THE EFFECT OF SPATIAL CUES ON THE SPACE-NUMBER ASSOCIATIONS: AN EYE-TRACKING STUDY

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ETHICAL DECLARATION

I hereby declare that I am the sole author of this thesis and that I have conducted my work in accordance with academic rules and ethical behaviour at every stage from the planning of the thesis to its defence. I confirm that I have cited all ideas, information and findings that are not specific to my study, as required by the code of ethical behaviour, and that all statements not cited are my own.

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ABSTRACT

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Mental Number Line (MNL) hypothesis suggests that people have a mental representation of an ascending series of numbers oriented from left to right. Additionally, research has suggested that small numbers are responded to faster with the left than with the right response side, and large numbers are responded to faster with the right than with the left response side. The aim of this thesis was to investigate SNA in fingers and saccades in the context of cognitive processes, with a special focus on the role of inhibitory control. Therefore, we integrated two tasks (procue/anticue) with a magnitude comparison task. Given that in the anticue/magnitude comparison block participants had to inhibit an ipsilateral response, we expected to find facilitation of SNA in the anticue/magnitude comparison task. Similarly, we investigated oculomotor inhibition in an antisaccade task integrated with a magnitude comparison task requiring saccade responses, by altering the preparation time. Results showed a significant SNA in finger responses, but not in saccade responses. Moreover, we found a significant main effect for task type, indicating faster reaction time in procue compared to anticue, and a significant main effect for PI, indicating faster reaction time in PI 350 ms compared to PI 650 ms. However, there was no significant effect of inhibition on the SNA in the magnitude comparison task. Further analysis showed that inhibition ability did not influence the SNA. Overall, our findings contribute to the previous studies' proposed inhibition of oculomotor movements that may not relate to the SNA.

Keywords: Space-number association, inhibition, antisaccade, magnitude comparison.

ÖZET

UZAMSAL İPUÇLARININ SAYI-UZAM İLİŞKİSİ ÜZERİNE ETKİSİ: BİR GÖZ İZLEME ÇALIŞMASI

DURAN, Elif

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Zihinsel Sayı Doğrusu (MNL) hipotezine göre, insanlar soldan sağa doğru artan bir sayı dizisinin zihinsel temsiline sahiptir. Bunun yanısıra, yapılan araştırmalar küçük sayılara sol tuşa kıyasla sağ tuşla, büyük sayılara ise sol tuşa kıyasla sağ tuşla daha hızlı yanıt verildiğini ileri sürmüştür. Bu tezin amacı, farklı motor hareketlerdeki SNA'yı, ketleyici kontrolün rolüne özel olarak odaklanarak, bilişsel işlevler bağlamında araştırmaktır. Bu nedenle, procue ve anticue olmak üzere iki görev bir büyüklük karşılaştırma görevi ile birleştirleştirilmiştir. Anticue/büyüklük karşılaştırma bloğunun, katılımcıların aynı taraftaki bir yanıtı ketlemek zorunda kalması göz önüne alındığında, anticue /büyüklük karşılaştırma görevinde sayı-uzam ilişkisinin kolaylaştırılması beklenmektedir. Benzer şekilde, sakkadik tepki gerektiren büyüklük karşılaştırma testi ile birleştirilmiş bir anti-sakkad testinde, göreve hazırlanma süresini değiştirerek okülomotor ketlemeyi inceledik. Sonuçlar parmak yanıtlarında anlamlı bir SNA göstermiş ancak sakkadik tepkilerde SNA'ya rastlanmamıştır. Ayrıca, görev türü için, anticue ile karşılaştırıldığında procue da daha hızlı reaksiyon süresini gösteren ve PI için, PI 650 ms'ye kıyasla PI 350 ms'de daha hızlı reaksiyon süresini gösteren önemli anlamlı ana etkiler bulunmuştur. Ancak ketleme görevinin büyüklük karşılaştırma görevindeki SNA üzerinde anlamlı bir etkisi bulunamamıştır. Aynı şekilde, yapılan ileri analizler ketleme becerisinin SNA'yı etkilemediğini gösterdi. Genel olarak, bulgularımız önceki çalışmaların okülomotor hareketlerin ketlenmesinin SNA ile ilgili olmaması yönündeki önerisine katkıda bulunmaktadır.

Anahtar Kelimeler: Sayı-uzam ilişkisi, ketleme, antisakkad, büyüklük karşılaştırma.

Dedicated to perseverance: for every moment of doubt, every challenge, and every small victory, along the way.

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Att-SNARC	Attentional SNARC
MNL	Mental Number Line
SNARC	Spatial Numerical Association of Response Codes
SNAs	Space-Number Associations

CHAPTER 1: INTRODUCTION

Numerical cognition studies aim to understand the cognitive mechanisms underlying the link between processing numerical information and its usage in the context of our environment. In accordance with this purpose, the research in numerical cognition has revealed a link between space and number, providing implications on how numerical knowledge is represented by individuals and how various paradigms may influence this process. This concept was first proposed by Sir Francis Galton in 1880, when he suggested that numbers are mentally arranged along a spatial axis, oriented from left to right. Earlier studies in this area were conducted by Moyer and Landauer in 1967 and Restle in 1970, who provided evidence for what they referred to as the mental number line (MNL). According to the MNL theory, individuals mentally organize analog representations of ascending numbers along the MNL. Within this mental line, the position of numbers is determined by their magnitude, with smaller numbers occupying the left and larger numbers extending toward the right (Dehaene et al., 1993). This theory suggests that our perception of numbers inherently constitutes a spatial component, which affects how we mentally represent and manipulate numerical quantities (Dehaene, 2011). Further insights into the space-number relationship emerged from studies conducted by Dehaene and colleagues in the early 1990s. In a parity judgment task where participants had to differentiate between even and odd numbers, it was observed that participants were faster to press the left button when responding to smaller digits (ranging from 0 to 5) and faster to respond with the right button when the digits were larger (6 to 10). These findings suggested that spatial aspects of response preparation were influenced by the spatially organized MNL (Dehaene et al., 1993). Subsequent studies in the 1990s showed behavioral demonstrations of the link between space and number. This phenomenon, known as the Spatial Numerical Association of Response Codes (SNARC) effect, was proposed by Dehaene in 1993. It was considered as one of the simplest, but significant behavioral evidence of the space-number association (Dehaene et al., 1993; Dehaene, 1997). It has been replicated across a multitude of paradigms encompassing various stimuli and task configurations (Fias et al., 2005). These findings further extend the understanding of the SNARC effect to various contexts, including not only left and right-hand responses (Fias et al., 2001) but also left and right-finger responses within one hand (Priftis et al., 2006), foot pedal responses (Schwarz and Müller, 2006) and even oculomotor movements, known as saccades (Schwarz and Keus, 2004). Although previous studies in SNA proposed SNARC effect with different motor movements, the large number of studies using SNARC effect instructed participants to use their two hands as an indication of left response code and right response code (see Wood et al., 2008 for a detailed review). Since most SNA research has included the SNARC effect, we have often mentioned SNARC effect research while providing information on the theoretical background of SNA in this thesis. However, we used finger responses as well as saccadic responses in a magnitude comparison task, but we did not measure two different hand responses. Thus, instead of the embodied codes of SNA, we focused on the bidirectional space-number relationships induced by the magnitude of numbers, response side of different motor movements (e.g., finger and saccade), and the physical size of numbers (i.e. size congruity) in the magnitude comparison task. Size congruity was described as a phenomena within SNA taxonomy by Cipora and colleagues (2020). But they considered it as an approximate SNA, since there was no explicit mapping between magnitude and physical size in the task. Notably, the approximate SNA related to the automatic processing, whereas the explicit SNA related to the the role of automatic and controlled processing is not very clear (Cipora et al., 2020).

1.1 Size Congruity Effect

Size congruity effect was first reported by Banks and Flora (1977) and also called the number-size congruency effect (NSCE) by Besner and Coltheart (1979). According to the size congruity studies, stimuli of small numerical size presented in small physical size and stimuli of large numerical size printed in large physical size, representing congruent stimuli, elicited faster reaction times (Paivio, 1975; Banks and Flora, 1977; Besner and Coltheart, 1979; Henik and Tzelgov, 1982). The congruency effect arises from the conflict between the physical size of visually presented numbers and their magnitude and refers to participants' reaction time differences when exposed to congruent (i.e. both small or both large in numerical and physical size) and incongruent (i.e. small numerical/large physical size or vice versa) numbers (Henik and Tzelgov, 1982).

Size congruence, like the SNARC effect, is considered an SNA phenomenon (Cipora et al., 2020). However, similar to other SNA phenomena, the origin of the size congruency effect is still debated. Cipora and colleagues discussed that most implicit SNA, such as size congruency, involves automatic processing of magnitude rather than a controlled process. Similarly, Banks and Flora (1977) argued that the size congruity effect occurs at an early stage of processing. To further investigate the relationship between size congruity and SNAs taxonomy, Fitousi and colleagues (2009) asked participants to judge the physical size of presented numbers while responding with their right and left index fingers. The results showed that both SNARC and size congruity effects were observed independently, suggesting that the tasks involve different visual systems. More specifically, size congruity is related to the "what" system, whereas SNARC is related to the "where" system (Fitousi et al., 2009; Goodale and Milner, 1992; Weis et al., 2018). Following Fitousi and colleagues' (2009) observation of an independence between SNARC effect and size congruity, to investigate whether the size congruity and SNARC effects arise from different representational spaces, Weis and colleagues (2018) presented participants with a magnitude-number judgment test in which they manipulated the physical size of numbers. However, their results did not report a significant interaction between physical size of numbers, magnitude, and response side. They also replicated the same results for a parity judgment task in which the SNARC effect was measured implicitly. They concluded that numerical representation may have distinct spatial and non-spatial components. Similarly, previous research suggested that the independence between size congruity and the SNARC effect may result either from differences arising from decision stages (Santens and Verguts, 2011) or from stimulus components that do not contain lateralized response tendencies in size congruity (Ansari et al., 2006), or from differences arising from motor stages of processing in SNARC effect (Cutini et al., 2014). On the other hand, Ren and colleagues (2011) found two significant interactions between response hand and physical size, and between response hand and magnitude. This means that the faster reaction times were observed when the right hand responded to large numbers and large physical size. Their findings were contrary to previous research.

The nature of these SNAs is diverse. They can involve approximate or exact numerical information and relate to different aspects of numbers, including their order in a sequence, their cardinality (the numerosity of a set), their spatial structure in multi-digit numbers, and their involvement in mathematical functions such as addition and subtraction (Cipora et al., 2020). These associations are influenced by a combination of grounded (universal), embodied (learning-related), and situated (task-dependent) factors. The grounded aspect is related to the physical properties of the world, whereas the embodied aspect is shaped by sensory and motor experiences. On the other hand, the situated aspect is influenced by cognitive factors (Dehaene et al., 1993, Fischer and Brugger, 2011). For example, task instructions have an impact on the SNARC effect, i.e. asking participants to imagine either a linear or a circular ruler result in standard or reversed SNARC effects (Ristic et al., 2006; Viarouge et al., 2014). In addition, the type of task may reveal different aspects of SNA. Deng et al. (2018) showed how the SNARC effect varied between magnitude comparison and parity judgment tasks. They argued that the earlier onset and greater stability of the SNARC effect was observed in the magnitude comparison task, whereas this effect fluctuated over time in the parity judgment task. In this thesis, we focused on SNA mechanisms shaped by cognitive processes.

1.2 Attentional-SNARC (Att-SNARC)

The mechanisms in SNAs have been studied, with different cognitive levels. Some research suggests that SNAs are shaped by early perceptual processing (Fischer et al., 2003). Several subsequent studies (Fischer et al., 2004; Mapelli et al., 2003) have contributed to this view, suggesting that the influence of SNAs occurs at automatic perceptual processing. One of the pioneering studies by Fischer et al. (2003) suggested that the influence of the MNL extends to the early stages of cognitive processing, even before the selection of a response. They demonstrated a Posner cueing paradigm to examine implicit numerical cognition. In their experimental setup, participants were presented with a dot that could appear to the right or to the left of a central fixation point. Their task was the detection of this dot with the same hand as their response. While participants performed this detection task, Arabic numerals were displayed in the center of the screen before each dot. Importantly, participants were informed that these digits were intentionally uninformative. Nevertheless, Fischer and colleagues (2003) observed that participants showed faster detection when the preceding digit was a small number presented on the left side. Conversely, when the preceding digit was a large number, they showed faster reaction times for the right side. They concluded that there was an attentional bias influenced by the association between space and number magnitude. Following that, Fischer and colleagues (2004) demonstrated the Attentional-SNARC (Att-SNARC) effect, where participants exhibited faster reaction times when targets were presented on the left/right positions corresponding to smaller/larger numbers, revealing a lateral shift of attention induced by perceiving the numerical cue, aligning with the activation of the MNL. Similar evidence of attentional bias was observed in numerical comparison tasks, such as in the study by Salvaggio and colleagues (2019). In this study, participants compared numbers presented vocally to a reference number while gazing at a blank screen. They found a late attention shift between the right and left sides of the screen when the numbers were small and an early shift when the numbers were large. Additionally, research involving mental arithmetic revealed a spatial bias toward the right or left for addition and subtraction, respectively (Masson et al., 2018). Furthermore, Casarotti and colleagues (2007) used temporal order judgments rather than dot detection and observed that when two dots appeared simultaneously and were preceded by a small number, participants judged the left dot as appearing earlier. Conversely, when these dots were preceded by a large number, the right dot was perceived to appear sooner. Other following research conducted by Ristic and colleagues (2006) and Galfano and colleagues (2006) also successfully replicated Fischer et al. 's findings, however, they discussed the feature of attentional shift that appeared to be influenced by controlled processes rather than automatic reactions.

The Att-SNARC phenomenon highlighted two fundamental aspects: the conceptual link between space and number, and the automatic nature of SNAs. The bidirectional link aspect is widely accepted, whereas the automatic nature of SNA is controversial (Cipora and Nuerk, 2023). Subsequent replications have shown that passive viewing of numbers does not necessarily elicit a spontaneous association between space and number (Pellegrino et al., 2019; Cipora and Nuerk, 2023, Colling et al., 2020). Cipora and Nuerk (2023) argued that while Att-SNARC provides evidence for the conceptual link between space and number, the automatic nature of SNA may be less straightforward. They reported that these findings illustrate the controversial research about the automatic processes of SNAs. On the other hand, They discussed that unsuccessful replications of the Att-SNARC did not necessarily challenge the conceptual link. Cipora and Nuerk (2023) have made an important contribution to the unraveling of these aspects of the Att-SNARC by providing various paradigms that substantiate this connection. In particular, they have emphasized that the conceptual link is bidirectional, shedding light on the fact that number processing may induce differences in spatial processing and vice versa, reallocation of spatial attention may influence number processing. A study by Loetscher et al. (2008) further demonstrated how participants' random number generation performance was influenced by their head movements. Although the implicit association between number and space may induce attentional shifts, the question of whether spatial cueing paradigms is related with the conflict arising from the incompatibility between the response side and the magnitude remains a topic of ongoing investigation. Given the limited number of studies that have examined the influence of spatial cueing paradigms on numerical processing, investigating the bidirectional link by reversing the procedure in Att-Snarc may also provide valuable insight into the second aspect of this theory (nature of SNA).

1.3 Dual-Route Theory and Stimulus-Response Compatibility

In contrast to the the Att-SNARC, Keus and Schwarz's (2005) study demonstrated a different perspective by exploring how non-numerical information can influence the processing of numerical information. In their research, they delved into the significant aspects of SNAs and the implications of these for numerical cognition. Their main aim was to investigate whether the SNARC effect is primarily induced by incongruencies between the position of the number on the screen and its representation on the MNL, regardless of the response side; or whether it is related to a later, response-related stage, resulting from incongruencies between the representation of the number on the MNL and the response side. In order to investigate this, participants were asked to judge the parity (even or odd) of numbers that were presented on either the left or the right side of the screen, using either vocal or manual responses. The only significant effect observed was related to the position of the number when manual responses were used. This led to the conclusion that the SNARC effect emerges predominantly at a later, response-related stage, rather than at earlier stages of processing. Building on this, the neural correlates of the SNARC effect were investigated in a study by Gevers and colleagues (2006). They focused on the stimulus-locked lateralized readiness potential (LRP), which is an increased electroencephalographic activity in the brain associated with the preparation of motor responses. Their findings provided information about the temporal dynamics of the SNARC effect. They also reveal the functional region where magnitude-based spatial coding conflicts. These results are consistent with a dual-route model of information processing. This dual-route model shows that there are two distinct processing routes in the human brain for the performance of specific tasks. The first, the fast unconditional route, is responsible for automatic and rapid associations between stimuli. The second, the slow conditional route, is activated when there is a conflict between these associations required controlled cognitive processes for conflict resolution. Importantly, this route represents a later stage of processing. This is consistent with the idea that the SNARC effect can be influenced by response-related factors. Gevers et al. (2006) showed that this LRP component emerged later in incongruent conditions (i.e. press left for large and press right for small numbers) compared to congruent conditions (i.e. press left for small and press right for large numbers), providing a dual-route processing model. According to the results of their study, in contrast to single-route processing accounts, the dual-route model posits that the SNARC effect arises from the activation of both magnitude and task-related instructions, shedding light on how the SNARC effect exploits incongruent stimulus-response rules. Their conclusion was that the SNARC effect results from the fast, unconditional pathway. However, when the stimulus-response (S-R) rules are incongruent, it must be the slow, conditional pathway that is resolved during the response selection stage.

The studies mentioned above are similar to stimulus-response compatibility (SRC) effects. The SRC effects are recognized as phenomena in which individuals show faster and more accurate responses when the response matches the spatial or manual characteristics of the stimuli (Fitts and Deininger, 1954). Two classic examples of SRC effects, the Stroop and Simon tasks, provided insights into the role of cognitive processing. In the Stroop task, subjects were given a list of color words, such as red/blue/green, then asked to name the color of the ink used to print the words. In the task participants were instructed to discriminate ink from color. Interference arose from the conflict between the meaning of the word and the color of the ink. This caused a delay in reaction time (Stroop, 1935). Similarly, Simon's task has an arrow stimulus and a target. If the target is not located on the same space as the arrow, Simon's incongruence occurs (Simon and Rudell, 1967). The Stroop effect is characterized by a delay in reaction time due to incongruence between the color of the ink and the color name. It is a hallmark of S-S (stimulus-stimulus) compatibility (Liu et al., 2010). Conversely, the Simon task, which involves responding to target locations relative to the arrow, falls under S-R (stimulus-response) compatibility (Gevers et al., 2005). The S-S type effects, such as the Stroop effect, arise in the semantic-representation stage, whereas the S-R type effects, such as the Simon effect, are associated with the response-selection stage (De Jong et al., 1994). However, the processing stage of the SNARC effect remains unknown. Research investigating the interaction between the SNARC, Simon, and Stroop tasks suggests that two effects interacting with each other underscore information about their common processing stage (Yang et al, 2021). Gevers and colleagues (2010), numbers ranging from 1 to 9 (excluding 5) were presented on the left or right of the center. Their first experiment included a parity judgment task, while the second experiment replaced it with a magnitude comparison task. In this way, they could examine the interaction between the parity judgment task, the Simon task, and the magnitude comparison task. Their results yielded three-way interaction in both experiments. More specifically, the Simon effect was more pronounced in the SNA-compatible trials than in the SNA-incompatible trials. In addition, Yan and colleagues (2021) examined the relationship between the SNARC, Stroop, and Simon tasks by integrating them into a unified task. Consistent with previous research, their results showed a significant interaction between the SNARC and Simon tasks, providing information that the SNARC effect occurs during the response selection stage.

Furthermore, a study by Georges and colleagues (2018) demonstrated the role of different types of interference in the SNARC effect. In their experiment, participants were instructed to perform parity judgment and magnitude comparison tasks while inhibiting the distractor stimuli of the Flanker and Stroop tasks. In the parity judgment task, the SNARC effect was negatively correlated with performance in the Stroop interference control, but not in the Flanker interference control. This suggests that the interference control associated with the Stroop task, may be related to the spatial coding of the SNARC effect in the parity judgment task. On the other hand, in the magnitude comparison task, the SNARC effect was correlated with performance in the Flanker interference control, but not in the Stroop interference control. This correlation may reflect a close link between numerical-spatial processing in the magnitude comparison task and spatial visualization in the Flanker task, since they are associated with common functions of the right parietal cortex (Lamm et al., 1999).

1.4 The Role of Cognitive Control in SNAs

In the study conducted by Zhang and colleagues in 2022, a cognitive control-based view of the SNARC effect was proposed, compromising a two-stage framework referred to as the "representation stage" and the "conflict stage". The first stage involves the spatial mapping of the semantic representation of numbers, which occurs in the parietal lobe through an automatic and implicit process. This initial stage relies on working memory (WM) and shifting components. In the representation stage, when participants judge the parity of numbers and apply the "left-odd and right-even" rule, small numbers automatically activate their magnitude representation, which triggers spatial attention and spatial mapping. However, the relationship between WM load and the SNARC effect is task-dependent, i.e. moderate spatial WM load enhances the occurrence of the SNARC effect, whereas higher spatial WM load attenuates the SNARC effect (Van Dijck et al., 2009; Deng et al., 2017). Therefore, the relationship between WM load and task type has a significant impact on modulating the SNARC effect in the representational stage. In addition, shifting (e.g., task switching, rule switching, and stimulus or response switching), which is a component of cognitive control, is also involved in the representation stage. However, whether the SNARC effect is smaller or larger in switching conditions compared to repetition conditions has been controversial in different studies. This inconsistency may be related to the specific type of switching used (Basso Moro et al., 2018; Pfister et al., 2013; Zhang et al., 2021).

The second stage, known as the conflict stage, focuses on the detection and resolution of conflicts that arise in the context of stimulus-response (S-R) mapping, especially in incongruent trials (Zhang et al., 2022). The resolution of these conflicts requires inhibitory control, meaning the ability to suppress irrelevant interference (Diamond, 2013). When the required S-R mapping matches the automatically activated S-R mapping, there is minimal conflict and cognitive control is less demanding. However, when there is an incongruence between the required and automatic S-R mapping, a conflict arises that inhibitory control must monitor and resolve. In such cases, inhibitory control prevents interference, thereby modulating the SNARC effect (Lindemann et al., 2008; Wendt et al., 2015). Zhang's (2022) framework, specifically the conflict stage, is consistent with previous findings on the impact of cognitive control mechanisms in managing conflict and inhibitory processes. The study of cognitive control including inhibitory control, as detailed in the next section, provides a foundational understanding for the study conducted by Zhang and colleagues (2022).

Numerical processing in the conflict phase of the SNARC effect was examined by the scope of cognitive control. More recently, it has been argued that this association between space and number may have been the result of cognitive control in operations such as conflict monitoring (Gut et al., 2012; Zhang et al., 2022). How these mechanisms are directly involved in the conflict stage of SNAs, specifically in numerical processing, was demonstrated by examining numerical processing, discussed in the following sections. This relationship emphasizes the role of cognitive control in the numerical cognition of SNARC effect. It also demonstrates its importance in how participants respond in numerical contexts, providing insight into how participants navigate numerical information and the cognitive demands involved. More recently, it has been argued that this SNA may be the result of cognitive control in tasks such as conflict monitoring (Gut et al., 2012; Zhang et al., 2022). However, there is still an ongoing debate that requires further research on the nature of SNA and the relationship between SNA and cognitive control.

1.5 Inhibitory Control and Conflict Monitoring Hypothesis

Cognitive control involves the ability to identify task-relevant features and suppress interference from irrelevant behaviors (Ridderinkhof, 2004; Diamond, 2013). This ability, called inhibitory control, can occur at different levels, including response inhibition at the behavioral level, selective attention at the attentional level, or cognitive inhibition involving the suppression of thoughts. The purpose of inhibition, also known as interference, is to minimize error rates by promoting non-impulsive behavior, focusing on task-relevant features, and eliminating distraction from irrelevant stimuli (Diamond, 2013).

Response inhibition posits that an increase in reaction time occurs when the stimulus is associated with a distractor that requires a motor response (Maniscalco et al., 2012). The conflict monitoring hypothesis proposes that the strength of control is adjusted based on the level of conflict. The system evaluates conflict level, translates this evaluation into appropriate response mechanisms, and adapts behavior accordingly (Botvinick et al., 2001). The strength of control is weaker in low-conflict situations (e.g., congruent trials), whereas it increases in high-conflict scenarios (e.g., incongruent trials) (Botvinick et al., 2001). This congruency effect, a behavioral phenomenon of conflict monitoring, may be a measure of control strength, as it decreases performance on incongruent trials but not on congruent trials, suggesting that low congruency effects require low levels of control (Hartmann et al., 2002). In addition, Gratton et al. (1992) demonstrated that the strength of inhibition is influenced by repeated stimulus presentation, known as the congruency sequence effect, a conflict-driven adaptation in cognitive control. This effect results in faster reaction times on current incongruent trials following previous incongruent trials. This is indicative of a reduced congruency effect and an increased level of control (Gratton et al., 1992; Egner, 2007).

As proposed by Botvinick et al., 2001 incongruent trials were characterized by high conflict. It leads to the adjustment of goal-directed behavior in response to stimuli (Botvinick et al., 2001). Previous research support for the conflict monitoring hypothesis is particularly evident in tasks such as the Eriksen Flanker task, a paradigm in which participants must discriminate target arrows from distractor arrows (Eriksen and Eriksen, 1974). Takezawa and Miyatani (2005) manipulated conflict in the Flanker task by varying the distance between the target and distractor stimuli. They showed not only slower reaction times for incongruent trials compared to congruent trials, but also a further slowing for shorter distances compared to the longer distances on incongruent trials. The results, which are consistent with the conflict monitoring hypothesis (Botvinick et al., 2001), suggest that the amount of inhibition is influenced by the level of conflict through conflict detection mechanisms. Further, to study inhibitory control, researchers commonly use various paradigms such as the Wisconsin Card Sorting Test (Berg, 1948), the Stop Signal Task (Verbruggen and Logan, 2008), and the Anti-Saccade Task (Hallett, 1978). Among these paradigms, procue and anticue tasks, which were included in the present study, are considered as valuable tools for studying cognitive control. These tasks allow researchers to manipulate cues and examine how individuals prepare for the next stimuli. In these tasks, cue is used as an irrelevant stimulus needed to be inhibited, and this process affects the initiating response to target following the cue

(Adam et al., 2015). Thus, it may be useful to examine particularly relevant for understanding the cognitive control mechanisms in the context of numerical processing and the relationship between space and numbers.

1.5.1 Procue-Anticue Task and Preparation Interval

The spatial cueing tasks, which include informative peripheral cues and targets, are designed to assess inhibitory control as seen in procue and anticue tasks. The goal of developing anticue/procue tasks is to create a paradigm that is logically and functionally related to antisaccade tasks by requiring participants to make intentional and controlled responses without relying on eye movement measurements (Jong, 2001). Both procue and anticue tasks require participants to respond quickly and accurately to targets while suppressing automatic, reflexive, or prepotent responses in the direction indicated by the cue. These tasks provide insight into the cognitive control processes (Jong, 2001).

The procue task has its roots in the finger-pre-cueing task introduced by Miller (1982), which involves a keypress response to spatial targets. In this task, a distractor cue appears on the left or right side of the screen prior to target onset, with the target presented in the same location as the cue, creating a spatially congruent condition. Procue task aims to demonstrate that informative cues automatically and rapidly activate the ipsilateral response side, meaning shorter reaction times for participants. Conversely, the anticue task developed by Adam et al. (2015) explores the temporal dynamics of proactive control and requires a more time-consuming and effortful process, resulting in longer reaction times (Ridderinkhof, 2002; Adam et al., 2015). Similar to the procue task, the informative cue precedes the target onset, but in this case the target appears on the side contralateral to the cue. In the task, participants are required to inhibit the ipsilateral response side when they see the cue. In addition, they must prepare the contralateral keypress response side to respond appropriately to the target (Adam et al., 2011).

Cue-induced reaction time facilitation depends on two factors. The first is the cue type, as described above. The second is preparation time. When participants are given a short time to prepare their response due to short cue-target intervals, they are allowed minimal preparation, resulting in increased reaction time costs. On the other hand, longer preparation intervals (PI) allow more time to decode the cue information, resulting in better detection of the target (Adam et al., 2021). Horváth

(2013) also showed that longer PI is associated with better preparation, leading to a decrease in distractor effects. Furthermore, PI is associated with the main differences between tasks with different cue types (e.g., procue/anticue). Due to spatial congruency between cue and target, procue can produce better responses even with short PI. Moreover, longer PI can enhance spatial congruency benefits due to carefully prepared responses. On the other hand, an anticue task requires a longer PI, so participants can inhibit the ipsilateral finger response and induce a contralateral finger response (Adam et al., 2015). Previous research showed that, with enough preparation time, the effect of spatial congruency on reaction time to target detection is eliminated, suggesting effective proactive control (Adam et al., 2015).

1.5.2 Antisaccade Task

Antisaccade task was employed as an efficient physiological measurement tool to examine the impact of spatial cues on cognitive processes. The antisaccade task, originally introduced by Hallett in 1978, is used to investigate the mechanisms underlying goal-directed and reflexive saccadic responses. In the same study, Hallett demonstrated that saccades directed to peripheral cues were reflexive and contracted with the demand for voluntary saccadic responses when targeting the actual stimulus. In the antisaccade task, participants are asked to inhibit the natural tendency to look toward the cue and instead make a voluntary saccade in the opposite direction in which the target appeared. This task assesses the ability to suppress reflexive eye movements and to exercise voluntary control over eye movements (Hallet, 1978). Conversely, in the prosaccade task, participants are instructed to make a saccadic eye movement toward a visual cue, such as a flashing light or a specific point on a screen. The efficiency of initiating a rapid and reflexive eye movement toward a salient stimulus are measured in the task.

There are diverse applications of antisaccade task in cognitive psychology, including investigation of executive dysfunctions (Reuter and Kathmann, 2004) and research of eye movements in response to visual cues, which provides insight into how individuals allocate their attention and make rapid decisions (Unsworth et al., 2015; Klapetek et al., 2016). Additionally, previous studies used the antisaccade task combined with other cognitive tasks to examine dual-task performance and the interaction between inhibitory control and other cognitive functions (Hutton et al., 2006). For example, Luo and colleagues (2022) combined the Stroop/Simon task and the antisaccade task to investigate whether eye movement inhibition shares the same domain as conflict monitoring. In their task, they also manipulated stimulus onset asynchrony (SOA), which is the time between the onset of the first stimulus and the onset of the second stimulus. By including this variable, they aimed to investigate the temporal dynamics of the role of eye movements requiring conflict control. They found that individuals who had better inhibitory abilities in antisaccade task also performed better in the Stroop task. Their results also showed that both the Stroop and Simon effects were weaker in the short SOA condition, implying reduced response control due to temporal dynamics. Notably, these findings were more pronounced in the antisaccade condition than in the prosaccade condition. They did not find the same significant result for the condition in which they used SOA but not the antisaccade/prosaccade task, suggesting that inhibition of eye movements was required for the appearance of declining response control over time. Furthermore, the temporal decrease in response control was modulated by saccade type (antisaccade/prosaccade) for the Simon effect, but not for the Stroop effect. Luo and colleagues (2022) argued that these results emphasize that the response conflict involved in these two tasks is different, which also explains the lack of correlation between these tasks in their results.

Based on previous studies that discussed the control of oculomotor movements and mechanisms underlying decisions in conflict tasks as sharing a common cognitive system (Luo et al., 2022), in this study, it was proposed that inhibition of oculomotor movements could affect participants' performance in number judgment tasks. Moreover, the role of oculomotor movements oriented left or right might facilitate number processing if the direction of the eye movement is aligned with the magnitude of the number (left/small and right/large). Consistent with the number-space association, the position of the numbers may influence reaction times during magnitude comparison. The spatial arrangement of the numbers may influence the SNA because the relationship between external space and the magnitude of the numbers implies an ordered line of numbers when responding to them (Dehaene, 1992).

1.6 Present Study

In this study, we aimed to investigate how SNA emerged by magnitude and response side interaction in magnitude comparison tasks was affected by spatial cueing tasks in relation to preparation interval (PI), shedding light on how SNAs are influenced by cognitive control. Procue and anticue tasks contained informative spatial cues to enhance target response by facilitating the interpretation of target location (Adam et al., 2011). Although there have been a large number of studies demonstrating that the conceptual link between space and number is bidirectional, the vast majority of these studies have only emphasized how the SNA influences attention to the target (Cipora and Nuerk, 2023). These studies proposed that SNA emerges from an early stage of the process, however, due to existence of S-R type effect, SNA may emerge from late response selection stage. Thus, in addition to investigating the effect of spatial cues on numerosity processing (procue task), it may be important to address the question of how the activation of mechanisms that inhibit cues affects the SNA effect in magnitude comparison when spatial cues are irrelevant (anticue task).

In Experiment 1, we combined the magnitude comparison task with each of the procue and anticue tasks. First, we expected that the magnitude-response side interaction would affect reaction time in the magnitude comparison task, i.e. participants would show faster reaction times when responding to small numbers with the left arrow and to large numbers with the right arrow. This relationship would indicate the presence of SNA. Although previous studies reported finger responses as SNARC effect (Priftis et al., 2006), since the vast majority of research on SNARC effect has focused on the use of two hands, we avoided using the term SNARC effect and focused on SNA in general. Furthermore, by presenting spatial cues prior to the target, this study allows us to examine the influence of task type on the magnitude-response side interaction in the magnitude comparison task as an indication of SNA. Due to the nature of the Procue task, trials consist of an empty box followed by a number at the exact position, and the given response is automatic and rapid (Jong, 2001). If the SNA is slow and occurs at the response selection stage consistently with results of Yan and colleagues (2021) study, the task which triggers an intention-driven process that selectively inhibits finger (Adam et al., 2015), should affect the SNA. Therefore, we expected that the interaction between magnitude and response side in the magnitude comparison task would be relatively unchanged or less improved and we still would see the magnitude - response side interaction in line with SNA (faster reaction times in left / small and right / large condition). Conversely, the conflict between spatial cues and target that occurred in the anticue task were expected to facilitate reaction time affected by magnitude and response side in the magnitude comparison task. Because anticue task would emerge mechanism to resolve the conflict between cue and target in which also facilitated incongruent SNA in magnitude comparison task (i.e. press left/right for large/small numbers). Duration between onset of the cue and onset of the target was also manipulated in Experiment 1. We expected a distractor effect decline over time triggered by execution of oculomotor movements (Horváth, 2013). Therefore, the magnitude-response side interaction in magnitude comparison task in long PI would be weaker compared to short PI. Moreover, Adam and colleagues proposed that when PI is 600 ms or longer, the reaction time difference between procue and anticue would diminish. Thus, we expected that the task type effect on magnitude-response side interaction would be eliminated in the long PI condition, indicating the elimination of distractor cues. Overall, we expected to find a weaker magnitude-response side interaction in the 650 ms. PI condition and in the anticue/magnitude comparison block, but the difference in the magnitude-response side interaction between procue and anticue would decrease in the 650 ms PI condition.

Another SNA phenomenon, the size congruity effect, was also expected to be influenced by the nature of the procue/anticue task. Since there is independency between SNA and size congruity (Fitousi et al., 2009) and this difference may result from the stimulus components that do not contain lateralized response tendencies in size congruity (Ansari et al., 2006), we expected a facilitated size congruity in the task where there is fast, reflexive activation of responses (procue task; Adam et al., 2011). Thus, physical size - magnitude relation in magnitude comparison task would be facilitated more in procue task compared to anticue task.

The procue/anticue task was designed to be logically and functionally isomorphic with the antisaccade task, but did not require eye movement measurements (Jong, 2001). However, it has been reported that eye movements were also usually observed in this version of the task (Nieuwenhuis et al., 2004). Thus, we included a combination of antisaccade task / magnitude comparison task in order to track the oculomotor movements. In the task, saccadic reaction time was used as a significant measure of oculomotor movements and was defined as the first saccade initiated by the stimulus onset and ending within the area of interest (AOI).

To investigate and highlight the role of inhibition of oculomotor movements during the magnitude comparison task we used the antisaccade task as a parallel task to the anticue task. In this antisaccade / magnitude comparison task combination, we measured not only the eye movements in the antisaccade task, but also the eye movements in the magnitude comparison task in order to see the SNA in saccade movements. For this purpose, we asked the participants to perform an eye movement to the left / to the right when the number is small / large, and vice versa. We expected an interaction between magnitude and response side in the magnitude comparison task, i.e. faster saccades to the left when the number is small and faster saccades to the right when the number is large (SNA). Furthermore, to investigate the influence of response control decline triggered by inhibition of oculomotor movements, we included two preparation intervals in the task. As in Experiment 1, the antisaccade task was divided into two sessions regarding the preparation interval (PI 350 ms and PI 650 ms condition). Ordaz and colleagues (2010) showed increased preparation led to enhanced performance in antisaccade tasks, indicating improvements in inhibitory control. Thus, it was expected that saccade to the left/right space would be faster when the number was small/large and this SNA would be affected by PI in the antisaccade task. Because the PI allowed participants to adjust their response by giving them more time, the conflict created by the incongruent cue was expected to be less effective on SNAs during the 650 ms PI condition, meaning the conflict of irrelevant cue would affect magnitude - response side interaction in magnitude comparison task, but this effect would be more pronounced in short PI since the distraction of stimuli would be higher compared to long PI condition. Moreover, because not only the response side affects the magnitude comparison task, but also the position of the presentation stimuli plays an important role in how participants respond to numbers (Fischer et al., 2010), we also expected that the presentation position of each target would affect the magnitude comparison task performed by oculomotor movements. Finally, we examined the relationship between target position and reaction time during the magnitude comparison task and expected that saccadic reaction times would decrease when the position of the numbers on the screen was in line with the SNA.

Because we could measure the ability to inhibit oculomotor movements in the antisaccade task, this task allowed us to examine differences in inhibitory ability among participants. Therefore, as a second measure, amplitude in the antisaccade tasks was examined to show whether the ability to inhibit oculomotor behavior was related to SNA in saccadic responses. Greater amplitude in the direction of the peripheral cue indicated difficulty in inhibiting the automatic reflex to look toward the target (Antoniades et al., 2013). We expected that individuals with higher levels of inhibition at the antisaccade task would show better performance at the magnitude comparison task and be less affected by the temporal decline in response control resulting from decreased PI.

CHAPTER 2: METHOD

2.1 Experiment 1

2.1.1 Participants

Fifty-one students from Izmir University of Economics (42 females and 9 males) aged between 18-35 (*M* = 21.02, *SD*= .424), voluntarily participated in the study.

To calculate the adequacy of the sample size, a power analysis was conducted by using the pwr package in R programming (Champely et al., 2022). The analysis showed that the current experimental design required 32 participants with a power > .80 and a medium effect size.

2.1.2 Stimuli

A fixation cross (0,0), a 35x35 empty box (+-217,0) were continuously shown in the procue-anticue tasks. Two small numbers (1, 2) and two large numbers (8, 9) were used to explore the SNA in the magnitude comparison task based on the reference numbers (5). To test the impact of the number's physical size, numbers were written in either Helvetica 55 or 85. Nevertheless, the size of the empty box remained the same throughout the study.

2.1.3 Tasks

2.1.3.1 Procue task

The procue task consisted of a cue and a target. The cue was an irrelevant stimulus and had to be ignored, whereas the target required a response. An empty box was visible as a square determined as the cue corresponding to the original task (Adam et al., 2011). The targets were selected as the numbers mentioned above. Procue utilizes spatially congruent mapping between cue position and the response position, referring to a left-position cue followed by a left response side and right-position cue followed by a right response side. Therefore, numbers appeared at the same location as the previous empty box during the task. According to Adam et al. (2015), the inhibition to the ipsilateral response side persists if the task is followed by a procue task. Due to this influence of the order, the procue task was always presented before the anticue task.

2.1.3.2 Anticue task

The cue and target stimuli were identical to those in the procue task. The only difference was that the cue and target were presented on the opposite sides of the screen (Adam et al., 2011).

2.1.3.3 Magnitude comparison task

In the magnitude comparison task, participants decided whether the presented number was smaller or larger than the reference number. Based on their comparison, they need to press the corresponding key to indicate their decision as quickly and accurately as possible.

2.1.4 Apparatus and Material

Individual experimental sessions were carried out in a soundproof, warm, and lightproof test chamber. Each participant's height and back angle could be adjusted in a comfortable chair which was placed in front of a table in the test chamber. .

The tasks were implemented by using python programming language with OpenSesame 3.3.10 Lentiform Loewenfeld (Mathôt et al., 2012) on a desktop computer (TECHNO PC 750GB HDD/ 4GB RAM/ AMD FX-6100 3,3Ghz/ 1GB VGA). Behavioral response data was collected from the right arrow and left arrow keys on the QWERTY keyboard. All stimuli were presented on a 19 LCD monitor with a resolution of 1600 x 900 a refresh rate of 60 Hz and a white background.

2.1.5 Participant Consent Form, Participant Information Form and Edinburgh Handedness Inventory

The Participant Consent Form (Appendix A) was prepared to inform participants about the purpose, procedure of the study, and their rights to refuse participation or to withdraw at any time during the study.

The Participant Information form (Appendix B) was prepared for the purposes of collecting information about participants’ gender, age, major and current psychological and physical well-being. Participants were asked to state whether they are bilingual, suffer from head trauma, have visual impairments, and have dyslexia, dyscalculia, or spatial neglect disorders. They were also required to state if they had participated in another experiment conducted in the Izmir University of Economics Mind, Behavior and Brain Research Laboratory, and if they participated, they were asked to specify the details of the study in which they had participated.

Edinburgh Handedness Inventory (Appendix C; Oldfield, 1971) was used to obtain information about the handedness of the participants. They were required to specify which hand they use in a Likert scale (always left, usually left, no preference, usually right and always right) during the activities which are writing, throwing, using scissors, using a toothbrush, using a knife, using a spoon, striking a match, and using a computer mouse. The score was calculated by subtracting "Always right" responses from "Always left" responses, dividing the result by the total number of responses, and then multiplying by 100. Negative scores on the Edinburgh Handedness Inventory indicated left-hand preferences, while positive scores indicated right-hand preferences (Oldfield, 1971).

2.1.6 Procedure

Participants were invited to the Mind, Behavior, and Brain Research Laboratory of Izmir University of Economics where the study was conducted. Upon arrival, they were assigned unique participant numbers for anonymous response tracking and taken to a waiting room to complete consent and information forms, including the Edinburgh Handedness Inventory (Oldfield, 1971). This process involved both verbal and written explanations of the study's purpose, procedures, and participant rights. Then, in order to gather information of gender, age, psychological and physical well-being, participants filled in a participant information form. After the participant information form, the information of handedness of participants was obtained by the administration of the Edinburgh Handedness Inventory (Oldfield, 1971).

Following the completion of the forms, participants were taken into the isolated, soundproof experiment chambers. At the beginning of the experiment, participants were given both verbal and written instructions on the procedure. The experiment consisted of two blocks: in the first block, participants were given the procue task with magnitude comparison task (procue/magnitude comparison block);

in the second block, participants were given the anticue task with magnitude comparison task (anticue/magnitude comparison block) (Figure 1). In each block, the sequence of presentation of stimuli was a fixation cross ("+") in the center for 1000 ms, an empty box on the right (217,0) or on the left (-217,0) side of the screen for 350 or 650 ms, and finally a number at the same or opposite position of the empty box for 2000 ms in which the magnitude comparison were performed. Participants saw two blank screens, one after the cue (50 ms) and the one after the target (500 ms). Only in the blank screen after the target, responding was allowed. This sequence was repeated 64 times for each number throughout the study by changing their font size and their position. However, the numbers (1, 2, 8, 9) were not allowed to be presented consecutively. Participants were asked to use only their right hand while using cursor keys. They were allowed to press any button to skip the instruction and start the experiment when they were ready. A practice trial was performed before each block in order to avoid mistakes caused by not understanding tasks. Practice trial contained 16 stimuli for each condition. The time interval between cue and target was 450 ms and after the 4 compatible (large or small in physical size and magnitude) and 4 incompatible (large/small in physical size but small/large in magnitude) stimuli presented, the assigned response keys were switched to the opposite. This practice trial was not included in the analysis. When the practice trial was completed successfully, the main study was started.

Procue/magnitude comparison blocks were presented before anticue/magnitude comparison blocks for each participant. Participants were informed that they would see an empty box on the right or left followed by a number throughout the experiment. During the presentation of the numbers, participants were required to respond to the number with the corresponding key given by instruction. Participants with the even participant numbers started with the compatible instruction and continued with the incompatible instruction. The participants with odd participant numbers saw the same instructions in reverse order. The compatible instruction required to respond with the left arrow key to the numbers smaller than 5, and with the right arrow key to the numbers larger than 5 (magnitude - response side compatibility). Contrary, incompatible instruction required to respond with the left arrow key to the large numbers and right arrow key to the small numbers. The time interval between the onset of the empty box presentation and the onset of the number presentation indicated preparation interval (PI). Each block consisted of two trials on the basis of the PI, and PI 350 ms and PI 650 ms conditions were utilized. For the PI 350 ms condition, the cue remained on the screen for 300 ms, then a blank screen was shown for 50 ms before the appearance of the target. Therefore, the total preparation interval for the participants was 350 ms. For each of the PI trials, the assigned response keys were reversed in the half of the magnitude comparison task. Consequently, half of the responses were compatible with the magnitude of the number (pressing right when the number is large, pressing left when the number is small) whereas the other half were incompatible (pressing right when the number is small and pressing left when the number is large) in the terms of space-number associations (SNAs; Dehaene, 1992). Numbers were followed by a blank screen and responses both in presentation of the target and the following blank screen were recorded. The PI 650 ms trial contained the same sequences except that the appearance of the cue was increased to 600 ms. All participants completed each of the PI trials. The order of the presentation of the PI trials was counterbalanced between the participants. Half of the participants were given the PI 650 trials first, and PI 350 trials second, the other half completed the PI 350 trials first, then PI 650 trials in both procue/magnitude comparison and anticue/magnitude comparison blocks.

Consistently with the concept of magnitude-response side compatibility, half of the numbers were presented in the large font size, and the other half were presented with the small font size to assess the relationship between numerical magnitude and physical size. This led to four distinct, randomly presented conditions:

1. Response Side-Magnitude and Physical Size-Magnitude Compatibility: Participants used the right arrow key for numerically and physically large numbers, and the left arrow for those small in both aspects (shown in A of Figure 1 and C in Figure 2).
2. Response Side-Magnitude and Physical Size-Magnitude Incompatibility: Participants responded to numerically small but physically large targets with the right arrow, and to numerically large but physically small targets with the left arrow (shown in B of Figure 1 and D in Figure 2).

3. Response Side-Magnitude Compatibility with Physical Size-Magnitude Incompatibility: Participants pressed the right arrow for large numbers and left arrow for small numbers, regardless of their physical size.
4. Response Side-Magnitude Incompatibility with Physical Size-Magnitude Compatibility: This condition involved pressing the left arrow for numerically and physically large numbers and pressing the right arrow for numerically and physically small numbers.

Each condition was presented 32 times to the participants. In total, each of the participants responded to the 128 stimuli throughout each block. Also, the position of the targets was balanced between the trials to ensure the response side was half of the time compatible and the other half of the time incompatible with the position of the target. While all responses were recorded, only those where the response side was aligned with the target's position were analyzed, in line with the task's nature.

At the end of the first block, the experimenter entered the experiment chamber to initiate the second block. The procedure for the second block (anticue/magnitude comparison block) included a practice trial and was similar to the first block. However, the main differences were in the instructions and the position of the cue. As in the first block, the cue was presented before the target, but on the opposite side. Participants were instructed not to look at the cue when it appeared, but to focus on the center of the screen. They were allowed to look at the target once it appeared.

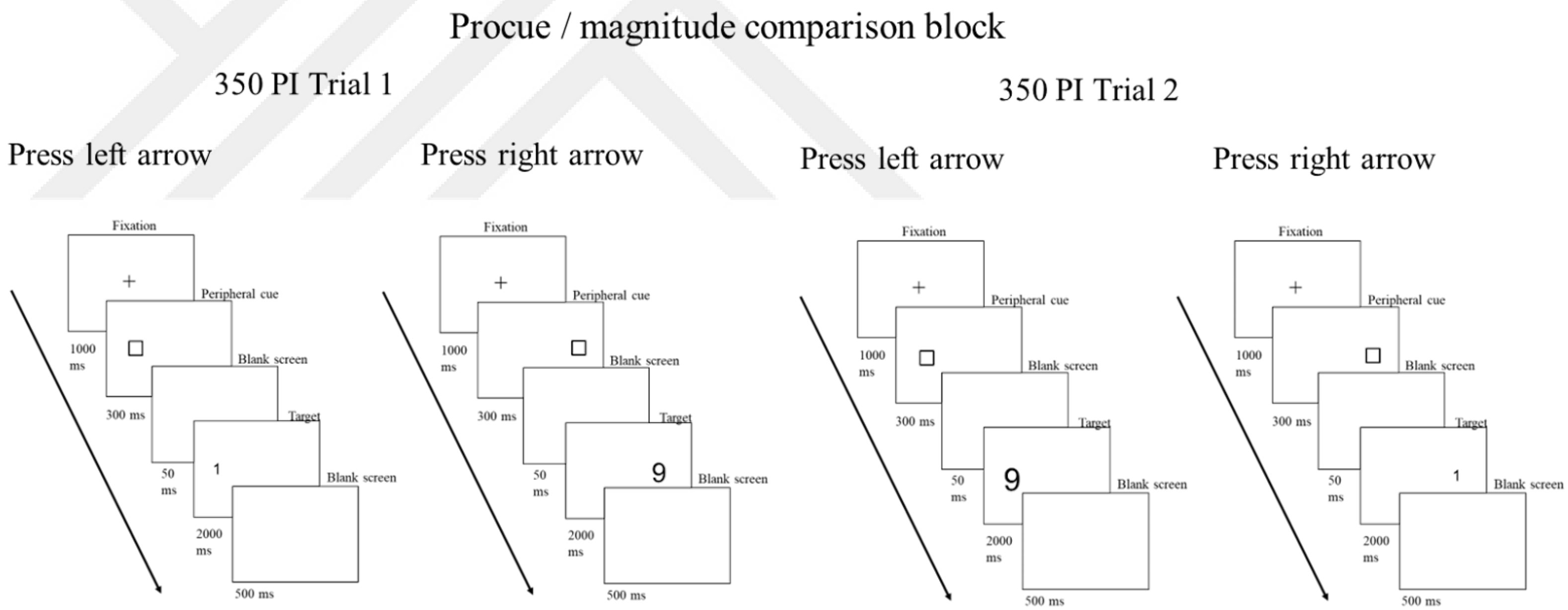

Figure 1. Schematic illustration of the sequence of events in experiment 1 procue/magnitude comparison block. In Trial 1, participants pressed left for small targets (left sequences of A) and right for large targets (right sequences of A). Conversely, in another condition, they pressed left for large targets (left sequences of B) and right for small ones (right sequences of B). Trial order was counterbalanced among participants.

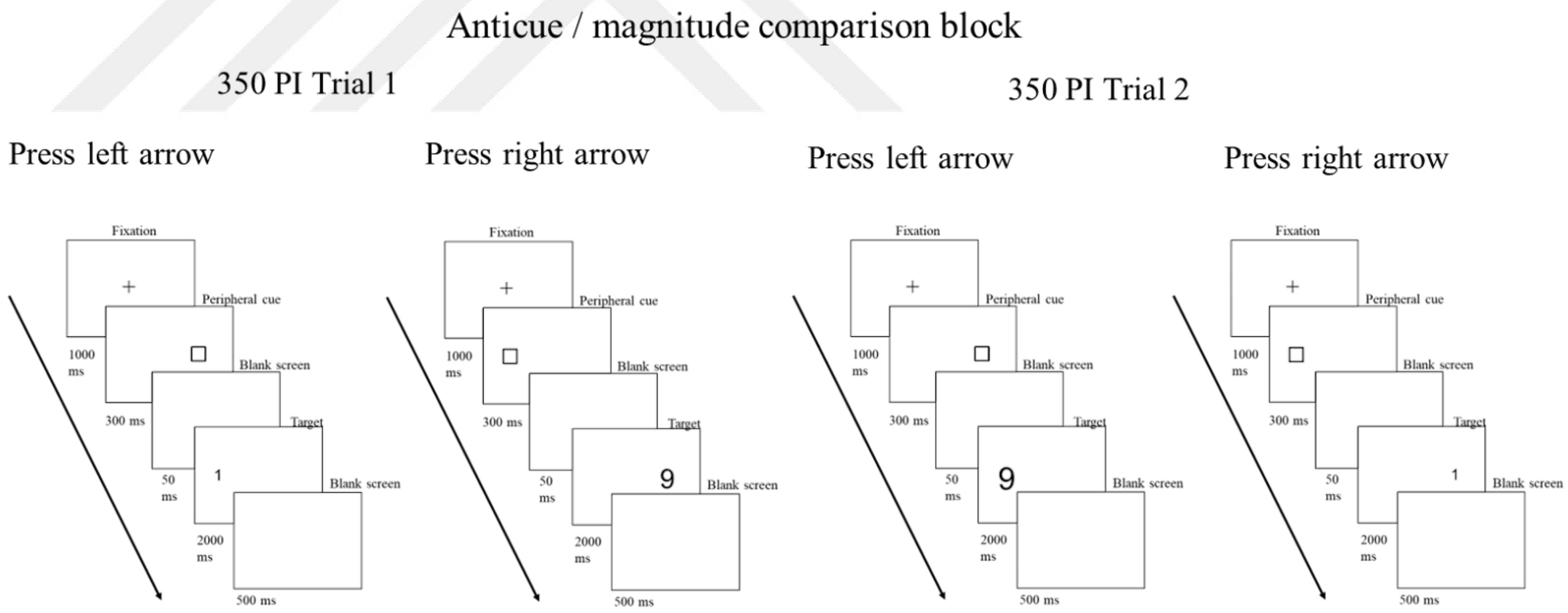

Figure 2. Schematic illustration of the sequence of events in experiment 1 anticue/magnitude comparison block. Trial order was counterbalanced among participants, with the same event sequences for PI 650 trials (not shown).

2.2 Experiment 2

2.2.1 Participants

40 participants aged between 18-35 (28 female, 12 male) engaged in the study voluntarily (M = 22.25, SD = 3.17). For the second experiment the current experimental design required 29 participants with medium effect size and < .80 power by using the pwr package in R programming (Champely et al., 2022).

2.2.2 Stimuli

Similar to the first experiment, in the second experiment a fixation cross, an empty box, and numbers from 1 to 9 with the exception of 5 were presented. The fixation cross was vertically centered and positioned 800 pixels away from each side of the 19.5-inch LCD display at full 1600x900 pixel resolution. The numbers and the blank box were presented 400 pixels away on the right or left side of the screen. In addition, two circles were presented on the right and left side of the screen (400 pixels apart) to facilitate the recording of saccade responses during the magnitude comparison task.

2.2.3 Tasks

2.2.3.1. Antisaccade Tasks

As a parallel task of anticue for oculomotor movements, an antisaccade task was used to examine oculomotor inhibition. Antisaccade tasks consist of peripheral cues followed by a target. At the beginning, participants were instructed to focus on a fixation point initially. When the empty box (peripheral cue) appeared, participants were instructed not to make a saccade in the direction of the cue. When a number (target) was presented in the opposite direction, participants were instructed to redirect their saccade towards this target. This task evaluates the ability to inhibit reflexive responses and to control oculomotor movements (Hallet, 1978).

2.2.3.2. Magnitude Comparison Task

The Magnitude comparison task served the same purpose as in Experiment 1. In Experiment 2, however, the comparisons were asked to be made by saccadic responses.

2.2.4 Apparatus and Material

Individual experimental sessions were carried out in a soundproof, warm, and lightproof test chamber and were recorded without interruption. There was a comfortable seat, height, and back angle in the test chamber, which was reconfigured for each participant (Figure 3). The seat was carefully positioned in front of a table. The Remote Eye-Tracking Device (RED250, SensoMotoric Instruments, Inc., Boston, MA, USA) was positioned beneath a 22" LCD display which will be used as a Stimulus PC. The gaze tracking data was recorded using the iView X system (SensoMotoric Instruments, GmbH, http://www.smivision.com). iView X was installed on a laptop included with the SMI package. The laptop was placed in close proximity to the Remote EyeTracking Device. SMI Experiment Center version 3.4 (SensoMotoric Instruments, GmbH. http://www.smivision.com) installed in Stimulus PC was used for the presentation of instructions, calibration procedures, presentation of tasks, and recording of manual and foveal activities. The tasks were implemented by using the Experimenter Center. The software already had a 13-point drilling algorithm for the calibration procedure. The moving point's size and color, as well as the background color of the calibration screen, were designed to match the background. In order to minimize measurement errors that might result from participants' head movements, a chin rest was applied.

2.2.5 Participant Consent Form, Participant Information Form and Edinburgh Handedness Inventory

The same forms and exclusion criteria were used in Experiment 2 as in Participant Consent Form (Appendix A), Participant Information Form (Appendix B) and Edinburgh Handedness Inventory (Appendix C). However, an additional exclusion criterion was implemented in Experiment 2: individuals who wore glasses or used contact lenses were not allowed to participate in the experiment. This

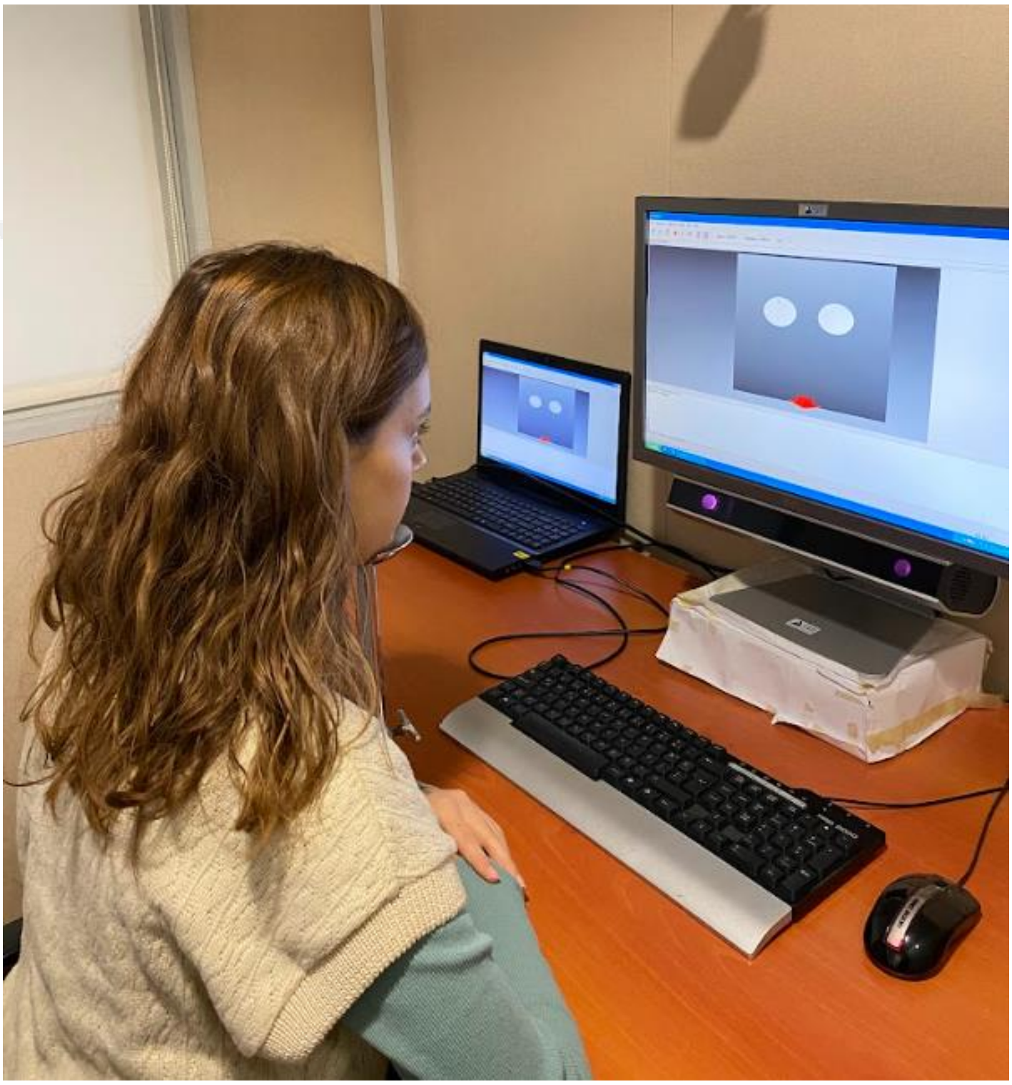

Figure 3. Experimental Setup for Experiment 2

exclusion criterion was used to reduce the noise produced by glasses reflections caused by the reflections from the gaze tracker's lights on glasses or contact lenses.

2.2.6 Procedure

Before the study, participants were taken to the waiting room where they were given verbal and written information and ensured they understood the aim of the study and their right to withdraw at any time during the study. They were asked to fill in the participant consent form, participant Information form and Edinburgh Handedness Inventory in the same order of Experiment 1. After completing the forms, they were taken into the isolated, soundproof experimental chamber. If participants had make-up on their eyelashes and eyelids, they were kindly asked to remove it using the cotton provided and a make-up removal solution, as make-up has been shown to affect foveal data (O'Brien, 2009). After the participants had placed their chin on the chin rest and looked directly at the monitor, iView X was initiated on the laptop next to the monitor for. iView X provided instructions with arrows showing where the eyes should be positioned. The arrows could be found at all four corners of the screen. Based on this, the necessary adjustments were made for the participant to sit comfortably and at an appropriate height in the chair. Calibration involved each participant focusing on a moving point which was positioned at 13 different locations .They were required to fixate their gaze on each location for 500 milliseconds. This process was repeated until the deviations from the fixated point did not exceed 0.80 on either the x or y axis, to ensure the accuracy of the experiment's eye-tracking data. Only when this requirement was reached, the experiment proceeded. This strategy compensated for individual differences between participants.

Sessions were divided by preparation interval. Half of the participants were exposed to calibration, 350 PI, calibration and 650 PI, respectively. The other half were first exposed to 650 PI. After the first calibration process, the practice trial for the antisaccade task was performed. The sequence of stimuli: fixation cross (750 msec), an empty box (300/600 msec), blank screen (50 msec), a number (1500 msec), fixation cross (750 msec) and two circles on the left and right side of the screen (until response). The sequence is shown in Figure 4. Participants who started with compatible conditions were instructed to not to look at the square when it appeared, then, if the number was small/large, to look as quickly and accurately as possible until the circle appeared on the left/right side of the screen. For the other participants who started with incompatible conditions, the instruction for the squares was the same, but they had to look to the right/left side of the circle for 500 msec if the number was small/large. In order to ensure that participants initiated their saccade at the center of the screen, the fixation cross was presented until participants fixated their eyes on it for 750 msec. If they moved their eyes to a different location, the time was restarted. The same procedure was used for the circle. Circles were presented until the participants made a saccade toward the correct circle and fixated their eyes on it for 500 msec. A blank screen was presented for 1500 ms after circles and the sequence of the trial was repeated (Figure 4). Consecutive presentation of the same numbers was not allowed. When the antisaccade task was successfully completed, the researcher entered the chamber and ended the experiment.

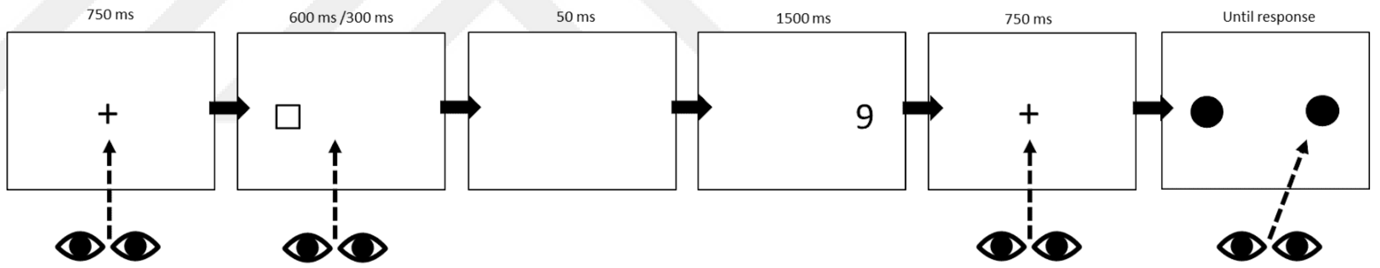

Figure 4. Schematic illustration of sequences of events in experiment 2. Trials were presented starting with a fixation cross in the middle of the screen until the individual fixated their eyes on the stimuli for 750 ms. Then, an empty box either on the right or left side of the screen for 300 or 600 ms depending on the session. A number on the opposite side of the empty box was displayed for 1500 ms followed by a fixation cross. Participants were instructed to look to the right if the number was greater than 5, and to the left if it was less than 5 (not shown) in the compatible condition. Unlike the compatible condition, the right circle was assigned as the correct response for the small numbers whereas the left circle was the corresponding response for the large number in the incompatible condition (not shown).

CHAPTER 3: RESULTS

3.1 Experiment 1

To ensure that all participants fully understood and engaged with the task, only those who achieved accuracy rates of at least 75% in each condition were included before the main analysis. Eight participants who failed to achieve this accuracy rate were excluded. Five extreme values were also not considered. In total, thirteen participants were removed based on these criteria, and the analysis was performed with the thirty-eight remaining participants, which was sufficient as shown in the power analysis. The data was distributed normally.

Reaction time data was subjected to 2 (response side: left arrow, right arrow) x 2 (magnitude: small, large) x 2 (task: procue, anticue) x 2 (PI: 350ms, 650ms) x 2 (physical size: small, large) within-subject ANOVA. The results yielded a significant main effect of Task ($F(1, 37) = 18.78$, $p < .000$, $\eta p^2 = .34$), indicating that participants were significantly faster during the procue tasks than the anticue task (Figure 5). There was a significant main effect for the preparation interval ($F(1,37) = 5.22$, $p < .05$, $\eta p^2 = .12$). This effect shows that the reaction times are faster in the short PI compared to long PI (Figure 6). There was no significant main effect for the physical size ($F(1,37) = .119$, $p = .73$), response side ($F(1,37) = .57$, $p = .46$) and magnitude ($F(1,37) = .02$, $p = .91$).

The results of the ANOVA yielded significant two-way interactions between physical size and response side ($F(1,37) =12.60$, $p < .001$, $\eta p^2 =.25$), between task and magnitude ($F(1,37) =4.79$, $p < .05$, $\eta p^2 = .12$), and between response side and magnitude ($F(1,37) =5.82$, $p < .05$, $\eta p^2 = .14$). A simple effect analysis was performed to examine the interactions. These follow-up tests showed that the participants responded faster with the left arrow key to the physically large numbers ($M = 569.60$, $SE = 18.93$) than the physically small numbers ($M = 588.60$, $SE = 21.32$, $p < .05$), contrary they were faster to respond to the physically small numbers ($M = 574.43$, $SE = 20.27$) than the physically large numbers ($M = 598.30$, $SE = 22.02$) with the right arrow key ($p < .05$) (Figure 7).

On the other hand, when the response side was left, participants responded faster to the small numbers (*M* = 561.75, *SE* =21.70) than large numbers (*M* = 596.45, *SE* = 20.23, $p < .05$), and when the response side was right, participants were faster to the large numbers (*M* = 568.07, *SE* = 21.14) than the small numbers (*M* = 604.66, *SE* = 23.90) in magnitude ($p < .05$) (Figure 8).

The examination of task and magnitude interactions showed that during both anticue and procue tasks, small numbers were responded faster in the procue task (*M* = 565.62, *SE* = 21.66) compared to the anticue task (*M* = 600.79, *SE* = 21.55, $p < .05$). Similarly large numbers were responded faster during the procue task (*M* = 549.14, *SE* = 19.86) than the anticue task (*M* = 615.38, *SE* = 21.12; $p < .05$). However, the reaction time differences between two tasks (*Md* = 35.173, *SE* =14.12) were shorter for small numbers than the reaction time differences between two tasks for large numbers (*Md* = 66.242, *SE* = 13.24, $p < .05$) (Figure 9).

There were no significant interaction effects between any other variables in the analysis (All *F*s< 3.58 and all $p > .07$).

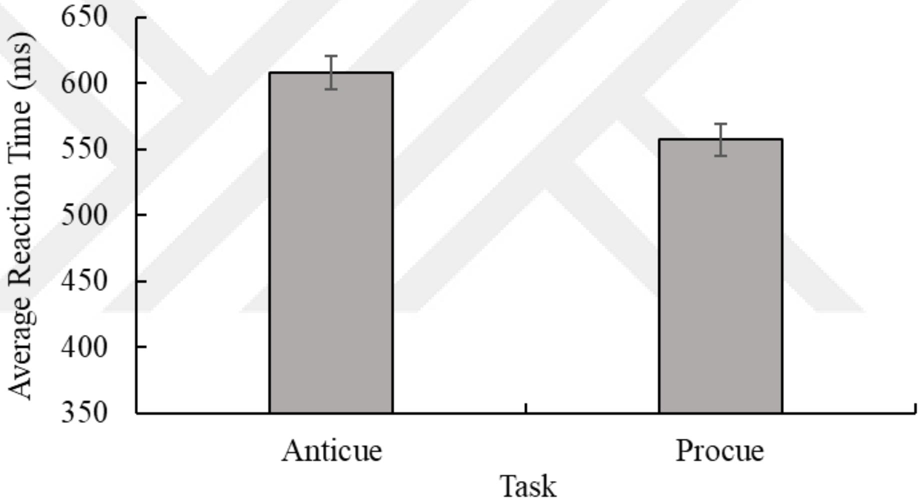

Figure 5. Mean reaction time in magnitude comparison task for each task (Error bars indicate 95% adjusted Confidence Intervals).

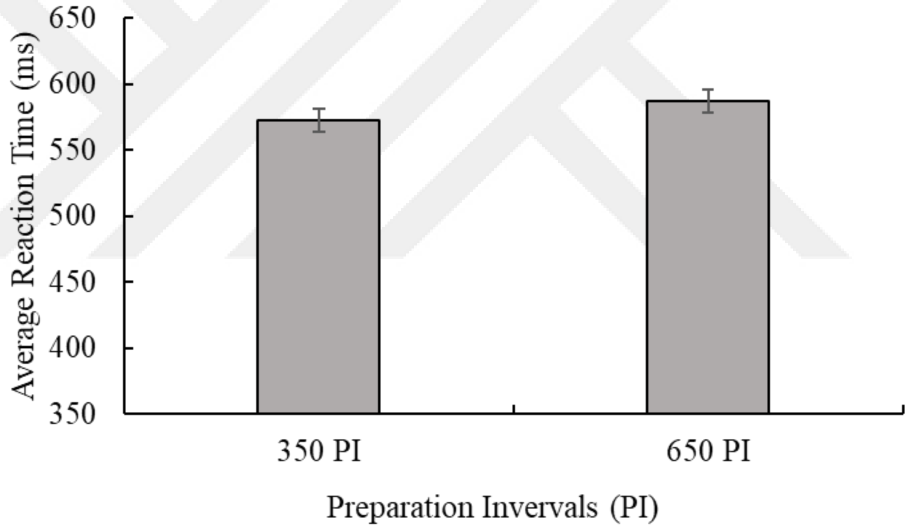

Figure 6. Mean reaction time in magnitude comparison task for each preparation interval (Error bars indicate 95% adjusted Confidence Intervals).

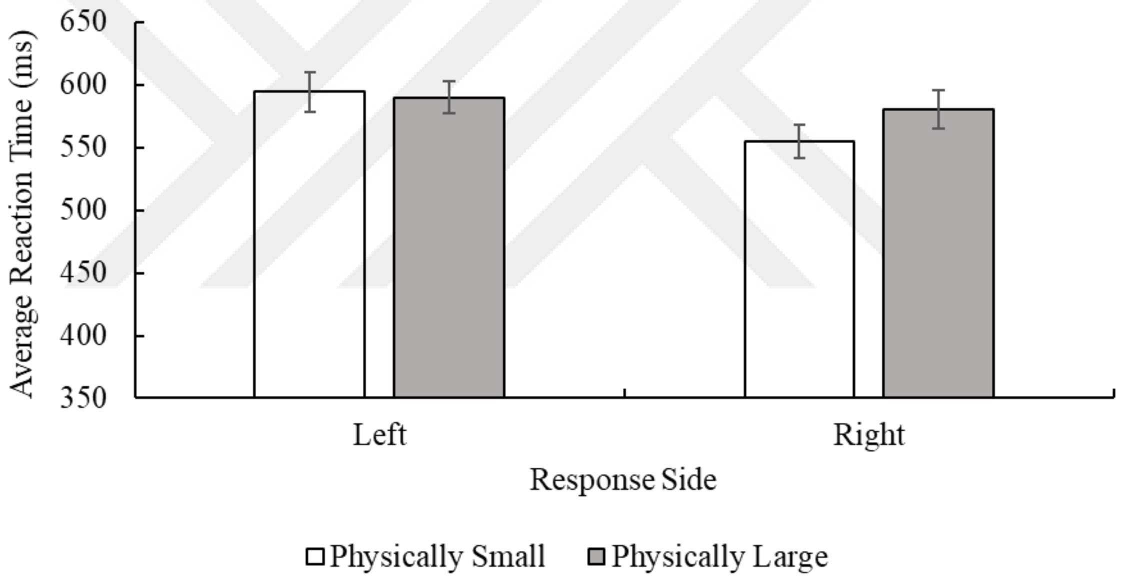

Figure 7. Mean reaction time in magnitude comparison task of each response side for physically small and physically large numbers (Error bars indicate 95% adjusted Confidence Intervals).

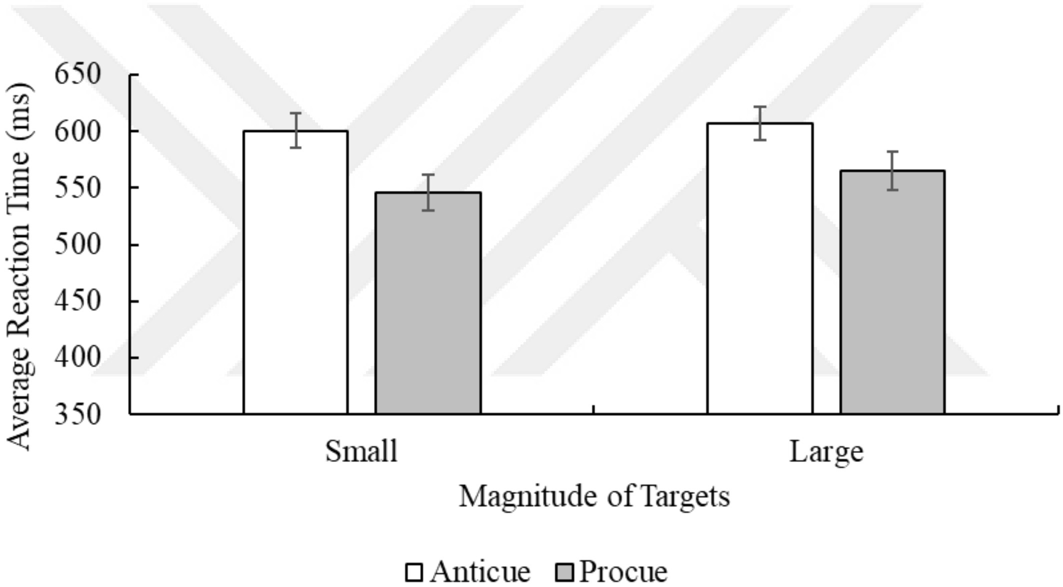

Figure 8. Mean reaction time in magnitude comparison task of small and large numbers for each cue task (Error bars indicate 95% adjusted Confidence Intervals).

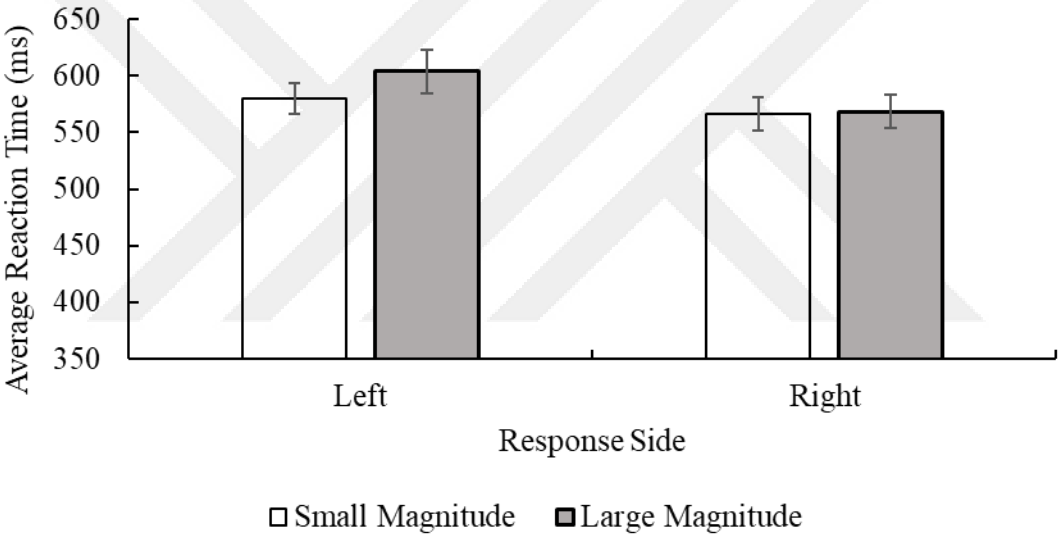

Figure 9. Mean reaction time in magnitude comparison tasks for each response side and magnitude conditions (Error bars indicate 95% adjusted Confidence Intervals).

3.2 Experiment 2

Prior to the main analysis, only the participants who performed above %75 accuracy rate in each condition were included to ensure that participants completely understood and engaged with the task. Therefore, six participants were excluded from the data. The analysis was conducted with the thirty-four remaining participants. The data were found to be normally distributed for the two analyses performed.

Saccadic reaction time data were analyzed using a 2 (response side: left, right) x 2 (magnitude: small, large) x 2 (position of target: left, right) x 2 (PI: 350 ms, 650 ms) repeated measures ANOVA. The analysis revealed a significant main effect of position ($F(1, 33) = 7.230$, $p < .05$, $\eta p^2 = .180$), indicating faster responses when targets appeared on the left side of the screen. Additionally, the response side was also significant, ($F(1, 33) = 5.356$, $p < .05$, $\eta p^2 = .140$), showing quicker saccadic reactions for the right side of the screen. No other significant main or interaction effects were obtained (All *F*s < 3.53 and all *p*s > .07).

Given our interest in participants' inhibition abilities, we conducted an exploratory analysis. Participants were divided into two groups based on the total amplitude of their gaze towards the boxes they were instructed to inhibit. The amplitude values, representing the level of successful saccade inhibition, were summed for each individual including all conditions. The median of these total amplitude (*Md* = 2.57) values was then used to separate participants into two groups: Lower-inhibition group (participants with amplitudes below the median) and higher-inhibition group (participants with amplitudes equal to or above the median) (Nachmias et al., 1996). This group aimed to assess the level of inhibition achieved by participants. Higher-inhibition groups would demonstrate a better inhibitory control compared to lower-inhibition group.

A subsequent 2 (response side: left, right) x 2 (magnitude: small, large) x 2 (position of target: left, right) x 2 (PI: 350 ms, 650 ms) mixed ANOVA yielded a significant main effect of position ($F(1, 32) = 7.08$ $p < .05$, $\eta p^2 = .18$), indicating that participants were significantly faster when the target appeared on the left side of the screen (Figure 10), and a significant main effect of response side ($F(1,32) = 5,07$, $p < .05$, $\eta p^2 = .14$), which indicated participants' saccadic responses were faster when they were looking at the right side of the screen (Figure 11). There was no significant main effect for the magnitude, PI and inhibition groups (All *F*s < 1.44 and *p*s $> .24$).

The results of the ANOVA yielded significant interaction between PI, magnitude and inhibition ($F(1, 32) = 4.63$ $p < .05$, $\eta p^2 = .13$). To examine this interaction, simple effect analysis was conducted. This analysis revealed that for participants in the higher-inhibition group, there was a significant effect of magnitude under the PI 600 ms condition, indicating individuals with higher inhibition scores responded faster to large numbers ($M = 68.45$, $SE = 1.68$) than small numbers ($M = 71.01$, $SE = 1.97$) when they were in PI 600 condition ($p < .05$).

There were no significant interaction effects in the analysis (All *F*s < 3.35 and *p*s $> .08$).

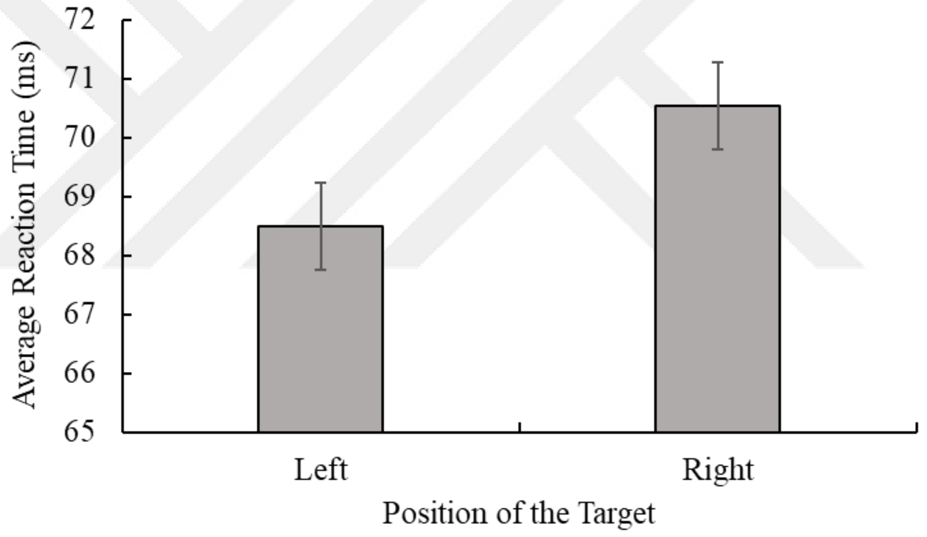

Figure 10.Mean reaction time in magnitude comparison task for each position of the target (Error bars indicate 95% adjusted Confidence Intervals).

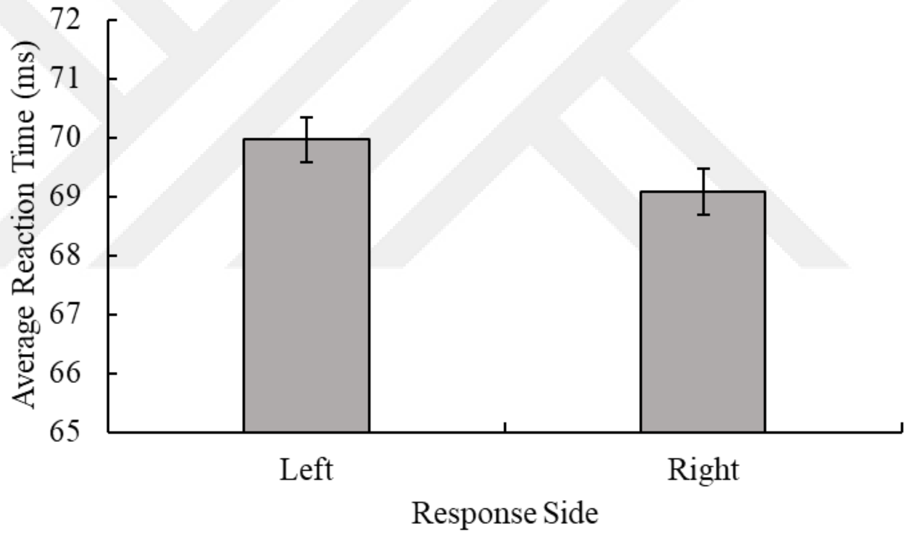

Figure 11. Mean reaction time in magnitude comparison task for each response side (Error bars indicate 95% adjusted Confidence Intervals).

CHAPTER 4: DISCUSSION

4.1 Experiment 1

As mentioned above, in this thesis we used a combination of procue/magnitude comparison and, anticue/magnitude comparison tasks in Experiment 1 and to test hypotheses about the interplay between inhibitory control and SNAs (magnitude-response side interaction). First, we expected to find a faster reaction time for congruent SNA conditions in the magnitude comparison task, meaning faster reaction time to small numbers with left arrow key compared to right arrow key, and faster reaction time to large numbers with right arrow key compared to left arrow key. Furthermore, to investigate the role of inhibitory control on SNA, we manipulated the position of irrelevant cues before the magnitude comparison task by using procue and anticue task. Because anticue task would activate the cognitive control mechanism (Jong, 2001), that might be also related to facilitation in SNA in magnitude comparison task, our specific aim for Experiment 1 was to find a weaker or no SNA in magnitude comparison task in anticue task compared to procue task. Furthermore, we manipulated the preparation time between the onset of the first stimuli and the onset of the second stimuli to emphasize the role of response control decline during the tasks. This paved the way for exploring how the effect of task type on SNA would diminish in magnitude comparison tasks, as the increased preparation time allowed participants to overthink their response, thus reducing or eliminating differences between anticue and procue tasks (Adam et al., 2015). Thus, by comparing 350 ms and 650 ms PI we aimed to measure not only the influence of cue inhibition, but also the influence of the distractor cue itself on the magnitude comparison task. Additionally, we explored the size congruity by manipulating the font size of the numbers. Thus, we included the physical size of the numbers and observed how inhibition would differentially affect both size congruity and SNA. Our aim was to reveal that the response side - magnitude interaction would be affected by the anticue task, whereas the physical size - magnitude interaction would be affected by the procue task, since it is irrelevant for lateralized response tendencies.

In Experiment 1, we found a significant difference in participants' reaction times between procue and anticue tasks. The observed reaction time differences can be explained by the different cognitive processing demands of the two tasks. In the procue task, the cue indicates the location of the target, which allows for a fast, straightforward response, whereas the anticue task contains an additional cognitive load due to the opposite presentation of cue and target (Adam et al., 2021). This explanation may also be valid for our significant reaction time differences for preparation intervals (PI). We found that participants responded faster when given a 350 ms preparation interval than when given a 650 ms preparation interval. Shorter PI may allow less time to overthink the response, which leads to less cognitive load and faster decision making. We also expected that PI would affect SNA in our experiment, and that this effect would be more pronounced in the anticue task, since increased preparation time reduces the distracting effect. Interestingly, contrary to our expectations, we did not find a significant interaction between PI and SNA (magnitude - response side). Luo et al. (2022) reported increased SOA was associated with decline in response control over time, hence weaker Stroop and Simon effect. Their results were the opposite of what we expected, but consistent with our finding regarding the faster reaction time in PI 350 ms condition regardless of the task type. High cognitive load in the long PI condition may lead to decline in response control over time. On the other hand, there was a difference in responding to small versus large numbers in different task types, as indicated by the significant interaction between tasks and magnitude. Responses to small numbers were faster in the procue task than in the anticue task. This difference may be due to the inherent spatial associations of numerical magnitude (small numbers associated with left space and large numbers associated with right space) being more salient in spatially congruent conditions which is the procue condition. Building on that, the lack of a significant main effect for physical size suggests that the physical size of numerical stimuli did not significantly affect response time. This may emphasize that the cognitive processing involved in these tasks may be more sensitive to conceptual rather than perceptual aspects of numbers. This finding is consistent with the significant physical size-response side relationship, which was contrary to the findings of Ren et al., (2011). In other words, participants may be responding based more on number magnitude rather than how large or small the numbers appeared on the screen.

Notably, our results yielded a significant relationship between magnitude and response, indicating participants tended to be faster when they were instructed to press the left arrow for small numbers and the right arrow for large numbers. By testing this relationship, our study contributes to the existing body of research on numerical cognition and provides further evidence for SNAs in finger responses in one hand (Priftis et al., 2006; Riello et al., 2011). This significant result allowed us to explore SNA in terms of its interactions with other variables included in the present study, which was our primary goal.

The main purpose of this study was to determine how inhibitory control developed through inhibition tasks would affect the performance in magnitude comparison tasks. It has been suggested that SNA has a fast pathway in congruent trials and a slow pathway in incongruent trials (Gevers et al. 2006). In addition, Yan and colleagues (2021) demonstrated that the SNARC effect arises from the response selection stage based on its interaction with the Simon task. Therefore, we expected a task and magnitude-response side (indicative of SNA) interaction. However, there was no significant interaction between task type, magnitude and response side. This nonsignificant results in Experiment 1 may be due to two stages of the conflict processing. These are conflict monitoring, in which task-relevant and task-irrelevant dimensions of stimuli are detected, and conflict resolution, in which conflicts regarding the goal of the task are resolved (Botvinick et al., 2001; Egner, 2008). While Botvinick and colleagues (2001) suggested both stages are domain-general, Egner (2008) proposed that conflict monitoring and resolution are domain-specific, meaning they address different types of conflict. Furthermore, Liu and colleagues (2004) proposed that while the conflict monitoring process is domain-specific, the resolution is domain-free. Luo and colleagues (2022) provided findings consistent with Liu and colleagues' proposal. They proposed there is a common system for the control of oculomotor behavior and conflict resolution, but the control of oculomotor behavior did not affect the S-S type effect conflict in Stroop task. The S-S type effect in Stroop arises during the early semantic-representation stage, whereas the S-R type effect in Simon task is seen in the late response-selection stage (De Jong et al., 1994). We developed our hypothesis based on research mentioned above that supports a late response selection stage in SNA. Nevertheless, the processing stages (semantic-representational stage and response selection stage) of SNA remains controversial. The SNA in finger responses may be related to the semantic-representational stage more than the response selection stage. Given not measured eye movements in the procue/anticue task and the processing stage involved in SNA may be different due to the magnitude comparison task, this may explain the lack of significant interaction between task, magnitude, and response side in Experiment 1.

4.2 Experiment 2

In Experiment 2, we combined the antisaccade/magnitude comparison task to examine oculomotor movements in anticue tasks. We hypothesized a faster saccadic reaction time in the magnitude comparison task when participants were instructed to look left for small numbers and right for large numbers. By altering finger responses to saccades in the magnitude comparison task, we were also able to examine SNA in different motor movements. Similar to Experiment 1, we incorporated two PIs to assess how the impact of inhibitory control would decrease with shorter preparations due to a decrease in response control. Finally, by manipulating the position of the numbers, we were able to assess how the presentation position of the numbers affected the magnitude comparison task performed with saccades.

In a further analysis, participants were divided into two groups based on their inhibitory abilities in Experiment 2. Our goal was to find a weaker SNA in the magnitude comparison task for the higher inhibition group compared to the lower inhibition group, emphasizing the level of inhibitory control affecting the magnitude comparison.

Although our results showed a significant SNA in fingers in Experiment 1, the same association was not significant when participants were instructed to use their eye movements in the magnitude comparison task. These findings provided evidence supporting SNAs in finger response, but not saccade movements, in contrast to Shwarz and Keus (2004) finding. Notable difference is that they used a different task to assess the SNA. Irwin and Thomas (2007) demonstrated that magnitude comparisons were suppressed, because execution of a saccade and comparing magnitudes relies on the same brain regions. They discussed that this suppression in the magnitude comparison during a saccade may have occurred as a result of dual-task interference within the dorsal-stream. On the other hand, parity judgments were not affected by saccade movements made simultaneously.

According to Dehaene (1993), parity judgment tasks measure SNA implicitly, whereas magnitude comparison tasks measure SNA explicitly. Thus, our results may be influenced by the way SNA is measured. Brain imaging research is required for further explanation. Aside from the different tasks, the saccadic SNARC effect may not be easy to replicate due to the nature of the saccades. Previous studies attempt to use saccade movement trajectories to investigate cognitive processes such as language, attention and memory. Nevertheless, the nature of saccades are rapid and have weak trajectory modulation. Despite the lack of SNA in eye movements, in Experiment 2 we found a significant main effect of position and a significant main effect of response side. Participants looked faster at the circle when the target appeared on the left side of the screen. This result is consistent with the expectation coming from the reading side in the Turkish sample. In contrast, they moved their eyes faster when they were instructed to look at the right rather than the left circle. Due to the reading side, we expected a faster reaction when the look was directed toward left, however it may be a result of seeing the target first, then executing the eye movements. This pattern may induce an inhibition of return (IOR) in participants, which refers to directing attention to novel locations (Posner and Cohen, 1984). Spalek and Hammad (2005) proposed a bias that results in large IOR when the initial cue is presented on the left, leading to left-to-right attention. Although circles were presented only if participants redirect their eyes to the fixation cross after the target for a certain time, this bias also affects the lack of SNA in the magnitude comparison task for Experiment 2.

Second, we expected to observe the same interaction between PI and magnitude-response side in magnitude comparison task like in Experiment 1. Similarly, to Experiment 1 there was no significant effect of PI on SNA. The reason for the lack of interaction between PI, magnitude, and response side may be due to the lack of SNA in saccades in Experiment 2.

Finally, we divided participants based on their performance in the antisaccade task to examine whether the inability to inhibit influenced the results of the study. However, contrary to our expectations, there was no significant effect, indicating that individual differences in inhibition do not affect magnitude comparison performance. Since saccades are rapid, they may be hard to inhibit, so it may not measure individual differences in inhibition, precisely. Thus, further studies including different inhibition tasks with simpler procedures may be conducted to investigate the individual differences in inhibition abilities (Brett and Machado, 2017).

4.3 General Discussion

Our goal was to contribute to the understanding of SNAs while emphasizing the impact of the cognitive control process induced by spatial cueing on numerical cognition. These results suggest that task type (procue/anticue) did not affect numerical magnitude processing, and response preparation time did not affect the inhibition produced by the antisaccade task. As mentioned above, in this study we only used magnitude comparison tasks with other cue tasks. However, it was important to measure SNA implicitly, since the magnitude becomes irrelevant in parity judgment tasks. Additionally, magnitude comparison tasks may share the same domain with saccade, therefore the first task required execution or inhibition of saccade may use resources so SNA in magnitude comparisons are suppressed. As highlighted above, magnitude comparison task and parity judgment task may be monitored by different control mechanisms (Georges et al., 2018). In this regard, inhibition may play a more important role in parity judgments than in magnitude comparison tasks. Therefore, further studies may combine cue tasks and parity judgment tasks in order to investigate the role of inhibition in SNA. Furthermore, to investigate SNA in saccades, a parity judgment task may be a better option. Additionally, we found that individuals with different inhibitory abilities did not differ significantly on the magnitude comparison task. However, antisaccade tasks may not give a precise individual difference since saccades are rapid in their nature and the difference between higher-inhibition group and lower-inhibition group was small in our study. Measuring individual differences in inhibitory control across different behavioral tasks (e.g. go/no go, stop signal paradigm) may provide deeper insights into the interplay between cognitive control processes and SNA. In addition to measuring inhibition, different cognitive control mechanisms involved in SNA should be investigated. As described above, two different stages have been proposed in the interaction between SNARC effect and cognitive control (Zhang et al., 2022). The first stage, called the representational stage, involves WM and the shifting cognitive control process, whereas the second stage emphasizes the role of inhibition in SNA (Zhang et al., 2022). Therefore, future studies should investigate the bidirectional link in SNA by emphasizing how different cognitive control mechanisms (e.g., WM, shifting) interact with spatial and numerical processing.

4.4 Conclusion

The main purpose of this thesis was to investigate the relationship between inhibitory control and SNAs using innovative task combinations with two types of measures which are behavioral and physiological. With motor and oculomotor responses, the study incorporated the presence of different motor movements in SNA. Although we found significantly faster reaction times in the procue task and short PI, this facilitation did not affect the magnitude-response side interaction that occurred in the magnitude comparison task. In addition, we found no significant effect for physical size and magnitude, indicating a lack of size congruity. Similarly, there was no significant effect of magnitude - response side interaction in Experiment 2. The other nonsignificant results in Experiment 2 may be due to the absence of SNA because oculomotor movements suppress the resources of the magnitude comparison task. Overall, these findings contribute to a broader understanding of spatial cues and cognitive control mechanisms and their impact on SNAs with different motor movements.

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APPENDICES

APPENDIX A- Participant Consent Form

Katılımcı no: ……..

Katılımcı İzin Formu

Bu çalışma kesirli sayıların büyüklük uzam ilişkisi kapsamında incelenmesi amacıyla yapılmaktadır.

Çalışma sırasında bilgisayar ekranında sunulan görsel uyarıcılara bilgisayar klavyesinin tuşları aracılığıyla tepki vermeniz beklenmektedir. Çalışma boyunca ekrandan sunulan yönergeleri dikkatlice okumanız ve sizden istenenleri olabildiğince doğru bir biçimde yerine getirmeniz gerekmektedir.

Çalışma kapsamında katılımcılardan elde edilen veriler isim kullanılmaksızın analizlere dahil edilecektir. Katılımınız araştırma hipotezinin test edilmesi ve yukarıda açıklanan amaçlar doğrultusunda literatüre sağlayacağı katkılar bakımından oldukça önemlidir. Ayrıca katılımınızın psikoloji alanının gelişmesi açısından da pek çok faydası bulunmaktadır.

Çalışmaya katılımınız tamamen kendi isteğinize bağlıdır. Katılımı reddetme ya da çalışma sürecinde herhangi bir zaman diliminde devam etmeme hakkına sahipsiniz. Eğer görüşme esnasında katılımınıza ilişkin herhangi bir sorunuz olursa araştırmacıyla iletişime geçebilirsiniz. Eğer deney sonrasında aklınıza takılan bir soru olursa aşağıdaki e-mail adresine yazabilirsiniz.

Araştırmacının e-mail adresi:

Okudum, kabul ediyorum.

Katılımcının imzası: …………………….

Katılımcı no: ……..

Çalışmanın amacını ve içeriğini ….. numaralı katılımcıya açıklamış bulunmaktayım. Çalışma kapsamında yapılacak işlemler hakkında katılımcının herhangi bir sorusu olup olmadığını sordum ve katılımcı tarafından yöneltilen bütün soruları yanıtladım.

Tarih ....……………………… Araştırmacının imzası ……………………….

Çalışmanın amacı ve içeriği hakkında açıklamaların yer aldığı "Katılımcı İzin Formu"nu okudum. Araştırmacı çalışma kapsamındaki haklarımı ve sorumluluklarımı açıkladı ve kendisine yönelttiğim bütün soruları açık bir şekilde yanıtladı. Sonuç olarak, uygulama esnasında şahsımdan toplanan verilerin bilimsel amaçlarla kullanılmasına izin verdiğimi ve çalışmaya gönüllü olarak katıldığımı beyan ederim.

Tarih ………………………. Katılımcının imzası ……………………….

APPENDIX B- Participant Information Form

Katılımcı no: ……….

Katılımcı Bilgi Formu

Yaş: ………….

Cinsiyet: ………………

Bölüm: ………………………

Yazışma adresi (telefon numarası ya da e-posta adresi): ………………………………….

1. İki dilli misiniz?

☐ Evet ☐ Hayır

Yanıtınız Hayır ise lütfen ana diliniz belirtiniz…………………….

2. Düzeltilmemiş bir görme bozukluğunuz var mı?

☐ Evet ☐ Hayır

3. Daha önce psikiyatrik/psikolojik bir rahatsızlık tanısı aldınız mı?

☐ Evet ☐ Hayır

Yanıtınız Evet ise lütfen konulan tanıyı belirtiniz…………………….

4. Daha önce nörolojik bir rahatsızlık tanısı aldınız mı?

☐ Evet ☐ Hayır

Yanıtınız Evet ise lütfen konulan tanıyı belirtiniz…………………….

5. Herhangi bir ilaç kullanıyor musunuz?

☐ Evet ☐ Hayır

Yanıtınız Evet ise lütfen ilacın adını belirtiniz…………………….

6. Daha önce kafa travması geçirdiniz mi?

☐ Evet ☐ Hayır

7. Aşağıda belirtilen bozukluklardan herhangi birine dair tanı aldıysanız lütfen işaretleyiniz (Birden fazla işaretleme yapabilirsiniz).

☐ Disleksi ☐ Diskalkuli ☐ Uzamsal İhmal

8. Daha önce laboratuvarda yürütülmüş bir psikoloji deneyine katıldınız mı?

☐ Evet ☐ Hayır

Yanıtınız Evet ise deneyin ne ile ilgili olduğunu kısaca belirtiniz.

……………………………………………………………………………………

APPENDIX C- Edinburgh Handedness Inventory

Edinburgh El Tercihi Envanteri

Lütfen aşağıdaki tabloda ilk sütunda sıralanmış olan aktiviteleri yaparken veya söz konusu aletleri kullanırken hangi elinizi tercih ettiğinizi ilgili sütundan işaretleyiniz.

	Her zaman sol	Genelde sol	Tercihim yok	Genelde sağ	Her zaman sağ
Yazma					
Fırlatma					
Makas					
Diş fırçası					
Bıçak					
Kaşık					
Kibrit					
Mouse					