.05). This means that groups did not differ from each other across durations. However, the interaction effect of duration and amount of load was significant (F (2, 70) =3.43, p=.038, η_p^2=.09). Low and high load differed from each other in terms of the difference between the long and short duration (F (1, 35) =4.58, p<.05, r=.12) whereas they did not differ from each other in terms of the difference between the long and medium duration (F (1, 35) =.37, p>.05). There was a significant 3-way interaction effect of group, duration and load (F (2, 70) =3.48, p<.05, η_p^2=.09). The difference between the long and short duration was significant when comparing the executive group to the memory group when load was high as compared to low (F (1, 35) =4.84, p<.05, r=.12). However, groups did not differ from each other in long and medium durations when comparing low load to high load (F (1, 35) =4.10, p>.05).

In the second analysis, absolute error/actual duration scores were used for comparison of the two experiments. A 2 (group: memory vs. executive) x 2 (load: low vs. high) x 3 (durations: short, moderate vs. long) mixed ANOVA was conducted. A significant main effect of amount of load was found (F (1, 35) =22.82, p<.001, η_p^2=.40).

Error score in the high-load condition (M=.47, SE=.02) was higher compared to error score in the low-load condition (*M*=.42, *SE*=.02). The main effect of duration was significant (F (2, 70) =53.37, p<.001, η_p^2=.60). Simple contrast analysis revealed that errors in the long duration (*M*=.52, *SE*=.02) was more severely than the medium duration (*M*=.44, *SE*=.02; F (1, 35) =106.41, p<.001, r=.75) and the short duration (*M*=.37, *SE*=.03; F (1, 35) =65.65, p<.001, r=.65). There was no main effect of group (F (1, 35) =.26, p>.05). Errors in the time estimation were similar for both executive (*M*=.43, *SE*=.03) and memory group (*M*=.45, *SE*=.03). The interaction effect of amount of load and group was not significant (F (1, 35) =.1.95, p>.05). Inaccuracy in time estimation did not change across low and high load depending on the group. The interaction effect of duration and group was not significant (F (2, 70) =.19, p>.05). This means that groups did not differ from each other across durations. However, the interaction effect of duration and amount of load was significant (F (2, 70) =3.87, p=.025, η_p^2=.10). Low and high load differed from each other in terms of the difference between the long and short duration (F (1, 35) =5.22, p<.05, r=.13) whereas they did not differ from each other in terms of the difference between the long and medium duration (F (1, 35) =.61, p>.05). Errors in the short duration for both low (*M*=.36, *SE*=.04) and high amount of load (*M*=.38, *SE*=.03) were similar whereas errors in the long duration were higher for high amount of load (*M*=.55, *SE*=.02) compared to low amount of load (*M*=.49, *SE*=.02). The three way interaction effect of group, duration and load was not significant (F (2, 70) =.51, p>.05). Groups did not differ from each other in accuracy of time estimation across duration and amount of load.

3.3.1. Discussion

The second experiment was compared with the first experiment in terms of ratio scores and absolute error scores. In the analysis of absolute error score, it was observed that groups had similar results. Accuracy dropped more when task load increased. Furthermore, increase in duration was associated with higher errors in time estimation. Inaccuracy in long duration was higher in high load condition compared to low load condition.

The results of analysis in terms of ratio scores revealed that the second experiment differed from the first experiment in terms of the interaction between duration length and different amounts of load. In the literature, studies indicate that time estimation is under the influence of the type of task demand of the secondary task such as executive (Zakay & Block, 2004) and memory (Fortin & Rousseau, 1998). An executive task requires inhibition of the inappropriate answer and response selection. In a memory search task, items need to be stored in short term memory. Although both tasks differ from each other in terms of their particular requirements, participants in the current study, however, estimated time similarly in both conditions. Similar effects of load and duration were observed, respectively. As stated in the literature (Block et al., 2010), increase in task difficulty is associated with decrease in time estimation. Additionally, longer durations were underestimated more than shorter duration. The results supported previous studies (Duzcu & Hohenberger, 2014). In addition, as indicated by the significant interaction between duration and amount of load, longer durations in particular were underestimated more when task difficulty increased. Although groups did not differ from each other in general, they differed from each other when comparing the long duration to the short duration in the low and high load conditions. In the executive group, the long duration was underestimated more than the short duration in the high load condition compared to the low load condition. However, underestimation in the long duration as compared to the short duration was similar when low and high load were compared in the memory group.

The present study differed from previous studies by using different secondary tasks with different resource requirements, in the same overall study. Thus, we were able to observe not only additive (main effects) but also multiplicative effects (interactions) among the three experimental factors: duration, amount of load, and type of load. Critically, one may remark that, although both tasks had two difficulty levels, the difficulty at the two levels may not be equal across tasks, respectively. The executive task, in particular the high load condition, may be more difficult because it needs more attention. Therefore, participants may underestimate time more severely in long durations as compared to short durations when the task was more difficult. However, this tendency was not observed in the memory task, which might have required less attention in general, as compared to the executive task, in particular in the high load condition. This would be consistent with previous findings that attention plays an essential role in the prospective paradigm.

CHAPTER 4

GENERAL DISCUSSION

The main aim of this thesis was to investigate the effects of types of cognitive load, amount of load and different duration length on time perception. In this study, a significant underestimation for high amount of task load compared to low amount of task load was found. Additionally, the significantly decreasing trend in reproduction with increase in interval duration indicates that people underestimate time more when duration increases. These findings were expected and supported previous studies (Block, 1989; Zakay,1993; Zakay & Block, 2006; Eagleman, 2008; Duzcu & Hohenberger, 2014). This thesis further aimed to explore whether these effects change depending on type of cognitive load in terms of memory and executive demands. The results of the two experiments demonstrated significant effects of duration length and amount of load for both types of cognitive load. However, they differed from each other in the interaction effect of durations and amount of load.

4.1. The effects of cognitive load on time estimation

Zakay et al. (2010) emphasized the effects of different amounts of cognitive load on duration judgment. They state that cognitive loads play a crucial role on time perception. People misestimate time depending on the characteristics of the secondary task. Experiments related to executive secondary tasks indicate that people underestimate time when they are performing an executive secondary task (e.g., Zakay & Block, 2004; Duke, 2005; Duzcu & Hohenberger, 2014). Because of the fact that an executive task needs more attention, less attention is left for timing (Block, 2008). Therefore, it was expected that participants would underestimate time when they were performing a Simon task and the results were consistent with these expectations and previous studies.

Studies based on memory secondary tasks and their effects on time perception suggest that time can also be underestimated when a memory search task is used as a secondary task (e.g. Fortin & Rousseau, 1987). However, the study carried out by Fortin and Rousseau (1998) indicated that the effects of a memory search task on time estimation change depending on where memory search processing takes place. In the experiment, there were two phases: encoding and reproduction. In the encoding phase, participants saw memory set items one by one during the time interval. In the reproduction phase, participants were required to reproduce their experienced interval. The difference between experiments was where the probe item was presented. If the probe memory item was shown in the encoding phase, participants underestimated time because short term memory processing was active during the encoding phase. On the other hand, participants overestimated time if the probe item was presented in the reproduction phase because short term memory processing was active during reproduction phase. Therefore, they state that time estimation was under influence of short term memory processing. On the basis of these experiments, it can be concluded that time production is under influence of the memory search task. Field and Groeger (2004) claim that maintaining memory items during the experienced time interval has little influence on time reproduction. In the present study, the memory search task was performed during the time interval. Participants completed several trials during the duration instead of just one trial. In this perspective, the results of the present study differed from previous studies. It was found that reproduction time was shorter than actual duration. Therefore, it can be concluded that the memory search task interrupted the timing task and led people to underestimate it. The results confirmed previous studies (Fortin & Rousseau, 1998).

The two tasks studied in this thesis differed from each other in terms of their task requirements. The Simon task required an executive function which means switching attention and inhibition of inappropriate and pre-potent responses (Smith & Jonides, 1999). The memory search task needed maintenance of information (Rammsayer & Ulrich, 2005). From this comparison, it can be concluded that storing items in memory is different from executive processes in working memory (Smith & Jonides, 1999; Baddeley & Logie, 1999). Although both tasks require different types of demands, they showed similar performance in time reproduction in this study. This may mean that after all it is a matter of the amount of resources needed to accomplish all task demands in a given dual-task; whether these resources are used for executive or memory demands may not be that crucial.

4.2. The effects of amount of load on time estimation

One of the factors which influence time perception is task difficulty. When comparing high amount of task load to low amount of task load, it was found that increase in amount of load led people to perceive time as being shorter in prospective duration judgment tasks (Block, 1989). There are several studies supporting this statement (e.g. Smith, 1969; Block, 1992; Khan et al., 2006).

The present study supports these previous studies. People perceive time as being shorter when the task has a high amount of load compared to when the task has a low amount of load. This result was found for both secondary tasks. The results were expected because limited attentional resources should be shared by two tasks. According to AGM, the proportional attentional resources dedicated to time change depending on

how much the secondary task needs attention to be performed (Block & Zakay, 2006).
Overall, there was no significant difference across executive and memory tasks when the high-load condition was compared to the low-load condition.

4.3. The effects of duration length on time estimation

According to Vierordt's law, there is a converse relationship between perceived duration and actual duration such that time estimates are shorter than actual duration if the duration is long, however, time estimates are longer than actual duration if the duration is short (Block & Gruber, 2014). Furthermore, it is stated that people misestimate longer durations more severely than shorter duration (Block & Zakay, 2006). The study conducted by Duzcu and Hohenberger (2014) indicates the effect of duration length on time estimation as well. They performed two experiments by using different secondary tasks in terms of temporal and executive tasks. It was found that there were no underestimations in the shorter duration for both experiments. They propose that the effects of the secondary task on time estimation were more profound in longer durations. Van Rijn and Taatgen (2008) explain this effect by the non-linearity of the time scale. According to this assumption, the secondary task causing fewer pulses to be counted in the accumulator influences longer durations more compared to shorter durations. This may be due to the fact that the intervals between the pulses increase when duration increases (van Rijn & Taatgen, 2008; Taatgen et al. 2007). The result of the present study supported these previous studies. Participants underestimated longer durations more compared to medium and short durations. However, our results seems to contradict Vierordt's law. On the hand, as expected, the long duration was perceived shorter. On the other hand, estimated duration for short duration was shorter than actual duration instead of longer. Therefore, it can be concluded that this study partially agrees with Vierordt's law terms of the shorter estimations in the long duration condition.

When examining the interaction between duration length and the amount of task load, it was observed that the long duration was underestimated more in the high load condition compared to the low load condition whereas the short duration was reproduced similarly in both conditions. This result was expected. Moreover, it supported the study carried out by Brown (1985). Brown (1985) investigated the effect of duration length and task difficulty and found that people perceived longer durations as being shorter compared to shorter durations when the task was difficult. This is due to the fact that increase in the need of attentional resources for performing the secondary task causes decrease in attention devoted to timing. Therefore, increase in distraction to attention devoted to timing would cause loosing later pulses. This, in turn, would influence longer durations more because of the more spaced-out intervals between later pulses in longer durations (Duzcu & Hohenberger, 2014).

4.4. The interaction effect of duration length, amount of load and group on time estimation

When comparing the executive group to the memory group, their estimations for duration lengths and amount of task load were similar. Both groups underestimated the long duration more than the short and medium duration. However, both groups differed from each other when comparing the long duration to the short duration in the low and high load conditions. In the executive group, the long duration was underestimated more than the short duration in the high-load condition compared to the low-load condition. However, this difference did not differ in the memory group.

It should be noted that both tasks have different performance requirements. Therefore, it was expected that these different requirements would lead to some differences in time estimation. The results of the memory group indicated that increase in the amount of task load caused participants to underestimate time more. Furthermore, underestimation increased when the duration interval increased. However, the amount of task load did not cause any differences in time estimation depending on duration. This result is in disagreement with the results of the experiments carried out by Neath and Fortin (2005).They investigated the effects of memory set size and durations on time estimation. They found an interaction effect of duration lengths and memory set size. Mean time reproductions were similar in shorter duration regardless of memory set size. On the other hand, mean reproduction in longer interval decreased when memory set size increased. However, they pointed out that the effect of memory set size depending on duration length was weaker.

Shorter time estimates were associated with higher memory set size. Additionally, shorter time reproduction was linked to higher duration length. Fortin and Neath (2005) explain these results by an accumulation/interruption assumption. According to this assumption, information about time starts to be gathered when the interval begins. However, this accumulation process is interrupted by the memory processing of the concurrent task. Increase in the memory demand of the concurrent task causes higher distraction of the timing task. Therefore, reproduction time is shorter compared to the actual time interval. Furthermore, increase in the duration leads to shorter time estimates.

Contrary to the memory group, time estimates in the executive group changed across duration depending on the amount of load. When comparing the short duration to the long duration for both low and high amount of load, the long duration was underestimated more than the short duration in the high-load condition compared to the low-load condition. These results were consistent with previous studies(e.g. Zakay, 1993; Zakay & Block, 2004; Duzcu & Hohenberger, 2014). Zakay (1993) manipulated the task difficulty and durations in time estimations. In this study, a Stroop task was used as secondary task. Participants read color names in the easy condition whereas they reported the name of the ink color in the difficult condition. He found that the effect of task difficulty was more profound in the long duration compared to the short duration. Although this study was similar to the present executive study, the present study differed from the former in terms of task switching in the difficult condition. In the executive group, participants gave responses depending on the cue which was presented at the beginning of each trial. Participants' response had to switch depending on the cue.

Therefore, the present study was similar to the study carried out by Zakay and Block (2004). They investigated the effect of task difficulty on time estimation by using a Stroop Task. Participants were required to read written color names in the easy condition whereas they were asked to report either the written color name or the name of ink in the difficult condition. The results revealed shorter reproductions in the difficult condition compared to the easy condition. The difference across difficulty levels of the secondary task was due to task switching costs (Fortin, Schweickert, Gaudreault, &Viau-Quesnel, 2010).

The results of the executive task in the present study can be compared with the results of the study of Duzcu and Hohenberger (2014). They also used the Simon Task in their study to investigate the effect of executive task demands on duration judgment. The study comprised two groups: an executive group and a non-executive group. Additionally, the effect of duration length was investigated. The results revealed that increase in attention demands of the secondary task resulted in stronger underestimation of time. Furthermore, this effect was stronger for the long duration compared to the medium and short duration. In this respect, the results of the present study replicated those of Duzcu and Hohenberger's study. The effects of the executive demanding task were more profound in high task load and longer duration.

The memory and executive group did not only differ from each other in terms of task requirements but also in terms of the nature of the high load. In the memory search task, the high load comes from an increase in memory set size. However, the high load comes from task switching in the executive task. In the high load condition of the executive task, participants reported that they hesitated shortly when deciding on the mapping rule. This may cause to neglect time in that moment. Therefore, attentional resources for timing might be reduced. Alternatively, the switch in the Attentional Gate Model might close only later due to in the delay in the decision such that timing of the upcoming trial is delayed itself. Additionally, the mapping rule changed randomly for each trial in the high load of executive group. Participants might have difficulty to adapt to the Simon Task. However, the rule was constant for the memory task. Participants saw a memory set with six digits and reported the presence or absence of the target item in the memory set. Therefore, costs due to increase in the amount of load in the executive task might be higher than costs in the memory task. Different manipulations of task difficulty might therefore be the reason for the difference between the memory and executive task when comparing the low-load to the high-load condition for each duration.

4.5. Findings of All Alternative Dependent Variables

Absolute error/ actual duration score and coefficient of variation score were used to evaluate time estimation as well as ratio scores. The absolute error/ actual duration score provides information about accuracy in time judgment (Brown, 1985). The CV score is important to see whether the results support the scalar nature of time estimation.

Estimated durations in terms of the ratio scores decreased depending on amount of load and (increasing) durations. This means that accuracy in time estimation drops depending on these factors. In the results of absolute error analysis, it was found that inaccuracy in time estimation increased when the duration increased and the task had a high amount of load. These findings supported previous experiments (Brown, 1985; Fortin & Rousseau, 1987; Duzcu & Hohenberger, 2014). Although both executive and memory group had similar results for the main effects of duration and amount of task load, they differed from each other in terms of the interaction effect of duration and amount of task load. Error scores did not change across durations depending on the amount of task load for the executive group. This means that accuracy dropped more in the long duration compared to other durations for each amount of task load. Additionally, inaccuracy was higher for high-load condition than low-load condition. However, errors in time judgment for memory group changed across durations depending on the amount of load. Inaccuracy in the short duration was similar for both amounts of loads whereas accuracy in long duration dropped more in high amount of task load compared to low amount of task load. The results of the comparison of the two experiments indicated that there was no difference between groups. Additionally, there was no significant 3-way interaction of amount of load, durations and group. This absence implies that accuracy in time estimation dropped more when duration and task load increased. However, this result did not change depending on the cognitive load of task.

According to SET, increase in duration is associated with increase in perceived duration. However, the coefficient of variation will be constant, i.e., when variance is divided by mean estimated duration (Penton-Voak et al., 1996).Therefore, a stable CV for all conditions was expected. The results were consistent with this expectation. All main effects and interaction effect were not statistically significant for either executive or memory groups. Therefore, it can be concluded that the present study supports the scalar nature of time estimation.

4.6. Summary

In summary, the present study examined the effects of cognitive load, amount of load and various durations on time perception. Effects of amount of load and durations were found. Perceived duration decreased as durations increased. Participants underestimated time more when the duration was longer. High amount of task load shortened perceived duration more compared to low amount of task load. Participants perceived the passage of time faster when the task was more difficult. Although there was no significant difference between memory demand and executive demand in duration judgment, they differed from each other in the interaction of amount of load and duration. However, the reason might not be due to different requirements of tasks, namely that costs in the executive demand task (particularly task switching costs) were higher than costs in the memory task.

CHAPTER 5

CONCLUSION

The present study aimed to investigate the effects of different types of cognitive load (memory, executive) due to different amounts of load (low, high) for various time durations (short, medium, long) on subjective time estimation by using the prospective paradigm. It was expected that time estimation varied according to kind of load, amount of load, and duration. Furthermore, it was predicted that time estimation ratios (between objective durations and subjective, reproduced durations) got smaller with longer durations for high memory and executive loads. To test the predictions, participant performed a duration judgment task with a secondary task with two different amount of load for various duration lengths. To test the effects of types of cognitive load, two different secondary tasks in terms of the Simon Task and the Memory Search Task were used. These tasks have different requirements. The Simon Task is related to executive function and requires response selection and conflict resolution (Duzcu & Hohenberger, 2014). On the other hand, Memory Search Task is related to short-term memory processing and requires storing information and recalling information when it is necessary (Smith & Jonides, 1999).

In the first experiment, participants completed the Simon Task as a secondary task with the duration judgment task. Participants performed regular the Simon Task for the easy condition whereas they completed the Simon Task with randomly changing two different mapping rules for the hard condition. As expected, long duration was underestimated more than short and medium durations. Although participants estimated time similar for both easy and hard condition, the long duration was underestimated more in hard condition than easy condition.

In the second experiment, participants completed the Memory Search Task with two different memory set sizes: two digits or six digits. As expected, time was underestimated more for the hard condition than the easy condition. Time estimates were lower for long duration compared to short and medium durations. However, time estimates did not differ across durations depending on task difficulty.

Both experiments had two different task loads which had to be accomplished during the same duration lengths. Therefore, they were compared to see whether performing different types of cognitive load would cause participants to estimate time differently across durations and different amount of task load. It was obtained that the long duration was underestimated more than the short duration when comparing high-load condition to low-load condition for the executive group. However, underestimation in long duration compared to short duration was similar when low and high load were compared in the memory group. The two tasks differed from each other in terms of how the amount of task load was manipulated. The high amount of load in the memory task came from increasing the memory set through which participants had to search in order to determine whether the target number had been in the previously presented number set or not; however, in the executive task, the high load was in terms of switching the rule according to which participants had to respond to the same stimuli on the screen. Therefore, it may be argued that rule switching costs are higher than costs related to the increase in difficulty in memory search.

Overall, studies based on time estimation have investigated duration length effect and task difficulty. Additionally, the effects of memory and executive load on time estimation have been studied. However, these effects have not been studied yet in conjunction within the same study. Therefore, we investigated the effect of cognitive load with various durations and different amounts of task load on time estimation. It was found that time was underestimated more in the long duration than the short duration when high amount of load was compared to low amount of load in the executive group. On the other hand, time estimates in the memory group were similar for high and low amount of task load when the long duration was compared to the short duration. Finally, the present study implied that time estimates changed across duration and the amount of task load depending on types of cognitive load.

5.1. Limitations of the Study

One of the limitations of present study concerns the manipulation of task difficulty in the two groups. It is not clear whether the difference in the results is due to type of cognitive load (executive or memory) or differences in hard manipulation across groups. The study aimed to investigate the effects of amount of task load and duration length on time estimation. Although these effects were examined in the present study, the group comparison may not be reliable due to possible differences in task difficulty of the secondary task. Therefore, one has to be cautious in concluding that both groups differ from each other due to different task requirements rather than due to the amount of load.

Another limitation of the present study is that there was no control condition (without any secondary task). It might be useful to evaluate the error in time reproduction. In the studies of time perception, time intervals were generally filled with a task. The task can be less or more demanding. For example, Duzcu and Hohenberger (2014) used a less demanding task in their experiments. Participants saw a series of colored rectangles and reported the order of colors during the trial afterwards. They only saw three colored rectangles. It was found that reproduced duration was close to actual duration. Therefore, in the light of studies which used less demanding tasks in the time reproduction, it can be assumed that a comparison of loads in the present study was not invalid due to having no control condition.

5.2. Further Research

Although the present study found a difference between the memory and executive demand task depending on the amount of load and duration, it was not fully clear why. Therefore, a further study should be conducted to test the effects of cognitive load in time estimation. Executive and memory demand tasks in the present study did not have the same difficulty levels. To manipulate the amount of load, task switching was used for the executive task whereas a different memory set size was used for the memory task. In that further study, different manipulations to increase the amount of task load should be used. For example, the Stroop Task could be used instead of the Simon Task. As in the study of Zakay and Block (2004), two different difficulty levels could be created. In the easy condition, participants just read the written color name while participants report the ink color in the difficult condition. Then there would be no task switching costs. The memory task would remain the same. Therefore, the possible additional effect of the task switching cost could be eliminated. Or, alternatively, there could also be a task switching demand for the memory task. Then, two different demanding tasks could be compared to see whether time estimates are influenced by cognitive load of task or by task switching.

In the present study, it was not clear that secondary task suffered from primary task. To evaluate whether interference is unidirectional or bidirectional, the task used as a secondary task can be carried out without using a duration judgment task.

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....
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TEZİN TÜRÜ : Yüksek Lisans ☐ Doktora ☐

1. Tezimin tamamı dünya çapında erişime açılsın ve kaynak gösterilmek şartıyla tezimin bir kısmı veya tamamının fotokopisi alınsın. ☐

2. Tezimin tamamı yalnızca Orta Doğu Teknik Üniversitesi kullancılarının erişimine açılsın. (Bu seçenekle tezinizin fotokopisi ya da elektronik kopyası Kütüphane aracılığı ile ODTÜ dışına dağıtılmayacaktır.) ☐

3. Tezim bir (1) yıl süreyle erişime kapalı olsun. (Bu seçenekle tezinizin fotokopisi ya da elektronik kopyası Kütüphane aracılığı ile ODTÜ dışına dağıtılmayacaktır.) ☐

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