TESTING THE NUMBER-SPACE COMPATIBILITY WITH A MODIFIED VERSION OF THE NUMERICAL STROOP TASK

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A Thesis Submitted to

The Graduate School of Izmir University of Economics

Master Program in Experimental Psychology

İzmir

2020

ABSTRACT

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July, 2020

This thesis was aimed to investigate the inhibitory response effect on number-space compatibility in a modified version of the Numerical Stroop task. Accordingly, through different instructions, two different tasks (Magnitude and Numerical Judgment) were applied regarding the N-S compatibility (manipulated the spatial position of the digits; smaller-left or bigger-right: compatible, smaller-right or bigger-left: incompatible), Stroop congruency (manipulated the repetition frequency; repeated as own value-congruent, repeated as the value of compared number-incongruent) and NDE (the numerical distance between reference and probe number ("5"): far-big, close, and far-small). Thus, the task consisted of four different stimulus categories: N-S compatible-Stroop congruent (e.g. 22 55555), N-S compatible-Stroop incongruent (e.g. 22222 55), N-S incompatible-Stroop congruent (e.g. 55555 22), and N-S incompatible-Stroop incongruent (e.g. 22222 55) that were presented in three distance categories. The number of correct judgments and reaction time were recorded as dependent variables. Multilevel analysis was used to examine the possible main and interaction effects by including each variable and its interactions one by one into the model, related with the hypotheses. Results indicated for both tasks that when the stimuli in "close" distance category were presented as incongruent-incompatible, moreover, when the presented stimuli is in "far-big" distance category compared to "far-small", significantly slower and less accurate reactions were obtained. The significant effect of numerical distance between the probe and the reference number, plus, the effect of numerical magnitude is accepted as an indicator of the mental number line which explains the number-space association with an analogical coding system of the brain.

Keywords: number-space compatibility, the SNARC effect, Numerical Stroop task, mental number line, inhibitory processes, cognitive control.

ÖZET

SAYI-UZAMSAL KONUM UYUMUNUN SAYISAL STROOP BENZERİ GÖREVDE TEST EDİLMESİ

Yavuz, Günce

Deneysel Psikoloji Yüksek Lisans Programı

Tez Danışmanı: Prof. Dr. Seda DURAL ÇETİNKAYA

Temmuz, 2020

Bu tezde, Sayısal Stroop görevinin değiştirilmiş bir versiyonu kullanılarak Sayı-Uzamsal Konum Uyumu üzerindeki ketleme etkisi iki farklı değerlendirme görevi (Miktar ve Sayı Değerlendirme) ile test edilmiştir. Bu doğrultuda sunulan uyarıcılar Sayısal Uzaklık Etkisi (uzak-büyük, yakın ve uzak-küçük) göz önünde bulundurularak hazırlanmış olup, Sayı-Uzamsal konum uyumu (miktar değerlendirme görevinde az tekrar eden rakamın sol uzamsal alandan sunulması: uyumlu (örn. 55 22222) ve sayı değerlendirme görevinde daha küçük olan rakamın sol uzamsal alandan sunulması: uyumlu (örn. 22222 55), tam ters durumlar uyumsuz) ve Stroop ketleme etkisine (her iki görev için de sunulan rakamların kendi rakamsal değerleri kadar tekrar etmesi: tutarlı (örn. 22 55555), sunulan rakamların birlikte sunulduğu rakamın rakamsal değeri kadar tekrar etmesi: tutarsız (örn. 22222 55)) göre sunulmuştur. Böylece dört farklı uyarıcı kategorisi: Sayı-Uzamsal Konum uyumlu – Stroop tutarlı (örn. 22 55555), Sayı-Uzamsal Konum uyumlu – Stroop tutarsız (örn. 22222 55), Sayı-Uzamsal Konum uyumsuz – Stroop tutarlı (örn. 55555 22) ve Sayı-Uzamsal Konum uyumsuz – Stroop tutarsız (örn. 22222 55) olarak oluşturulmuştur. Doğru cevap yüzdesi ve tepki süresi, bağımlı değişkenler olarak kaydedilmiş, ve Çok Aşamalı Model, ana etkiler ve etkileşim etkileri oluşturulan hipotezler doğrultusunda değişkenleri sırasıyla modele dahil ederek oluşturulmuştur. Sonuçlar incelendiğinde, Stroop görevine göre tutarsız ve Sayı-Uzamsal Konuma göre uyumsuz denemeler Sayısal Uzaklık Etkisi'ne göre "yakın" olarak sunulduğunda, ayrıca, "uzak-küçük" uyarıcılara kıyasla "uzak-büyük" uyarıcılarda tepki süresinde anlamlı bir düşüş, hata yüzdesinde bir artış bulunmuştur. Buna göre anlamlı Sayısal Uzaklık Etkisi ve Büyüklük Etkisi, Sayı-Uzamsal Konum Uyumu etkisini analog kodlama sistemi olarak gören Zihinsel Sayı Doğrusunun varlığını destekler nitelikte olduğu söylenebilir.

Anahtar Kelimeler: sayı-uzamsal konum uyumu, SNARC etkisi, Sayısal Stroop görevi, zihinsel sayı doğrusu, ketleme etkisi, bilişsel kontrol.

To life with endless opportunities

And the two men who are the greatest of all…

ACKNOWLEDGMENTS

First I would like to express my gratitude to my supervisor, my lecturer Prof. Dr. Seda DURAL ÇETİNKAYA. I've learned so much from her since 2012, the time I started my undergraduate education, until the time I am finalizing my thesis, and in the future, hopefully. Through her guidance and the experience she conveyed, this journey is ending in the best way possible.

I also would like to thank Prof. Dr. Canan BAŞAR EROĞLU for her luminous energy, graciousness, and warmhearted welcoming whenever I fall into despair. It was a great pleasure to witness someone who loves and does her job with passion. I am much obliged for the scientists she raised up to now and still have been raising. It is an invaluable opportunity to be one of those.

I would like to send my special thanks to Assoc. Prof. Seda CAN not only for the support for this thesis but for the guiding spirit she scatters. As I am moving forward towards the career that I am dreaming of, I know that all the knowledge I gained from her is inestimable.

I owe my other lecturers a debt of gratitude for every contribution they made for me to improve. Prof. Dr. Hakan ÇETİNKAYA for guiding me with his wisdom and inspiring me with the lectures he gave, during my undergraduate education. It was so great to learn from you, I wish I will have a chance to learn more. Assoc. Prof. Burak ERDENİZ, Asst. Prof. Yasemin MERAL ÖĞÜTÇÜ and Asst. Prof. Nevra CEM ERSOY, for enlightening me with their knowledge. It was a great opportunity for me to both learn from all those great scientists and also work with them.

My dear friends Ilgım HEPDARCAN SEZEN and Merve BULUT, we surpass the last three years, side by side, every day. Thank you for everything you made, those were the memories that I will never forget. Ezgi PALAZ, my dear friends, the person I have known for a long time. It was so great to know you better. And Mert KÜÇÜK…my dear friend, my companion. Thank you for all the support in and out of the class. I hope we will see each other soon, and I hope the effort you put on your work results in the best way.

I want to thank my family, my dad Cengiz YAVUZ and my mom Nurcan YAVUZ. Dad, if I am here writing these words, it is all because of you. Thank you for believing me from the beginning, in every step of my life. You are a true gift to me and mom, even though I feel disinclined from time to time, I always tried to follow what you taught to me and I always saw its benefits. I am so grateful for your endless effort to make my life amazing, you succeeded. I also would like to thank my family with paws Zeze, Pina, Piknik, Şeker, Tonik, and Miço. I love all of you so much. Even if it cannot be in a direct way, you were and will always influence my life in the best way.

Last but not least, my dear, Tolga ERGİYEN. It is always a pleasure to share this journey, every journey with you. Thank you for being with me from the very beginning until the last moment of this adventure. I've always fascinated with your goodwill, and the greatest energy you scatter not only to me but all the people around you. The power you give clears my way from all the drawbacks, I cannot even imagine how hard it would be without you.

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CHAPTER 1: INTRODUCTION

In this thesis, the behavioral outcomes of the number-space association were examined in a modified version of the Numerical Stroop task. Before getting the lowdown on the information about the inhibitory processes involved in the number-space compatibility, initially, how do we perceive the numbers and in which manner we visualize them in our minds?

1.1. How the Numbers are Associated with the Space

When we hear the word "fifty-six", do we automatically visualize the figure of "56"? Or while multiplying, adding, subtracting, or dividing the numbers, do we first visualize, and then operate a specific arithmetic process? If ever we do that, in which manner we visualize them? In 1880, J. Francis Galton, for the first time, asked the question of "How do we visualize the numbers?" and opened the doors to a new field of study that was worth searching further. The self-reports that Galton gathered for his article *Visualized Numerals* revealed that, while visualizing the numbers, people tend to generate a variety of so-called unconscious and automatic strategies. The critical question is, are these strategies indeed unconscious and automatic? Or is there an evanescent period of consciousness?

How individuals differ while visualizing numbers is strongly affiliated to how their mental representations evoked (Galton, 1880), accordingly, while some people reported their mental representation of the numbers in a clock-like manner (mostly for the numbers from one to twelve) (Figure 1A), some of them reported that numbers are ordered in an ascending/descending scale (Figure 1B, and 1C), as a straight line (Figure 1D, and 1E), on a line in which some colors and/or shades were associated with numbers (Figure 1F), or as the months of the year/days of the week (Figure 1G) (Galton, 1880a & 1880b; Bertillon, 1882, as cited in Seron, Pesenti, and Noel, 1992). The trustworthy and carefully reported remarks in Galton's work were the preliminary indicator of the variation in visualizing numbers, hence, further studies intended to determine some specific characteristics to attain certain distinctions between these mental organizations.

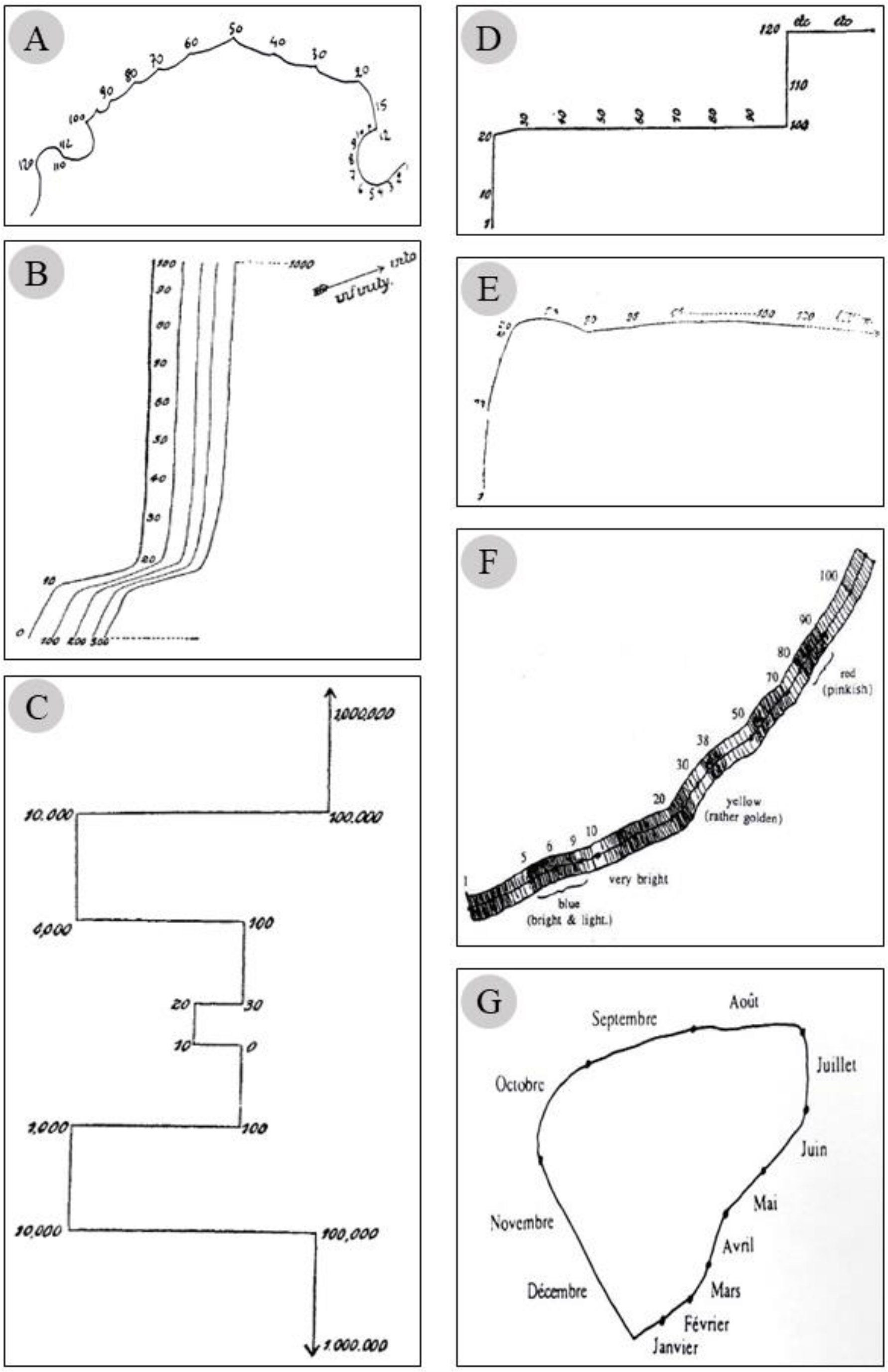

Figure 1. (A) Clock-like arrangement between one and 12 and the numbers after 100, (B) an ascending order, following with an infinite line after 1000, (C) both ascending and descending orders with flexible intervals, (D and E) a straight line from left-to-right in which the number 19 is smaller than the rest, (F) with fluctuation in brightness and colors, and (G) months on a distorted circle. (Source: Galton, 1880 and Seron, Pesenti, and Noel, 1992).

Seron et al. (1992) provided more substantial evidence to Galton's remarks, by defining common characteristics to the variety of number representations. Between different mental organizations such as clock-like, straight line, associated colors, associated months of the year/ days of the week… etc. there is a common ground! The numbers are occupied in the same position. In other words, regardless of the structure of the representations, the same colors, shades, locations, or sizes were assigned to specific numbers. In order to ascertain the underlying mechanisms, Seron et al. (1992) conducted a series of experiments. Initially, they collected all possible representational aspects of numbers through a short questionnaire. Results indicated two main aspects of number representation: (1) Number Form (NF) and (2) Colored codes, associated images, and synaesthesia (a stable cross-modality imagery (Baron-Cohen et al., 1987)). Consistent with the remarks of Galton, a significant number of people reported that they mentally represent numbers in a NF, hence, the NF's varied in respect to their structure. Accordingly, some of the cases reported that they visualized the numbers on a horizontal line (Figure 2A) while others referred to a vertical line, in which the background color specifies the distinctiveness of the number (Figure 2B). Moreover, some cases reported a clock-like organization of numbers between one and 12, besides, others representation indicated more of a grid form where an ascending column organization was followed until number 99 (Figure 2C). Despite that, among the subjects that were associated colors and/or shades with numbers (Figure 2D), stronger number-color associations were found for the numbers below 10 or 12 and decades (e.g. 20, 40, 50, 70 …etc.), to construct an immediate and automatic semantic linear order. Seron and colleagues (1992) conducted a further study in which the two cases (number representations of NF, and colored codes), were compared with the subjects that did not report any kind of number representation, by the generalizability of their mental imagery. The results were sufficiently striking! For the second case, which had the number representation of the number-color association, the results were not generalizable. The subjects were not consistent with the associated colors after number 12. Thus, a personal strategy has been followed. However, for the first case (had the NF representation) a between-subjects consistency with Galton (1880a, 1880b, 1883); Bertillon, (1880, 1881, 1882) as cited in Seron et al. (1992), and Spalding and Zangwill (1950) were found regarding the decade boundary, the fuzziness of the far number/clearness of the close number, and the clock-like organization. Based on these

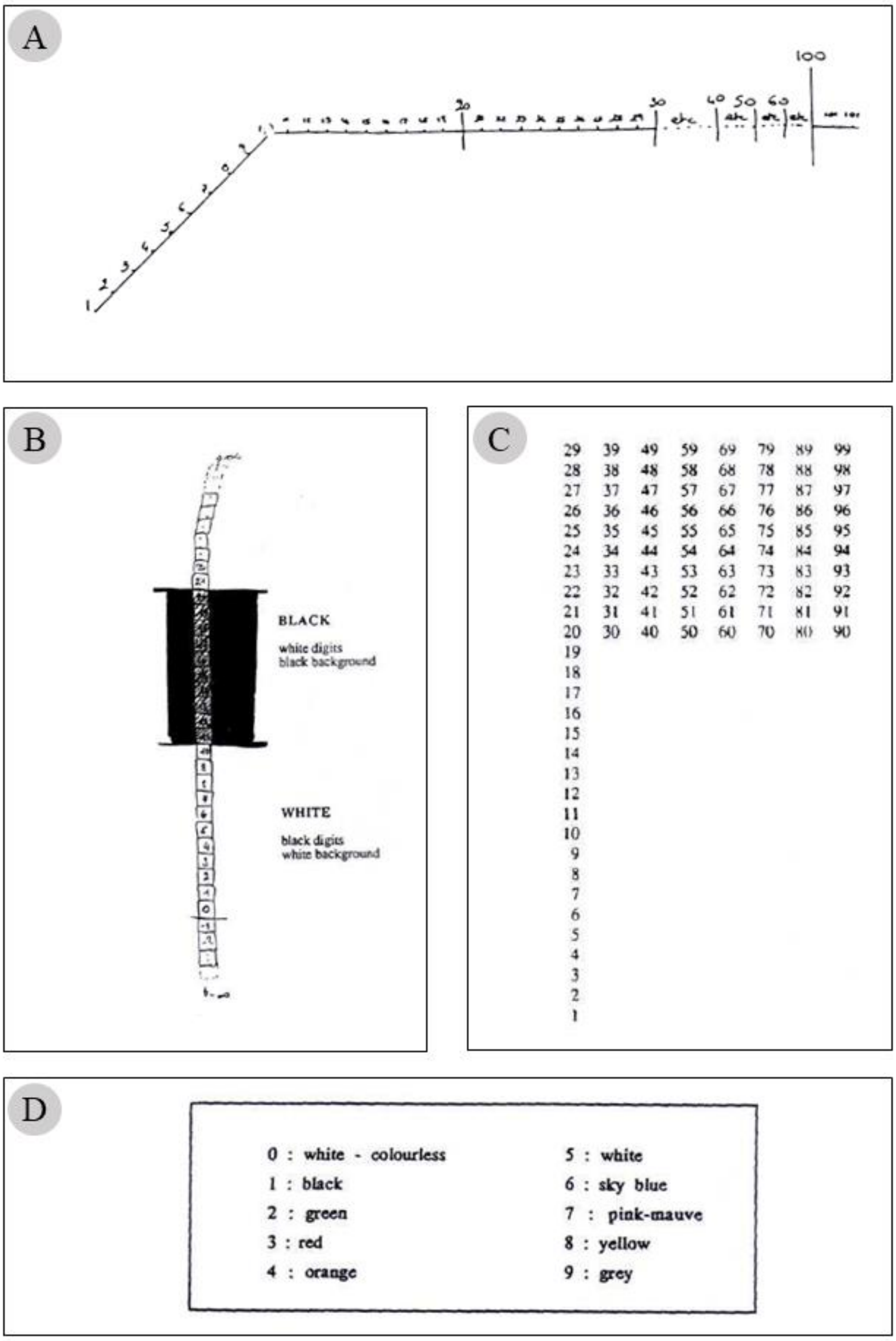

Figure 2. (A) A horizontal graduate line, (B) a vertical line divided with boxes, (C) on a grid number form, and (D) associated colors with numbers. (Source: Seron, Pesenti, and Noel, 1992; page 166 and 167).

it can be said that there is a prominent sign of a number processing procedure. But, how do we process this numerical information?

As an answer to that question, four different models of the human numerical cognition were propounded. In 1985, McCloskey and colleagues, formed the *McCloskey's model* that initiated the first explanation of human number processing. The model tells us that, how we mentally represent numbers is by translating each numerical input (verbal numbers and/or Arabic numbers) into an amodal abstract representation (Figure 3A), yet, how we access them later (for instance during mental calculations) is not directly as verbal or Arabic numbers, but again through an amodal abstract representation of these numbers. Years later, the second model was propounded by Noel and Seron (1992), *the preferred entry code hypothesis*. According to them, all numerical input is first transcoded into a unique notation. In other words, the verbal number inputs transcoded into verbal codes and Arabic number inputs into Arabic number codes. And so, how we access them was related to the one's number-related knowledge (Figure 3B). Nevertheless, what if the individual differences were included in the coding system? Or, what if some individuals have an auditory coding system, but others have a visual coding system? The *Interactive model* proposed by Campbell and Clark (1988, 1992) behaves as all numerical codes are interconnected, even the given input is in an Arabic format or verbal format, how we access the mental representation of the input is by interconnecting between two systems (Figure 3C). The final explanation was formed by Dehaene (1992), a *Triple-code model (TCM)* for numerical cognition. According to the TCM, each specific input code was tied to a specific output code. Thus, unlike the McCloskey's model, we cannot talk about an amodal representation, but, as defined by Dehaene (1992), the number processing is an interrelated act of auditory-verbal code (which uses language modules that follows an analogue word sequence), visual Arabic code (in which the numbers are manipulated by Arabic format), and analogue magnitude code (in which the numbers are activated over an analogical mental number line) (Figure 3D).

Regarding all the information above, what can be deduced is that, even there was a variety in the structure of the mental number arrangement and even if a score of people visualize the numbers by associating them with a corresponding color, a significant number of people predominantly visualize the numbers by assigning them to specific spatial locations, regarding their numerical magnitudes. What could be the

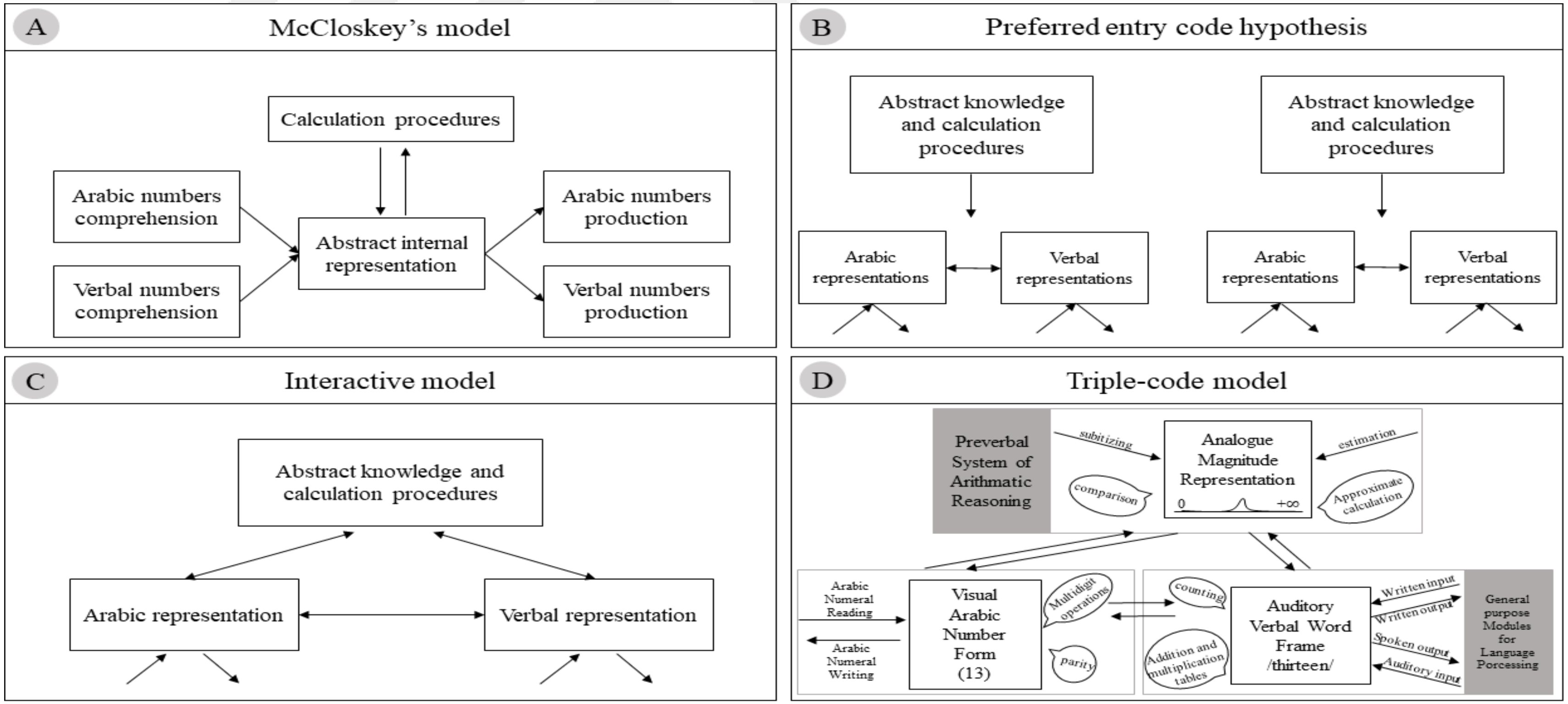

Figure 3. Schematic representation of (A) McCloskey's model, (B) Preferred entry code hypothesis and (C) Interactive model, and (D) Dehaene's Triple-code model. The figures were illustrated based on Dehaene, 1992; page 28 and 31.

behavioral consequences? Do you think that this tendency of locating the numbers into specific places in space regarding their numerical value might facilitate the given reaction towards them?

1.2. Spatial-Numerical Associations of Response Codes (The SNARC Effect)

In 1993, Dehaene, Bossini, and Giraux showed a phenomenon in which the small numbers were associated with the left hand, and larger numbers were associated with the right hand. The effect was first noticed in a parity judgment task, where the participants were asked to make comparisons upon numerical stimuli and respond to target stimulus which can be either odd or even, by pressing one of the two keys that were determined to be either in the left or right. Results indicated a strong relationship between the response side and number magnitude (experiment 1). Participants respond significantly faster to the smaller numbers (e.g. "0" or "1") with their left hand and the larger numbers (e.g. "8" or "9") with their right hand. In order to see whether the effect was expandable to the variety of numerical/non-numerical formations or not, a series of following studies were conducted upon two-digit Arabic numerals (numbers from 10 to 99) (experiment 2), different numerical intervals (0-5 interval and 4-9 interval) (experiment 3), letters (ACE-BDF as isomorphic to the numbers from zero to five) (experiment 4), left-handers (to assess the effect of handedness) (experiment 5), crossed hands (experiment 6), Iranian subjects (to assess the direction of reading and writing) (experiment 7), normal and mirror images (to assess the nature of the notation) (experiment 8), and Arabic and verbal numerals (numbers from zero to 19) (experiment 9) (Figure 4). Between all the experiments, participants who were asked to make a judgment upon two different intervals (0-5 and 4-9), who were left-handers, and the stimuli which were presented as normal and mirror image, showed a strong tendency to associate the numerically smaller digits with the left-hand response and larger digits with the right-hand response, correspondingly revealed faster and more accurate response when the stimulus presentation and response hand were associated. The authors then designated this behavioral tendency as the Spatial-Numerical Association of Response Codes (the SNARC effect). Besides, the information on which conditions the SNARC effect did not occur was at least as important as the conditions where the effect occurred. For the second and the ninth experiments, where the participants were required to respond to two-digit Arabic numerals, the SNARC

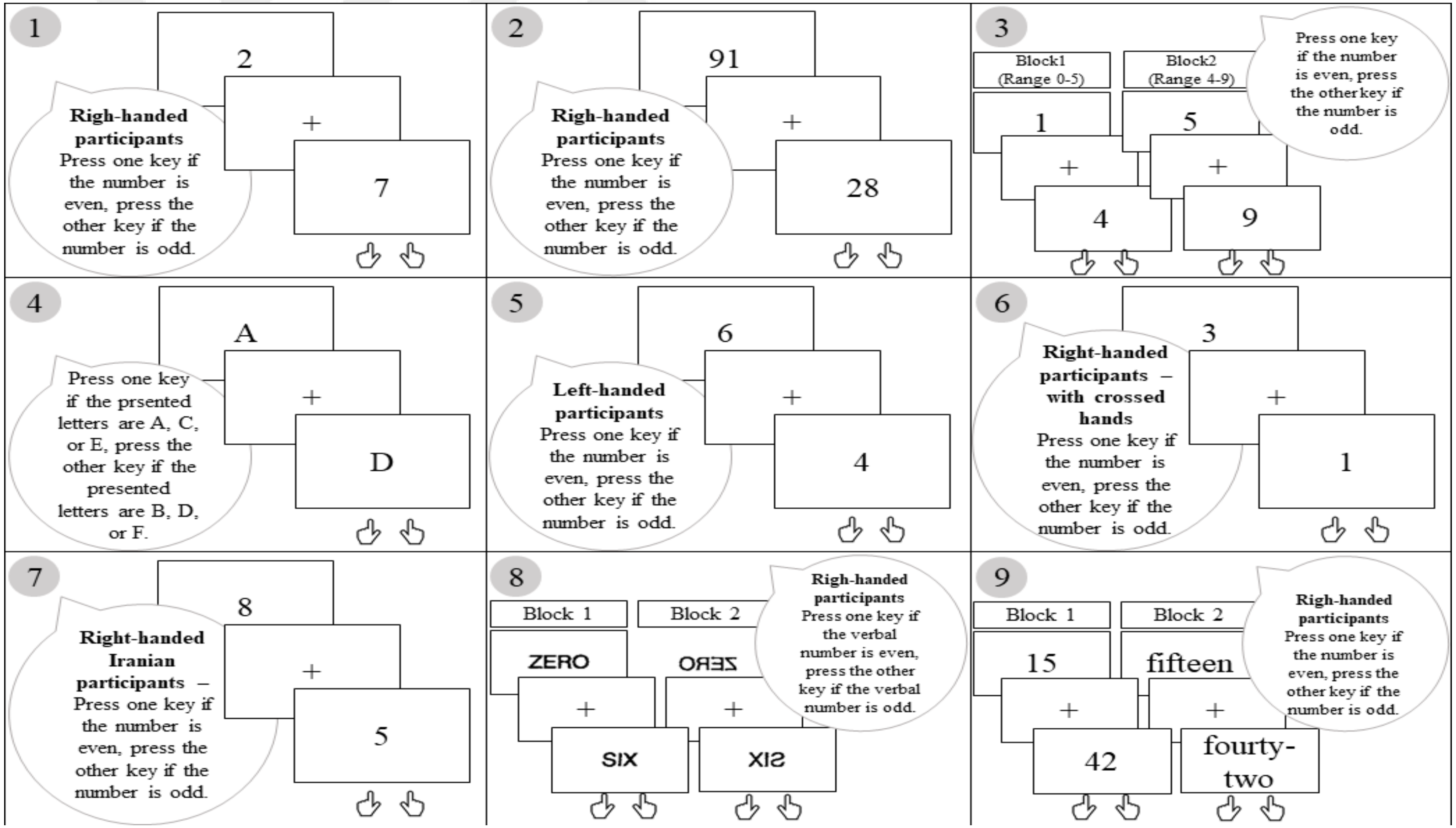

Figure 4. An illustration of all experiments of Dehaene et al. (1993) which were designated in reference to the original work. The determined keys for all the experiments were located either on the left or the right side of the keyboard to create a response side preference.

effect was not confirmed, plus, the results were directed the experimenters to make their interpretation by considering the effect of the rightmost digit. Most probably, the subjects made their judgments by considering only the rightmost digit, hence, the effect is not generalizable to two-digit Arabic numerals. The finding of the fourth experiment was determinative regarding generalizability of the effect among non-numerical formations. Yet, results indicated a non-significant SNARC effect. Consequently, the effect was interpreted as being specific to numbers. Lastly, for the sixth and the seventh experiments, the experimenters tried to clarify what would happen if contrary conditions were created. Would the effect disappear or be reversed? Results revealed for the sixth experiment that, when the response hand was manipulated, the effect was accentuated (not reversed, not diminished). So, there is no hand preference, but a response side preference exits. Finally, for the seventh experiment, where the Iranian subjects participated, the *reversed SNARC effect* was found (see 1.5.3. Left-to-right or Right-to-left Orientation: The Effect of Script Directionfor a detailed information). Participants responded to smaller numbers faster with their right hand, and larger numbers with their left hand. Each examination revealed very valuable results to the experimenters to draw some boundaries (when we see and when we cannot see the effect).

As it was seen from a very widely scaled series of experiments, the SNARC effect is quite robust to some different numerical notations, hence, depending on the conditions, the power of the effect may increase, decrease, or reversed.

1.3. Different Explanations for the SNARC Effect

1.3.1. Polarity Correspondence Principle

Polarity correspondence principle reveals on one hand, a positive polarity (+) if the stimulus and the response alternatives correspond, on the other hand, a negative polarity (-) if these sets of stimulus and response alternatives do not correspond. Regarding this, to clarify the principle within the scope of the SNARC effect, it is necessary to address the third study of Dehaene (1993), which was briefly explained above (see section 1.1.2.), once again, in more detail. "Do we associate numbers with specific locations depending on their absolute characteristics?" The findings of Dehaene (1993) pointed to the answer, no. When it was required from the participants to make an odd/even parity judgment by using the determined keys for the left and right side responses, upon two different intervals (0-5 and 4-9), it was found that the numbers "4" and "5" (that were included in both intervals) were judged relative to the stimulus set. In other words, these two numbers were associated with the left-side response when they were numerically located on the extreme left (4-9 interval) and right-side response when they were located on the extreme right (0-5 interval). The underlying mechanism was interpreted regarding *the spatial correspondence effect* in which the small numbers were associated with negative polarity and bigger numbers were associated with positive polarity. Yet, does that polarity contain only a continuum that follows a horizontal line? Ito and Hatta (2004) conducted two experiments that examined the effect of polarity correspondence through a horizontal and a vertical line. Both results yielded the SNARC effect. So that, the interpretation of the SNARC effect within the context of the polarity correspondence account refers not *only* to a left-to-right continuum, but also refers to a coding system where the large numbers are associated with positive, and small numbers associated with negative polarity.

1.3.2. Dual-Route Architecture

Very complex tasks, such as Simon (Simon, 1969), Eriksen Flanker (Eriksen and Eriksen, 1974), or Stroop (Stroop, 1935) require a parallel processing of two different routes; (1) automatic spatial coding and (2) activation of task-dependent instructions. Accordingly, if the task instruction and the stimulus location activate the same response codes (compatible), a relatively faster and more accurate responses are obtained. Yet, if those aspects activate the opposing codes (incompatible), relatively slower and less accurate responses are obtained. What about the SNARC effect? Do the underlying mechanisms of the effect might follow a similar process with the above-mentioned model?

To clarify this, Gevers et al. (2006) conducted alternate experiments, in which the model was tested within the context of the SNARC effect by using single-digit numbers between one and nine (except the reference number five). Results indicated a significant SNARC effect, regardless of the task (whether parity judgment or magnitude comparison tasks). However, while for parity judgment task continuous results were revealed, for magnitude comparison task, a categorical shape was obtained. Why? During a parity judgment, each number is coded to a corresponding parity status, however, the magnitude comparison task uses a type of categorization that counts only the greatness or the smallness of the number. The nature of this finding was accepted as the results of distance and time course effect (one of the indicators of the dual-route architecture). In the following experiment, an arbitrary mapping task, which is very similar to parity judgment, was presented to assess the switch between stimulus-response mappings, as in the first experiment. Once again, the SNARC effect was supported. In furtherance, to present robust evidence to the scientific standpoint of "the SNARC effect is processed by using a dual-route architecture", Gevers and his colleagues (2006) conducted another experiment that revealed both behavioral and electrophysiological outcomes for the model implication. Substantial evidence gathered through behavioral data. Accordingly, reaction time for the small numbers decreased when participants respond with their left hand, and for the big numbers, the reaction time of the participants decreased when respond with the right hand. In a similar vein, the results of the electrophysiological analysis indicated a dual-route architecture as well. While the early latency of P300, the speed of stimulus classification to discriminate one event from another (Sur and Sinha, 2009), did not differ across compatible and incompatible trials, the deflections in Lateralized Readiness Potential (LRP) (the preparation and execution of motor response) did differ. In other words, when the participant was prepared to give a response with their left hand, a larger potential is found over the corresponding brain area, the precentral gyrus.

1.3.3. Mental Number Line Account

Moyer and Landauer (1967), in their seminal work, found that, as the numerical distance between two numbers decreases, both the reaction time and the error percentage of the response automatically increase, due to the so-called numerical distance effect (NDE). From that study forward, the effect was reviewed and represented several time consistently in behavioral (Dehaene, Dupoux, and Mehler, 1990; Duncan and McFarland, 1980; Sekuler and Mierkiewicz, 1977), and neuronal (Nieder, Freedman, and Millner, 2002; Pinel et al., 2004) researches. To investigate the underlying mechanisms of NDE thoroughly, Restle (1970), approached the subject within the scope of three elementary theories: (1) simple memory search (2) a digital system and (3) an analog system. According to the interpretations of the experimenters who were searching NDE further, such as Grohen (1967) and Suppes, Hyman, and Jerman (1967), most likely, the process should be more than a simple memory search, yet, none of them were precise on whether a digital or an analog system is involved. Nonetheless, both the results of Moyer and Landauer (1967) and Restle (1970) referred to the existence of an analog system, moreover, according to Restle (1970), that analog system uses a number line. Starting from this point of view, Piazza et al. (2004) analyzed the effect within the context of the overlap between two numbers. Accordingly, presenting a single number does not activate that number itself, but also activates the neighboring numbers. Therefore, the closer two comparison numbers are, the more overlap (because of the more shared neighboring numbers) exists. As an alternative account, van Opstal et al. (2008) addressed the issue from the point of a decision-making process. In this respect, the NDE, in a simple comparison task, exists as a consequence of the relationship between stimuli and response nodes. Hence, if the two numbers are numerically close, both response nodes were activated similarly (monotonous increase) and this competition results in a delay in reaction time.

The other determinant of the N-S association is the *size effect*. In reference to the Weber-Fechner law, the perceived intensity is proportional to the logarithm of the stimulus (Portugal and Svaiter, 2011). In other words, the difference between the two numbers perceived differently by the magnitude of numerical values (Moyer and Landauer, 1967; Restle, 1970). From this point of view, what size effect states that, the discriminability between two numbers decrease, as the numerical values of those numbers increase even though the numerical distance remains constant, such as the discriminability between "1 and 2" compared to "8 and 9" (Dehaene and Changeux, 1993). The effect was consistent when it was applied to different age groups, (Siegler and Robinson, 1982), in different research methods (Dehaene, 1989; Nieder and Miller, 2003 & 2004; Nieder et al., 2002; Reynvoet and Brysbaert, 2004; Reynvoet, Brysbaert, and Fias, 2002), notations (Dehaene, 1990; Koechlin et al., 1999; Buckley and Gillman, 1974) and across non-human animals (Platt and Johnson, 1971; Cantlon and Brannon, 2006; Nieder and Miller, 2003). But by which process is this accomplished? Is the effect occurring as a result of an analog system as NDE or is there another process involved? To find and answer to that question, Krajcsi and his colleagues (2018), compared two possible explanations of the number processing system (analog number system (ANS) and discrete semantic system (DSS)). Results addressed to a strong correlation between ANS and DSS. As a consequence, DSS could be accepted as an alternative and more profound explanation to the size effect. Accordingly, how we process the numbers strongly affiliated to an analog system, plus, a semantic system where the connection of different nodes reflects their semantic relations.

Through the knowledge gained by the means of *distance* and *size effects*, it can be said that, in a numerical comparison task, when the numerical distance between two numbers decrease or when the numerical magnitude of those numbers are greater (e.g. 8, 9…etc.), the time required to make decision increases (Moyer and Landauer, 1967; Suppes et al., 1967; Groen, 1967; Dehaene et al., 1993). The logic that lies behind those effects addressed to an analogical coding system of the brain, in which the numbers are formed as *quantities*. In a sense, what we simply do while deciding on which number is the greater or smaller than the compared number is by comparing those quantities in the brain. Restle (1970), provided shreds of evidence to this mechanism considering the adding and comparing processes. Accordingly, while we are comparing A + B vs C, gradually, we calculate and/or approximate the distance of A, B, A + B, and C from the origin; OA, OB, O (A + B), and OC. If O (A + B) and OC falls under the same region, in other words, if the different magnitudes create *sub-set of units*, close numbers overlap and a delay in reaction time occurs.

If we accept the correctness of the MNL as the explanation of the SNARC effect, there is still a remaining question. If an MNL exists, what is the direction of the orientation of the line? Is that a horizontal line, or a vertical line? A study conducted by Schwarz and Rabeling (2004) implemented their evidence by presenting more concrete results, through the instrument of an Eye-tracker device by counting both manual and saccadic responses. Results were in furtherance with the behavioral SNARC effect. For the smaller stimulus, eye movements showed an earlier left starting movement, whereas, for the larger stimuli, earlier right starting movement was observed.

1.3.4. Working Memory (WM) Account

WM is the process that keeps limited information active for a short amount of time (Baddeley and Hitch, 1976). The system is composed of attentional control and central executive systems (Figure 5A) that collaborates with three sub-systems: phonological loop (verbal information storage), episodic buffer (later added in Baddeley, 1996) and visuospatial sketch-pad (visual information storage) (Baddeley, 1986) (Figure 5B). Accordingly, how does the system work for numerical information? In a numerical comparison task, the spatial information of the number temporarily represents in visuospatial sketchpad (Figure 5 C and D). Consequently,

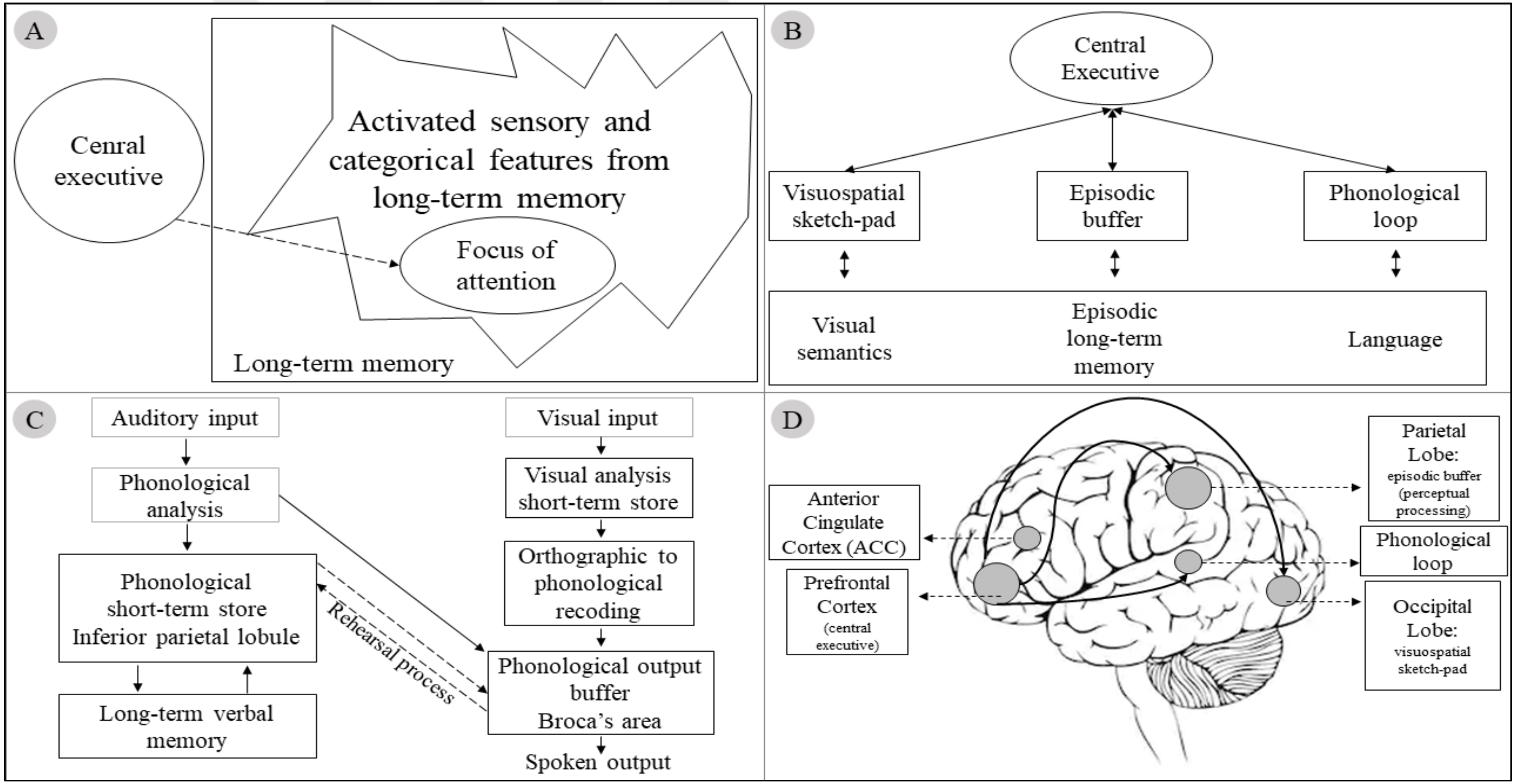

Figure 5. Adapted from the multicomponent WM model by Baddeley, 2010.

depending on the numerical interval of the applied task, the performance of the participant either enhances of decreases. In other words, what evokes the SNARC effect lies behind the retrieval phase from the long-term memory (LTM)?

After the seminal work of Dehaene and his colleagues (1993), studies conducted on number and space association indicated an analogical coding system of the numbers that are organized regarding their numerical proximity (Viarouge, Hubbard, and McCandliss, 2014; Herrera, 2008, Gibson and Maurer, 2016; Lohmann et al., 2018; Chen, Zhou, and Yeh, 2015). However, is it a semantic representation on a horizontal line along a left-to-right continuum as the MNL account propounded? From the beginning, the SNARC effect was investigated through different perspectives and what can be deduced from all these works is, the number-space association is not as stable as the MNL account assumes. Rather, the effect was found to be both interval-dependent (Dehaene et al., 1993), context-dependent (Fischer et al., 2010), and task-dependent (Herrera, 2008). For this reason, even encoding the numbers follows an inherent ordinal structure, the N-S association should not be addressed to inherited reasons. Whereas, the association is constructed during the task execution which is indicated to a system that activates through a *current goal* which addressed to the working mechanism of WM, in fact, the study conducted by Herrera (2008) ensued that, the magnitude of the SNARC effect depends on how available our resources are in WM.

1.4. The Role of Parietal Cortex (PC)

To start with a general information, the role of the PC is to manage the magnitude processing or in other words *the temporal processing*. Moreover, brain imaging studies have demonstrated that the abstract representation of the quantity process is also mediated by PC (Dehaene and Cohen, 1997; Dehaene et al., 1993; Dehaene, 1992; reviewed in Dehaene et al., 2003). From this point of view, the conducted researches (reviewed in Colby and Goldberg, 1999) on N-S association in PC were found that the brain region that is responsible for number processing, at the same time responsible for processing spatial information, in fact, Dehaene and his colleagues (2003), in their review, addressed to a region of PC that is involved in the numerical representation of numbers, the *intraparietal sulcus* (IPS), more specifically, the horizontal segment of the IPS; the HIPS.

In a similar manner, a neuroimaging study conducted among the hemi spatial (representational) neglect patients also addressed to the role of HIPS, especially the right lobule (Zorzi et al., 2012). Plus, the activation of HIPS, in general, is related with spatial manipulation of numbers, and this activation was greater when a non-numerical scales/objects were presented as stimuli (Schütz-Bosbach, Haggard, and Fadiga, 2008) and over the right hemisphere (Pinel et al., 2001; Dehaene, 1996; Harrington, Haaland, and Knight, 1998).

In their work, where the primary focus was to examine the perceived midpoint of the patients with right hemi spatial neglect, Zorzi et al. (2002) were found a leftward deviation for smaller numbers and rightward deviation for larger numbers. Following that study, Rusconi et al. (2008) examined the SNARC and the Simon effects by using Transcranial Magnetic Stimulation (TMS). Nominately, results entailed a posterior parietal lobule (PPL) stimulation, in other words, number and space have a partially shared neural circuit. In another study, Kaufmann et al. (2007) found in a Stroop-like task where the participants should make a judgment upon digit pairs, the size, and the numerical value of the number overlapped in HIPS. Still, in some cases, that were examined by using neurophysiological techniques damage, in the left parietal region can cause disruptions in number processing (Dehaene and Cohen, 1997).

In line with all these information, Dehaene and his colleagues (2003) were defined three criteria that demonstrate that SNARC effect is not culturally shaped, but there is a cognitive mechanism involved: the effect is seen across non-human animals (see 1.5.4. Is Left-to-Right Orientation Human Species-Specific or Not?), infants (pre-school, see 1.5.2. Development of the N-S Association: Age Differences), and human adults, thus, species-independent. In addition, the findings indicated that, for both human and non-human animals, the neurons in IPS are responsible for numerosity encoding, moreover, the magnitude of firing varies regarding the magnitude of numerosity (Nieder and Miller, 2004). In parallel with these information of why SNARC effect is biologically acquired rather than being culturally shaped, Hubbard et al. (2005), reviewed both the behavioral (Fias, Lauwereyns, and Lammertyn, 2001; Fischer et al., 2003; Calabria and Rossetti, 2005; Fischer, 2003; Andres et al., 2004) and neuropsychological (Benton, 1992; Roux et al., 2003; Zorzi, Priftis, and Umilta, 2002; Göbel, Walsh, and Rushworth, 2001) studies to reveal the parietal basis of N-S association. Accordingly, the neural circuitry that enables to orient our attention along the MNL is also involved in the process in which the abstract representation of space is executed: Lateral Intraparietal- Ventral Intraparietal (LIP-VIP circuitry).

What can be deduced from all these studies is, where the spatial updating of the incoming information is processed and transferred the attention along an internal number line, is the same brain region where the arithmetic operations administered. Asserted that, where the number and space is associated and established is a brain region that is responsible for both of the processes, thus, while talking about the consequences of the N-S association, although the effect of culture should not be ignored, the crucial role of PC should be accepted as the primary focus point.

1.5. How was the Number-Space Association Studied?

In the previous sections, primarily, the nature of the N-S association, and later on, the information about the different explanations and the underlying mechanisms of the SNARC effect were covered. Nonetheless, the effect was and still being examined in various contexts. What we know for now is that, even if the effect seems stable as a result of the processing of PC, some examples indicate how the N-S association enhances or reduces its strength or reversed the direction of the effect.

1.5.1. Patient Studies: Examining Different Samples

The left-to-right orientation has been widely studied among neglect patients, due to the corresponding brain region, PC, and among the unsighted subjects, due to the nature of the effect, spatial orientation.

Neglect is caused by unilateral brain damage and can be simply defined as having trouble to be aware of the contralesional side, mostly the left side caused by right brain damage (Parton, Malhotra, and Husain, 2004). Accordingly, when it is asked to place the midpoint in a line bisection task, patients with hemi spatial neglect show a rightward placing tendency because of their impaired awareness of the contralateral side. But, what about the number line?

As a respondent to this question, a study conducted by Zorzi et al. (2002), in which both the right hemisphere damaged (RHD) patients with and without neglect were compared with healthy controls, asked to bisect the MNL to see whether they display a similar pattern with line bisection or not, revealed some important pieces of evidence. RHD patients with neglect showed significantly the highest error rates when compared to other groups. However, more importantly, they also showed significantly the highest rightward deviation from the midpoint in an MNL. This behavioral outcome encourage us to think in a way that, neglect disrupts that MNL, thus, MNL is not just a metaphor, but it has a function as an isomorphism to a physical line. Similarly, Salillas et al. (2009) were examined the effect though a simple Go/No-Go task in which one group of participants were asked to respond to the numbers higher than five, and the other group were asked to respond to the numbers lower than five. Results revealed clear signs of impairment while responding to the stimuli presented in left visual field. Nominately, the response time to numbers lower than five was significantly slower compared to the numbers higher than five for RHD patients with neglect, yet, no such significant results were obtained across RHD patients without neglect and healthy participants. In furtherance with these results, Vuilleumier and colleagues (2004), in a series of studies, had shown that when the participants were asked to make a judgment upon the magnitude of the numbers based on a reference number, for instance *number five*, RHD patients with neglect showed the slowest reaction time when compared to other two groups. Moreover, the reaction time was even slower to number four, which is the closest left side number on MNL. The results were consistent when the reference number was selected from the different parts of MNL, for instance, *number seven*, this time for numbers five and six, an extreme increase in reaction time was observed. These results were the indicator of the lateralized impairment of the left side, plus, the NDE, indeed.

As seen through the previously accounted studies, apparently, this effect is observed more in RHD patients with neglect than RHD patients without neglect. Also, if we consider that the increase in bias is due to a brain injury, it would have seen in both groups. To examine the underlying mechanism of the tendency in patients with PC damage, instead of collecting data from the patients, Göbel et al. (2006) examined the healthy volunteers' TMS stimulation during a naming task with numbers. The results were parallel with both brain imaging and behavioral studies. When the TMS stimulation was on the right posterior PC, the participants showed a rightward deviation. This study explicitly revealed the role of PC, and how the impairment of PC can result in.

As well as the neglect patients, if the topic is approached from a different angle, the effect of *visual experience* should be taken into account. The explanation comes from the visuospatial coding of magnitude, the MNL hypothesis. In our numerical cognition, the numbers are spatially oriented from left-to-right. But what about congenitally blind (blind from birth) individuals? In order to see the effect, participants who were congenitally blind, late blind, and blindfolded (eyes closed) were examined by either the left or right head-turning movement which was determined with a randomly uttered number (Pasqualotto, Taya, and Proulx, 2014). Accordingly, regardless of the group characteristics, all participants generated much smaller numbers. Yet, participants who were congenitally blind were generated significantly more small numbers when their heads were turned to the right, and less small numbers when their heads were turned to the left compared to the other groups. However, when the early blind, sighted, and late blind individuals were tested in a numerical comparison task, although the early blind individuals showed the slowest response time, overall results revealed the SNARC effect (small numbers, faster left-hand response; bigger numbers, faster right-hand response) regardless of the group characteristic. Eventually, the congenitally blind individuals revealed a clear demonstration of the effect of visual experience although there is no brain damage.

1.5.2. Development of the N-S Association: Age Differences

Studies in recent years showed that the building blocks of preverbal numerical cognition are accompanied by an innate numerical mechanism (see the review of Sella, Hartwright, and Cohen Kadosh, 2018) which consists of two fundamental systems: (1) Object Tracking System (OTS) and (2) Approximate Number System (ApNS[1]). The OTS enables human infants to track Spatio-temporal characteristics by providing visual short-term storage capacity of 3-4 items, moreover, enables them to determine the small set of numerosity without counting. Besides, in ANS, numbers are presented on an MNL. Accordingly, ANS is a ratio-dependent analogical system that acts in a logarithmic model (according to Weber's law). In other words, the more the numerical ratio, the less discrimination, in fact, when the ratio approaches zero, it is accepted as the easiest task.

Based on the theoretical background of innate mechanisms of the SNARC effect, to see whether our numerical cognition and knowledge of spatial information is an ascriptive aspect that develops as the age grows or is a learning mechanism that a person can gain with preschool education, 65 children (aged 1 to 3) were assessed by their automatic access to the magnitude and spatial information (White, Szücs, and Soltész, 2012). In order to examine automatic access to magnitude information, the

[1] In the original study, ANS is used but in this thesis, it is abbreviated as ApNS because ANS is used for the analog number system abbreviation.

Numerical Stroop task (Henik and Tzelgov, 1982) was applied. Accordingly, the participants were asked to compare the numerical magnitude and physical size of the digit pairs that were presented through the left and right side of the screen in either zero unit distance (e.g. 1 1), one unit distance (e.g. 1 2) or seven units distance (e.g. 1 8) and in three different sizes (40, 45, and 50 font size). Subsequently, to examine automatic access to spatial information, a parity judgment task was applied in which the participants were asked to decide whether the presented number is odd or even. For both tasks, the participants were asked to press either left or right keys as quickly and as accurately as possible. Results indicated clear SNARC and NDE effects when the numerical magnitude of the number was the main interest. Furthermore, the results of the parity judgment task also showed that, when children (aged 2 and 3) were asked to make a judgment upon spatial locations, the SNARC effect was observed once again. Since those children did not receive a primary school education, the observed SNARC effect should be interpreted as a result of long-term memory (LTM), not a single mechanism because of a default coding system of numerical information. Similar results were obtained when the Give-a-Number task (Wynn, 1990) and size comparison task was applied (Patro and Haman, 2012). In another study, van Galen and Reitsman (2008) examined the age effect by comparing 1st, 2nd and 3rd graders with adult participants by applying two different tasks; Magnitude judgment (have to decide on whether the number is smaller or larger than the reference number "5") and Detection tasks (to detect whether target stimulus is small or big). The results of the Magnitude Judgment task indicated the SNARC effect for all groups. In contrast, for the Detection task, only the 3rd graders showed a SNARC-like effect.

As its seen from the studies exemplified above, MNL is an innate mechanism. Accordingly, even though the children who were not exposed to numerical information (before preschool education), they still can detect, compare, and make judgments upon parity and magnitude of the numerals.

1.5.3. Left-to-right or Right-to-left Orientation: The Effect of Script Direction

In reference to the MNL hypothesis (see 1.1.3.3), while the numbers are spatially oriented from left-to-right on an imaginary number line, small numbers are associated with the left, and large numbers are associated with the right internal representational space. Consequently, when it is required to make a judgment upon the numerical magnitude, the reaction time of the response decreases if the numbers are presented in their associated spatial locations. Could this tendency be only a result of cognitive processes? Even so, are there no external factors that can interfere with our cognitive processes, such as linguistic habits?

In their seventh experiment, Dehaene and his colleagues (1993), examined the effect of spoken language on the SNARC effect among Iranian subjects, whose direction of reading and writing (RW) habit is right-to-left oriented. Accordingly, when it was required to make a parity judgment upon, first, east Arabic numerals and then, west Arabic numerals between zero and nine, participants who were long been exposed to western language showed significant SNARC effect, hence, who were born and lived in Iran showed weaker and reversed SNARC effect (larger numbers were associated with the left visual field). Following that experiment, up until the present time, many studies were conducted to ascertain the explicit effect of language and of course the implicit effect of culture.

To address the role of RW habits and flexibility of spatial mapping of numbers, Shaki and Fischer (2008) investigated the effect by comparing the Russian participants with the Hebrew participants concerning their RW habits. All the participants were required to read a 150-200 word text in either language and to answer questions in a comprehension test. Those participants who displayed high comprehension ability of that language, were accepted to continue to the parity judgment task (odd-even judgment upon numbers from one to nine, except five). On one hand, a significant SNARC effect was observed for both groups, on the other hand, the magnitude of the effect reduced across the participants with right-to-left oriented RW habit. These results were consistent when the effect was examined across participants from Hong Kong (Ito and Hatta, 2004), or Japan (Lee et al., 2014) whose RW habit is also directed from right-to-left.

A year after, Shaki, Fischer, and Petrusic (2009) conducted another study to examine the effect across Canadian (left-to-right orientation), Israeli (right-to-left orientation), and Palestinian (right-to-left orientation but minimal exposure to left-to-right too) participants. This time, they were asked to make a parity judgment either upon numbers from one to nine (except five) or the corresponding Arabic-Indic numbers. Results indicated a significant SNARC effect for Canadians, however, for Palestinians, a reversed-SNARC effect was observed. Thus, it can be concluded that, the representation of all numerosities is spatially categorized, yet, the side of the representational space you start counting in one culture depends on the direction of reading and writing (RW).

Nevertheless, the studies mentioned above make it clear that the RW activity is also involved in the number mapping procedure, which means, the SNARC effect is not flexible, can change with spatial strategy.

1.5.4. Is Left-to-Right Orientation Human Species-Specific or Not?

Even if the long-standing debates within N-S association regarding whether the MNL account is culturally or biologically acquired, is still going on, studies on chicks (Biro and Matsuzawa, 2001), monkeys (Thomas, Fowlkes, and Vickery, 1980; Brannon and Terrace, 1998), parrots (Pepperberg, 1994), pigeons (Xia, Siemann, and Delius, 2000; Emmerton, Lohmann, and Niemann, 1997), and rats (Davis, MacKenzie, and Morrison, 1989) showed that animal numerical cognition might be an indicator of biological predisposition of the MNL.

The first evidence that non-human animals show the SNARC effect comes from the study conducted by Rugani and his colleagues (2007). Accordingly, when the chicks were trained to peck the target hole which was placed between 16 vertically oriented identical holes, even if in the test phase the holes were reoriented in a horizontal line, the chicks were able to find the target. Moreover, the chicks asserted left-hemispheric bias! According to this, they showed better performance while selecting the target placed on the left-hand side. These results indicates that chicks are able to locate the *ordinal positions*, plus, left-to-right MNL is not species-specific but it exists in non-linguistic and non-human species, as well. As a further evidence regarding the asymmetry found in chicks, the effect was examined between a day-old domestic chicks and adult Clark's nutcrackers over their pecking behavior that was learnt first. In parallel with findings of the previous study, an asymmetry was found (Rugani et al., 2010). So what is the reason that lies behind that asymmetry? Is that as a result of a *pseudoneglect* (Regolin, 2006), an attentional mechanism or a real asymmetry in the brain? The studies conducted to examine the functioning of the bird's brain were found that the right hemisphere is responsible for the processing of spatial information (Rugani et al., 2015c; Vallortigara et al., 2010b). Thus, the observed left-to-right biased behavior might come from a right hemisphere dominance that results in the asymmetry in brain working mechanism.

In another study, Adachi (2014) examined the SNARC effect across chimpanzees. To do that, in the baseline condition, Arabic numerals from one to nine were presented in random locations, thereby, the chimpanzees were trained to touch all the numbers in correct order, from smaller to larger. In order to test whether the chimpanzees learned the sequence of numbers or not, numbers *one* and *nine* were presented on a horizontal line in various distances. Significantly faster responses were acquired when *one* was presented from left and *nine* was presented from the right. Furthermore, Drucker and Brannon (2014) examined the Rhesus macaque monkeys to examine their ability to understand the ordinal position and whether they can do N-S mapping or not. Accordingly, they first trained the monkeys to respond to the item that is the fourth (the target) from the bottom of five items that are oriented vertically. To acquire the behavior, each correct response was conditioned by a green screen and a pleasant sound. For both of the test phases (ordinal and N-S mapping), the subjects were required to determine the fourth item in the sequence, but, while in ordinal mapping the items were vertically rotated, for the N-S mapping, both horizontal and vertical rotations were used. Results of the ordinal position test entailed that, the monkeys followed an ordinal sequence that was followed while coding the objects in the space, more than a physical coding. Additionally, the results of the N-S mapping test showed that, when the line is rotated to a vertical position, monkeys tried to reach the fourth position from the left, rather than right. Both the studies conducted in numerical cognition and the evidences of the SNARC-like effect of non-human animals showed that the SNARC effect may be a biologically acquired tendency rather than culturally acquired.

1.6. The Role of Cognitive Control and Inhibitory Processes in N-S Association

Executive control or in other words *cognitive control* refers to a set of process that has an effect on forming/shaping or suppressing a particular behavior (Miller and Cohen, 2001). However, as it is seen from the aforementioned studies in this thesis, most of them were approached to the N-S association from the perspective of shaping behavior, which is an excitatory process.

In 2003, Mapelli, Rusconi, and Umiltà examined the relationship between the SNARC effect and Simon effects. To do that, left or right response keys were assigned to respond to either left or right side of the screen in a parity judgment task. Accordingly, the primary objective was to investigate the delay in reaction time when the side of the determined key and stimulus presentation were *incongruent*. Hereunder, results indicated that, the incongruency between response and stimulus presentation side lead to a delay in reaction time.

In another study that aimed to examine the spatial-directional processing, Shaki and Fischer (2018) tested the horizontal and vertical spatial-numerical associations (SNAs) on a Go/No-Go task. Accordingly, when it was asked to make an orientation judgment of the arrows (e.g. arrow facing left, Go) that were presented in every direction both horizontally and vertically, results indicated a significant congruity effect for vertical SNA. These findings brought out a totally new information that tells the horizontal SNA might be a result of contextual priming, rather than inherently determined.

In furtherance, among people with ADHD (attention deficit hyperactivity disorder) -without clinical diagnosis-, the inhibitory processes were examined and compared within the scope of Stroop and Eriksen Flankers tasks (Georges, Hoffmann, and Schiltz, 2018). During the examination of both tasks, it was asked from the self-reporting ADHD people to make both parity judgment and magnitude comparison. Results indicated a weaker interference control during Stroop task, yet, stronger interference control during Eriksen Flankers task. Results of this correlational analysis not only dissolved the operational mechanism of those tasks, but also exhibited how the magnitude of inhibitory control differentiate in two different tasks that were aimed to test those mechanisms. Furthermore, in a Numerical Stroop task, suppressed automatic activation in the response level was found for the incongruent trials (the irrelevant combination numerical size and physical size) (Cohen Kadosh, Notebaert, and Gevers, 2011).

In addition to this, a brain imaging study conducted with a Stroop-like task asserted the congruency effect over the SNARC effect very clearly. In the experiment, conducted by Cohen Kadosh and colleagues (2007), the Stroop-like effect was investigated over functional magnetic resonance imaging (fMRI) and event-related potentials (ERP). The fMRI findings pointed to a different activation of primary motor area (M1) when the response hand and the congruency of the stimuli are incongruent. Moreover, abnormal activation of Ipsilateral Motor Cortex during incongruent trials was also observed. These findings are the indicator of an irrelevant dimension processing in the response selection stage. In conjunction with this, ERP results showed reduced amplitude of P300 during incongruent trials, which denotes the reduced functionality of stimulus evaluation and categorization.

All in all, despite the SNARC effect depends on the explicit or implicit nature of the numerical task, the interference control is determinative on the magnitude of the effect (Georges et al., 2018). Moreover, to understand the underlying structural mechanisms of the N-S association entirely, it is crucial to understand the role of the inhibitory processes. And even if a fair amount of studies were clarified those processes on one level, there is still need for a further examination.

1.7. Aim of the thesis

In this thesis, it was aimed to investigate how inhibitory processes were affected by the N-S compatibility (compatible and incompatible), Stroop congruency (congruent and incongruent) and numerical distance categories (far-big, close and far-small) when two different instructions (select the bigger/more frequent number or select the smaller/less frequent number) were applied over two tasks (Magnitude Judgment task and Numerical Judgment task). Accordingly, a detailed description of each concept is explained and exemplified below.

(1) Tasks and Instructions: Two different instruction groups were formed to determine different target stimuli for different tasks. Accordingly, when the subject was assigned to *select the bigger/more frequent number condition*, it was required to respond to *numerically bigger digit* (e.g. when the presented stimulus was "2222 55", the correct judgment is to select the "55") during *Numerical Judgment task*, and *more frequent digit* (e.g. when the presented stimulus was "2222 55", the correct judgment is to select the "22222") during *Magnitude Judgment task* and the contrary is true for the second instruction group.

(2) N-S compatibility: N-S compatible and incompatible stimuli were determined considering the spatial information and numerical or magnitude congruency (whether the smaller/less-frequent digit was presented on the left visual field and vice-versa or the contrary). Accordingly, for the *Numerical Judgment task*, the stimuli presented as *N-S compatible* were arranged as the *numerically smaller* number on the *left*, and *numerically bigger number* on the *right* hand side (e.g. 22222 55 or 22 55555) and for the N-S incompatible stimuli, numerically smaller numbers were presented on the right, and bigger numbers were presented on the left hand side (e.g. 55 22222 or 55555 22). Besides, for the *Magnitude Judgment task*, *N-S compatible* stimuli were arranged as the *less*

frequent number on the *left*, and *more frequent* number on the *right* hand side (e.g. 22 55555 or 55 22222) and for the *N-S incompatible* stimuli, the less frequent numbers were presented from the right, and more frequent numbers were presented from the left hand side (e.g. 22222 55 or 55555 22).

(3) Stroop congruency: The Stroop congruent and incongruent stimuli were determined considering the numerical value and frequency of the repetition (whether the frequency of the number is consistent with the numerical value or not). Thus, regardless of the spatial position, if the number was presented as its *own numerical value*, such as number "2" is presented as "22" and number "5" is presented as "55555", that is accepted as *Stroop congruent* trial (22 55555), however, if the frequency of the number was determined regarding the *numerical value of the paired digit*, that is accepted as the *Stroop incongruent* trial (e.g. 22222 55).

As stimuli, horizontally aligned digit pairs (a reference number "5", and a probe number that is either 2, 3, 4, 6, 7 or 8 -grouped as 1 unit distance, 2 units distance, and 3 units distance from reference number-) were presented regarding N-S compatibility and Stroop congruency. Accordingly the stimulus categorization was followed as: (1) congruent-compatible, (2) congruent-incompatible, (3) incongruent-compatible, and (4) incongruent-incompatible. By considering all the information above, the developed hypotheses were listed below.

Hypothesis 1: The amount of time passes before participants' reaction will be the longest when the probe number were closest to the reference number.

Hypothesis 2: The number of correct judgments will be the lowest when the probe number were closest to the reference number.

Hypothesis 3: The amount of time passes before participants' reaction will be shorter when the reference number is determined from far-small distance category compared to far-big distance category.

Hypothesis 4: The number of correct judgments will be higher when the reference number is determined from far-small distance category compared to far-big distance category.

Hypothesis 5: The amount of time passes before participant's reaction will be longer during incongruent trials, compared to congruent trials.

Hypothesis 6: The number of correct judgments will be lower during incongruent trials, compared to congruent trials.

Hypothesis 7: The amount of time passes before participants’ reaction will be the longest during incongruent-incompatible trials.

Hypothesis 8: The number of correct judgments will be the lowest during incongruent-incompatible trials.

Hypothesis 9: The amount of the time passes before participants’ reaction will be the longest when the presented stimuli is in the "close" distance condition and presented as incongruent-incompatible.

Hypothesis 10: The number of correct judgments will be the lowest when the presented stimuli is in the "close" distance condition and presented as incongruent-incompatible.

CHAPTER 2: METHOD

2.1. Participants

A total of sixty-eight graduate/ undergraduate students and staff from İzmir University of Economics voluntarily took part in the study (41 females, 22 males). The mean age of the participants was 22.92 (*SD* = 2.09) with a range of 19 to 29. Participants with the histories of:

(1) a serious problem related to vision,

(2) diagnosis of any neurological and psychological disorders,

(3) any psychoactive drug usage,

(4) any medical treatment were excluded from the study in order to prevent possible confounding effects.

Out of sixty-eight, the participants who reported a seriously impaired vision due to a brain injury (*N* = 1) and receiving medical treatment (*N* = 1) which could affect their performance were not included in the study. Additionally, two participants were excluded from the study as an outlier (because of behaving too persistent in one answer and making repetitive mistakes). Therefore, all statistical analyses were conducted by using data obtained from sixty-three participants.

The participants were randomly assigned to one of the following experimental conditions[2]:

(1) High Frequency/ Big Digit Condition (HF/-B Digit Condition)
(2) Low Frequency/ Small Digit Condition (LF/-S Digit Condition)

In Figure 6, a detailed diagram illustrates the distribution of the participants across the conditions, which were composed of two different tasks. Task order was counterbalanced across the participants

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[2] See page 30 for a detailed explanation of the experimental conditions.

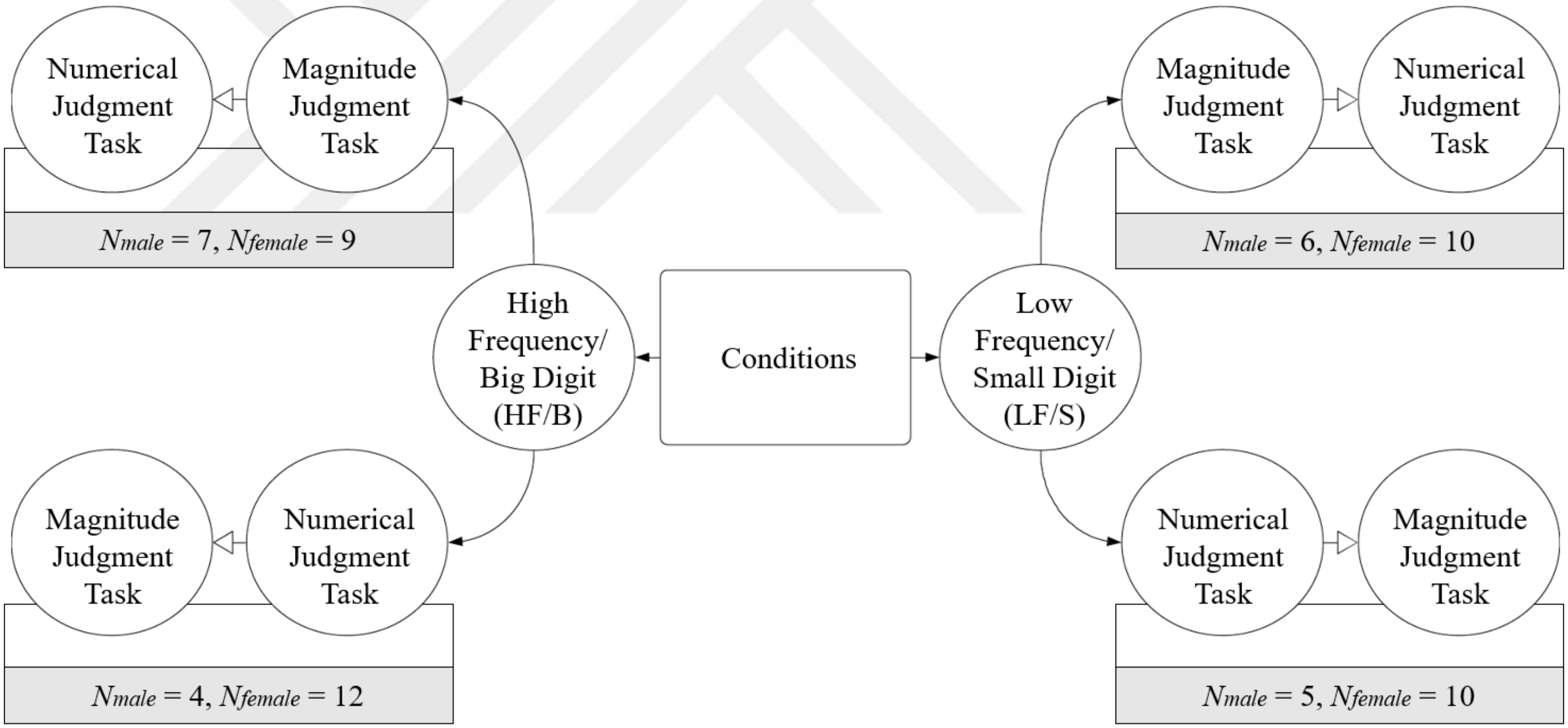

Figure 6. The distribution of the participants in different experimental conditions.

2.2. Participant Forms, Stimuli, and Apparatus

2.1.1. Participant Forms

Participant Information Form, and Informed Consent Form was prepared to inform the participants about the purpose, the procedure in general (not in detail), and the approximate duration of the study (Appendix A and Appendix B). The Participant Evaluation Form was prepared to obtain both demographic information and experiment related personal information (Appendix C).

2.2.2. Stimuli

The stimuli consisted of Arabic digits, printed in Arial font and the type size was arranged to 64. All stimuli were presented in white ink against a black background and composed of a *digit pair,* in which the digits were centered around the vertical midpoint.

Different stimulus sets were used for practice trials and the main experiment. For the practice trials, two different digit pairs were selected to present as stimuli: (1) "one" and "three", and (2) "two" and "four". While determining which digits to use to construct a pair, the main consideration was to make the trials as easy as possible when the requirements of the task were involved. Hence, the digits with the smallest numerical values were selected. Unlike practice trials, for the main experiment, the pairs were composed of a *reference number* and a *probe number.* For all pairs, the reference number was determined as "five" (Song and Nakayama, 2008; Hofmann et al., 2013; Gevers et al., 2006). However, probe numbers were selected regarding the *numerical distance effect (NDE)* (closeness/farness to the reference number "five") and *size effect* (greatness/smallness than the reference number "five"). Thus, six probe numbers were selected and categorized as: (1) far-small (digits "two" and "three"), (2) close (digits "four" and "six") and (3) far-big (digits "seven" and "eight").

2.2.3. Apparatus and Stimulus Presentation Program

All the stimuli were prepared by using the stimulus presentation program SuperLab^{TM} (Version 4.0, Cedrus, Inc.) and presented to the participants via desktop computer (TECHNO PC 750 GB HDD/ 4 GB RAM /AMD FX-6100 3,3 GHz/ 1GB VGA) on a 20-inch LCD monitor (TECHNO MONITOR HKC). The viewing distance of the participants was approximately 50 cm from the monitor. The position of the head and the distance of the participant from the monitor was stabilized by using a chin rest (Figure 7). Moreover, for the participants to respond, *d* and *k* keys were used in Turkish QWERTY keyboard.

Two different stimulus presentation programs were carried out in order to meet the requirements of two different tasks (Magnitude Judgment task and Numerical Judgment task) that were presented under different experimental conditions: (1) (HF/-B Digit, and (2) LF/-S Digit. For both conditions, same stimulus set was presented to the participants and the stimulus presentation was executed regarding the: (1) N-S compatibility (e.g. N-S compatible: 2 and 5, N-S incompatible: 5 and 2), and (2) Stroop congruency (e.g. Congruent: 2 2, Incongruent: 2 2 2 2 2). Yet, what was required from the participants was differentiated regarding the instructions: (1) selecting the digit with higher versus lower frequency for Magnitude Judgment task and (2) selecting the digit with bigger versus smaller numerical value for Numerical Judgment task. Thus, for the HF/-B Digit Condition, the participants were directed via instructions to select the digit with higher frequency during Magnitude Judgment task and the digit with bigger numerical value during Numerical Judgment task, and for the LF/-S Digit Condition, the participants were directed to select the digit with lower frequency during Magnitude Judgment task and digit with smaller numerical value during Numerical Judgment task.

In accordance with the previous studies (Heister, Ehrenstein, and Schroeder-Heister, 1986; Kerzel, Hommel, and Bekkering, 2001; Ivanoff et al., 2014; Seibold, Chen, and Proctor, 2015), the location of the digits on the screen was determined to correspond with the N-S Compatibility. Thus, for two different tasks (Magnitude Judgment task, and Numerical Judgment task) different procedures were followed to meet the requirement for N-S Compatibility. For the Numerical Judgment task, the *numerically* smaller digits were placed on the left side, and bigger digits were placed on the right side of the screen for N-S Compatible stimuli (e.g. 22222 and 55). Whereas, for N-S Incompatible stimuli, *numerically* smaller digits were placed on the right side, and *numerically* bigger digits were placed on the left side of the screen (e.g. 55 and 22222). For the Magnitude Judgment task, the frequency of the digits was the key consideration. Thus, for the N-S Compatible

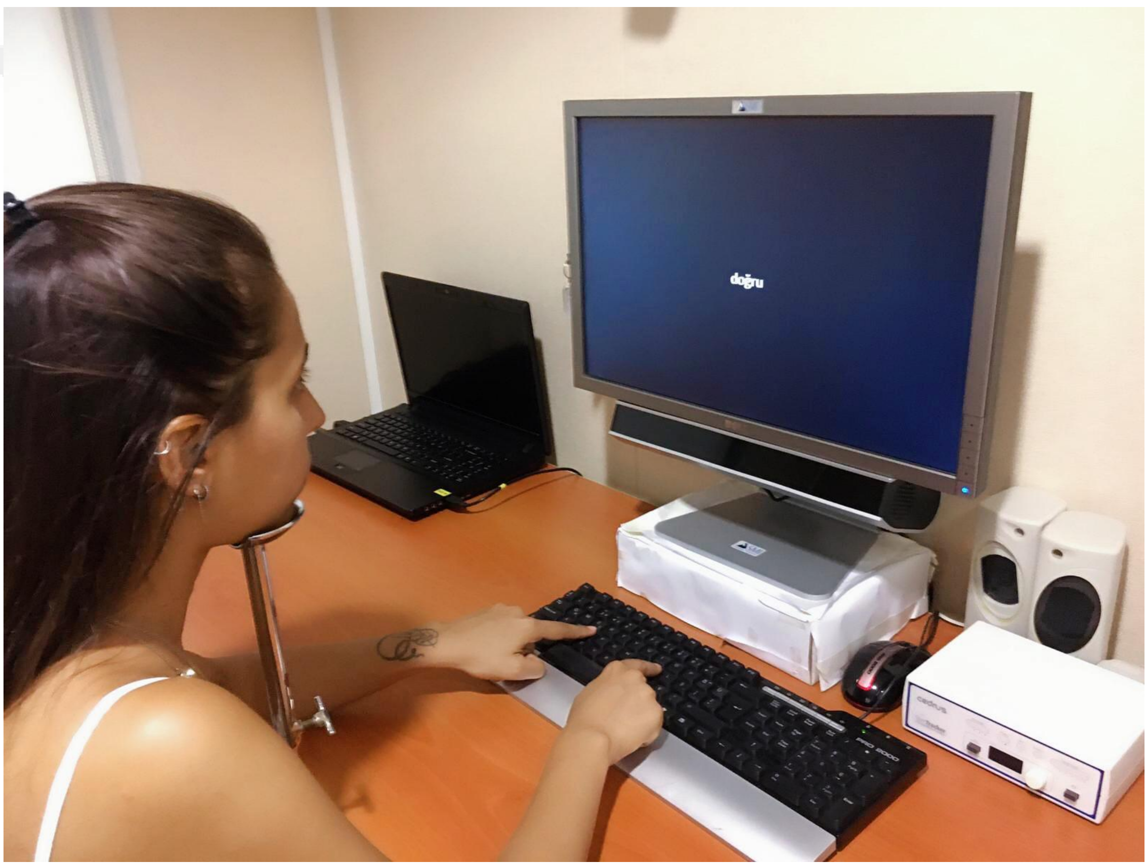

Figure 7. Experimental setup.

stimuli, the digits that were *less frequent* were placed on the left side, and digits that are *more frequent* were placed on the right side of the screen (e.g. 55 and 22222). On the other hand, for N-S Incompatible stimuli, the *less frequent* digits were placed on the right side, and digits that are *more frequent* were placed on the left side of the screen (e.g. 22222 and 55).

For the Stroop congruency, the main consideration was whether the integer is equal to the number of its own copies or not (Bellon, Fias, and De Smedt, 2016). Unlike N-S Compatibility, for the Stroop Congruency, the same rules were followed while constructing Magnitude Judgment and Numerical Judgment tasks. Consequently, the digits that were repeated in as much as its *own numeric value* were accepted as Congruent stimuli (e.g. 22 and 55555), and the digits that were repeated in as much as *the numeric value of the paired digit* were accepted as Incongruent stimuli (e.g. 22222 and 55).

Figure 8 for the Numerical Judgment task and Figure 9 for the Magnitude Judgment task illustrate the configuration of six different digit pairs, regarding the rules of N-S Compatibility and Stroop Congruency.

2.3. Procedure

Initially, each participant was taken to the soundproof experimental chamber in İzmir University of Economics, Department of Psychology, Neuroscience of Mind and Behavioral Research Laboratory. Then, it was required from each participant to read the Participant Information Form and the Participant Evaluation Form. After that, they were required to read and sign the Informed Consent Form. Before the experimental procedure started, the terms "Magnitude Judgment" and "Numerical Judgment" were explained by using a one-page information paper (Figure 10). The purpose of the informative paper was to be sure about participants understood the terms clearly. The exact same information was given to each participant.

After that, the participants were randomly assigned to one of the two experimental conditions: (1) HF/-B Digit, and (2) LF/-S Digit. Throughout the study, parallel instructions were followed between the tasks of each condition; (1) Magnitude Judgment task (selecting the less-frequent digit) and Numerical Judgment task (selecting the smaller

A

Congruency / Compatibility	Congruent	Incongruent	Congruent	Incongruent
Compatible	22 55555	22222 55	333 55555	33333 555
Incompatible	55555 22	55 22222	55555 333	555 33333

B

Congruency / Compatibility	Congruent	Incongruent	Congruent	Incongruent
Compatible	4444 55555	44444 5555	55555 666666	555555 66666
Incompatible	55555 4444	5555 44444	666666 55555	66666 555555

C

Congruency / Compatibility	Congruent	Incongruent	Congruent	Incongruent
Compatible	55555 7777777	5555555 77777	55555 88888888	55555555 88888
Incompatible	7777777 55555	77777 5555555	88888888 55555	88888 55555555

Figure 8. The stimulus sets of the Numerical Judgment task; (A) far-small: 2/5 and 3/5, (B) close: 4/5 and 5/6, and (C) far-big: 5/7 and 5/8.

A

Compatibility \ Congruency	Congruent	Incongruent	Congruent	Incongruent
Compatible	22 55555	55 22222	333 55555	555 33333
Incompatible	55555 22	22222 55	55555 333	33333 555

B

Compatibility \ Congruency	Congruent	Incongruent	Congruent	Incongruent
Compatible	4444 55555	5555 44444	55555 666666	66666 555555
Incompatible	55555 4444	44444 5555	666666 55555	555555 66666

C

Compatibility \ Congruency	Congruent	Incongruent	Congruent	Incongruent
Compatible	55555 7777777	77777 5555555	55555 88888888	88888 55555555
Incompatible	7777777 55555	5555555 77777	88888888 55555	55555555 88888

Figure 9. The stimulus sets of the Magnitude Judgment task; (A) far-small: 2/5 and 3/5, (B) close: 4/5 and 5/6, and (C) far-big: 5/7 and 5/8.

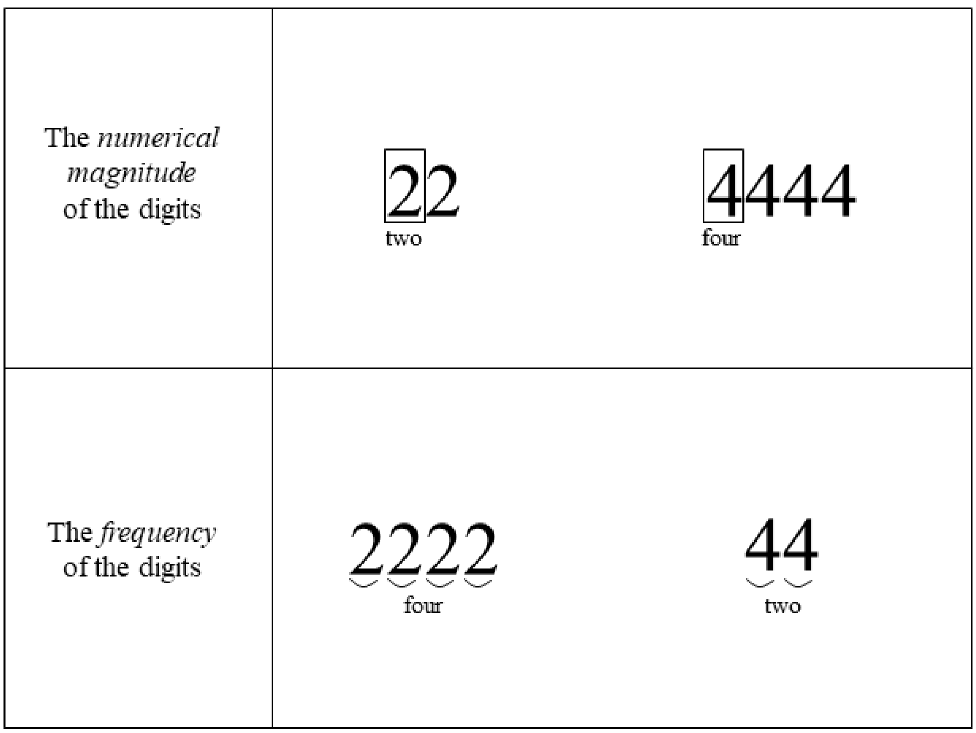

Figure 10. The example of informative paper.

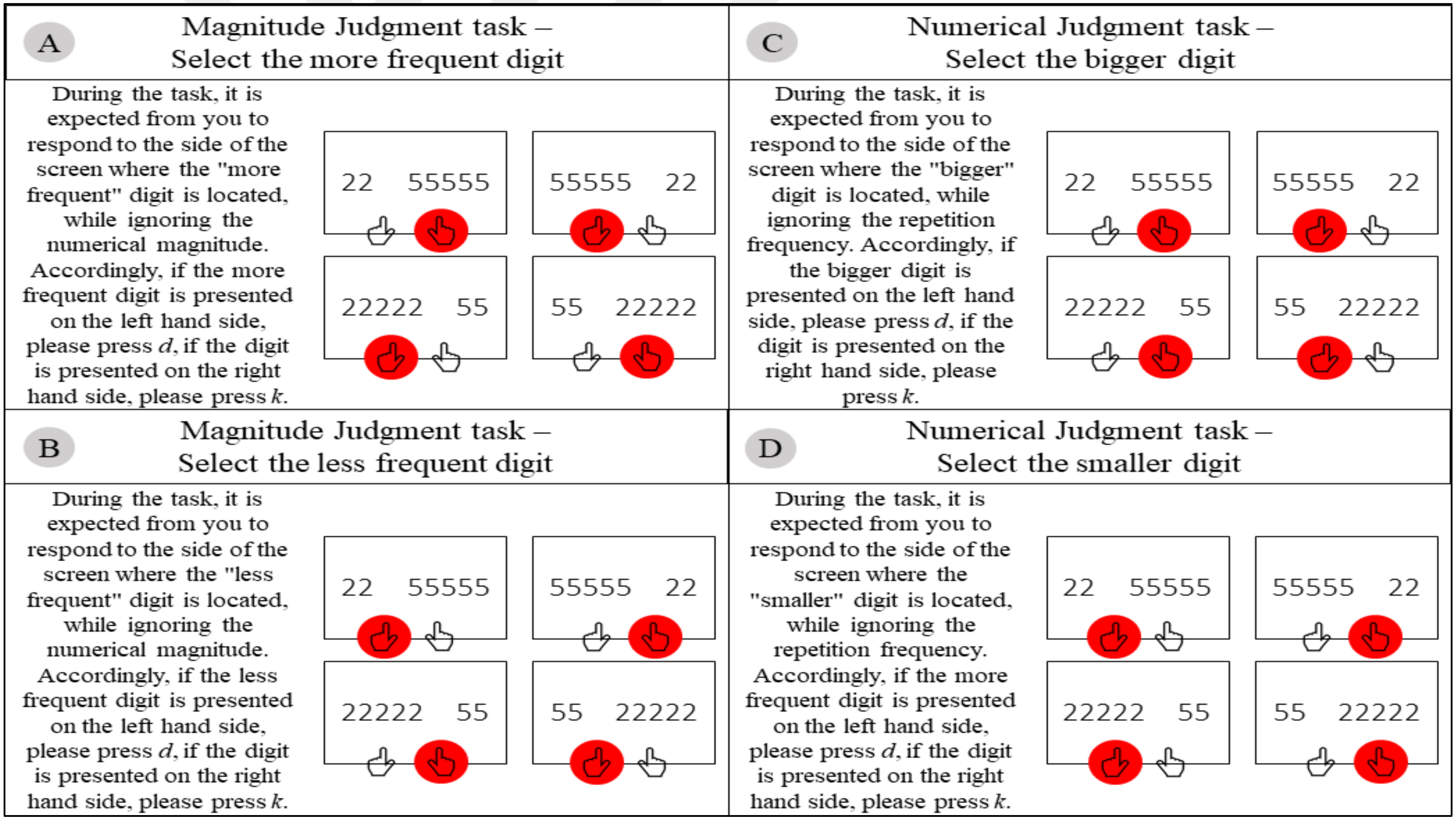

Figure 11. The instructions for Magnitude Judgment task; (A) Selecting the digit with higher frequency and (B) Selecting the digit with lower frequency and Numerical Judgment task; (C) Selecting the digit with bigger numerical magnitude, and (D) Selecting the digit with smaller numerical magnitude. Red ink was used to demonstrate the correct responses.

digit) and (2) Magnitude Judgment task (selecting the more-frequent digit) and Numerical Judgment task (selecting the bigger digit) (Figure 11).

Whole range of studies highlighted the effect of key distance, which may reduce or increase the spatial stimulus-response compatibility (Schiller, Eloka, and Franz, 2016; Heister, Schroeder-Heister, and Ehrenstein, 1990). Therefore, the distance between key identified for the left hand and key identified for the right hand was considered while determining the response keys to obtain stronger SNARC effect. Accordingly, in the current study, to see the Stroop Interference without any confounding effect, the registered key for participants to respond with the left index finger to the stimulus in the left visual field of the screen was determined as *d*, and the key to respond with the right index finger to the stimulus in the right visual field of the screen was determined as *k*, on a standard Turkish QWERTY keyboard. Figure 11 shows the correct responses regarding different judgment tasks of the experimental conditions. The information of which key and hand to use was explained to each participant verbally before the study and reminded with the instructions during the study before each session.

2.3.1. Practice Trials

A practice trial was conducted before each task. During the practice session, neither the accuracy nor the reaction times of the responses were recorded. The aim was to familiarize the participants about the task that would follow. During the practice trials, it was expected from the participants to make a judgment for the relevant task (e.g. Numerical Judgment task /selecting the digit with bigger numerical value) by pressing either *d* or *k*. After the stimulus presentation, which was conducted until a response was given to the either side of the screen, if the participant gave the correct response to the stimulus, the feedback screen was presented as "correct", and if the given response was incorrect, the feedback screen was presented as "incorrect". The feedback screen was presented for 500 ms, followed by a fixation point for 500 ms (Figure 12). Before each stimulus presentation, the fixation point ensured the participants to refocus on the center of the screen and maintain their attention for the following stimulus presentation.

Figure 13 A and B illustrate Magnitude Judgment and Numerical Judgment tasks, respectively, for HF/-B Digit Condition, and Figure 13 C and D illustrate the Magnitude

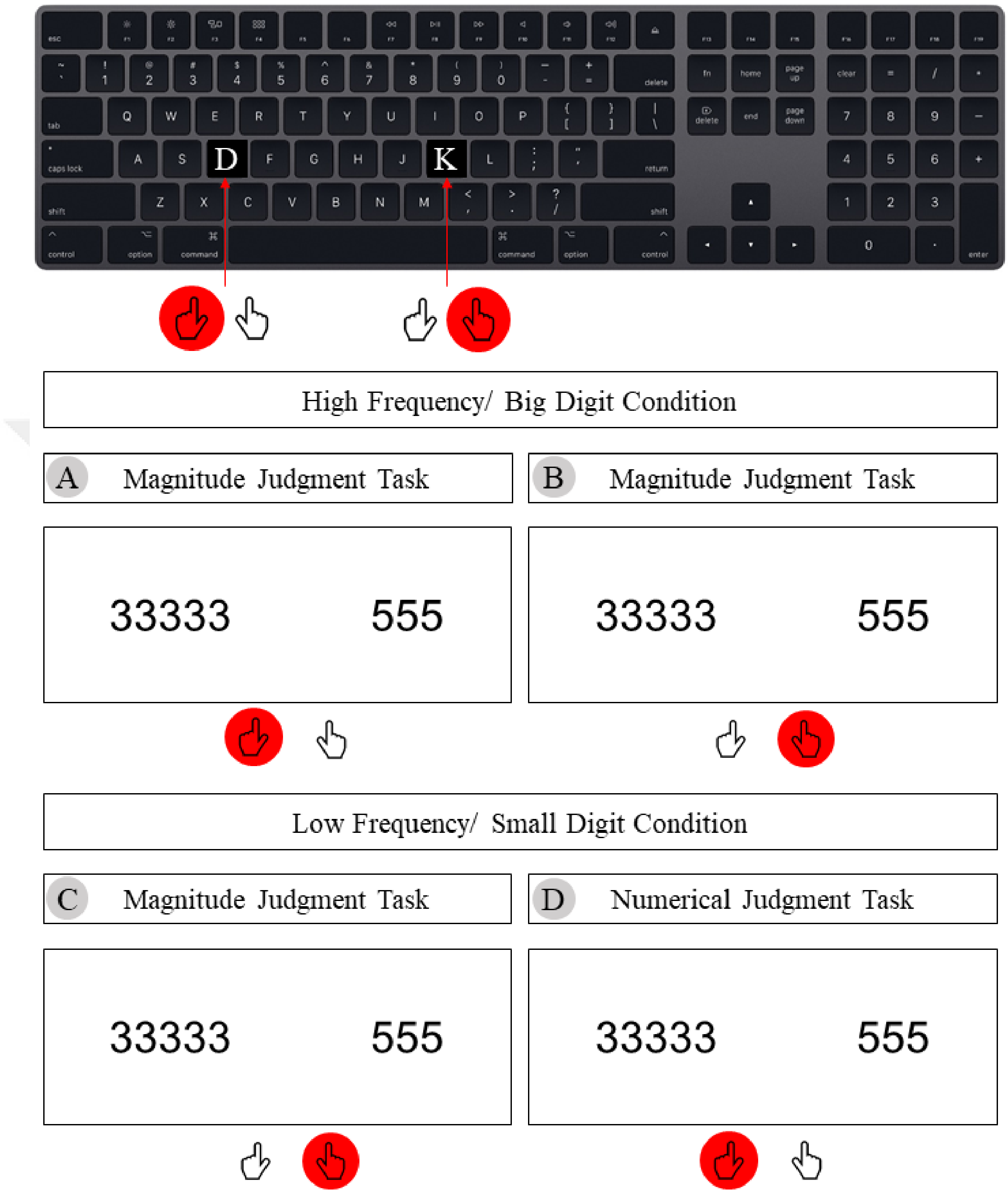

Figure 12. An illustration of how the correct responses were varied according to the different experimental conditions. Red inks demonstrate the correct responses.

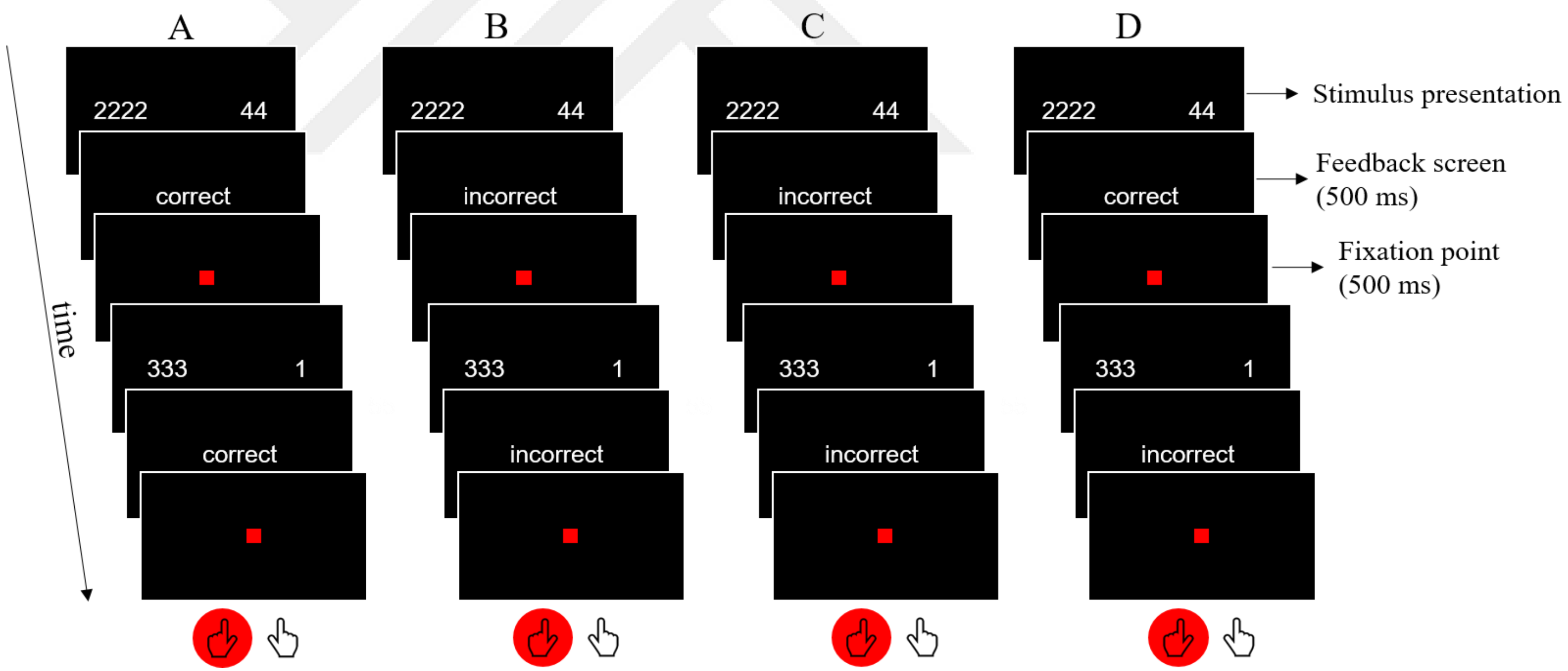

Figure 13. The illustration of how the correct response differentiated across different experimental conditions when the participant responded to all stimuli by using left hand. Red ink on the hands was used to show the preferred hand.

Judgment and Numerical Judgment tasks, respectively, for LF/-S Digit Condition.

2.3.2. Main Experiment

In the main experiment, all the participants were required to respond to stimuli that were presented regarding different judgment tasks: (1) Magnitude Judgment, and (2) Numerical Judgment, that were presented under different experimental conditions. Thus, from the participants that were assigned to HF/-B Digit Condition, during the Magnitude Judgment task, it was required to respond to the side of the screen where the digits with higher frequency were located and during the Numerical Judgment task, to respond to the side of the screen where the digits with bigger numerical value were located (Figure 14). In contrast, for the LF/-S Digit Condition, it was required from the participants to respond to the side of the screen where digits with lower frequency is located during Magnitude Judgment task, and to respond to the side of the screen where the digits with smaller numerical value were located (Figure 15). Before the experiment started, the participants were informed to press *d* to respond to the left side of the screen, and press *k* to respond right side of the screen.

During the main experiment, participants had to respond to 24 different digit pairs, which were presented within three blocks (for each task). The duration of the stimulus presentation was 500 ms. If ever a participant could respond within the given time period of 500 ms, a fixation point was presented for 500 ms, and then the following stimulus presentation was conducted. If the participant could not respond within 500 ms, a blank response screen was presented to the participants to give their response. This response screen remains until the participant gave any response by using the determined keys for either side of the screen. When a response was given, a fixation point was presented, from the center of the screen for 500 ms, as an indicator of the next stimulus presentation. Each participant would have to make a judgment upon seventy-two stimuli for different tasks separately, that sums up to a total of 144 stimuli.

The first two stimuli of the main experiment were presented in the same order for each participant. These stimuli were selected across the digit pairs, which were presented during practice trials. The purpose of this procedure was to eliminate possible errors that might be made because of the orientation problems to give response within 500 ms in the main experiment, unlike practice trials. After those two stimuli, the stimulus presentation of the main experiment was conducted in random order.

2.3.3. Research Design

In this thesis 2 (N-S compatibility; compatible, incompatible) x 2 (Stroop congruency; congruent, incongruent) x 3 (numerical distance; far-small, close, far-big) repeated design was used for two different judgment tasks (Magnitude judgment and Numerical Judgment). Accordingly, the stimulus presentation was conducted by considering N-S compatibility and Stroop congruency rules, hence, regardless of the task, the presented stimuli were the same across all of the participants as: Far-small, close and far-big , to correspond with the NDE.

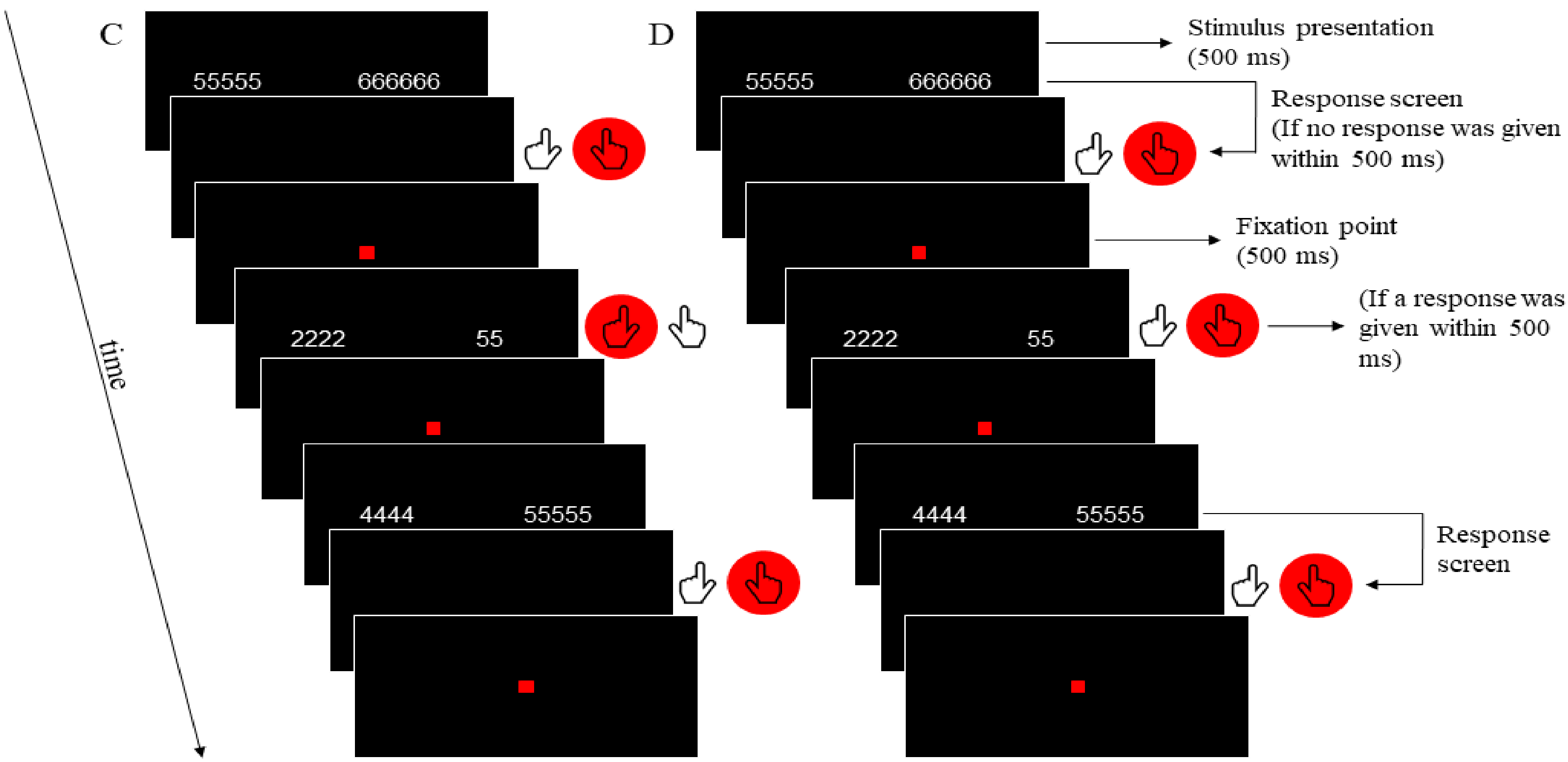

Figure 14. A demonstration of the experimental procedure for (A) Magnitude Judgment task and (B) Numerical Judgment task for HF/-B Digit Condition. The same digit pairs were used as an example to show the difference between the two tasks. The red ink on the hands are showing the correct response.

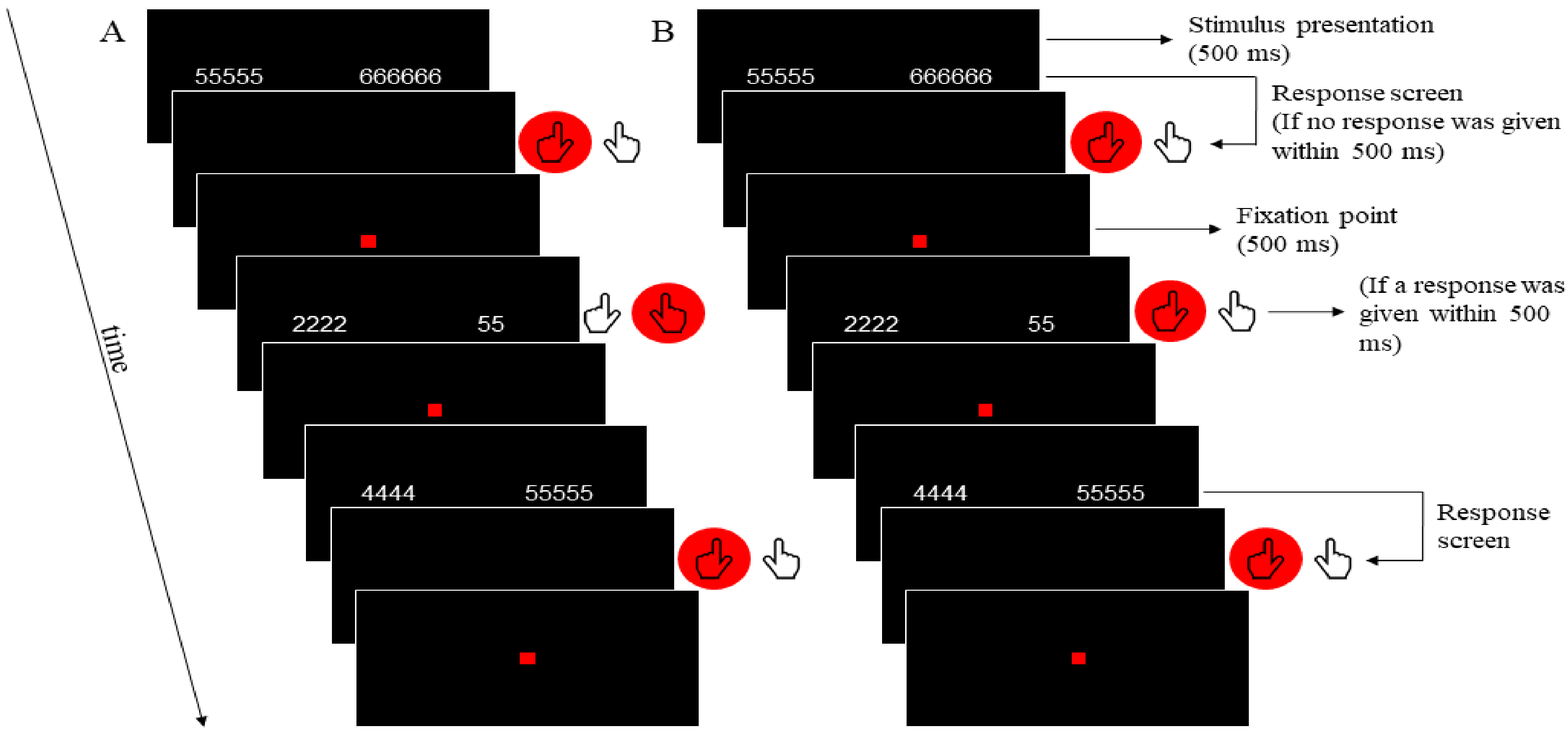

Figure 15. A demonstration of the experimental procedure for (A) Magnitude Judgment task and (B) Numerical Judgment task for the LF/-S Digit Condition. The same digit pairs were used as an example to show the difference between the two tasks. The red ink on the hands are showing the correct response.

CHAPTER 3: RESULTS

In order to investigate the effects of Stroop congruency, N-S compatibility and the numerical distance on the reaction time of the correct judgments and the number of correct judgments of the participants, multilevel modelling was used. The following section briefly describes what multilevel modeling is and why it is used.

3.1. What is Multilevel Modelling?

The multilevel models (MLM), in other words, Hierarchical Linear Models (Raudenbush and Bryk, 2002), Linear Mixed Models (Littell et al., 2006) or Random-Effects Models (Longford, 1995), have an increasing trend upon the field of psychology, specifically, upon the experimental behavioral and social researches. Multilevel models are used to analyze the data with repeated measures, or in other words *nested* levels (Raudenbush, 2002) and requires a regression analysis for the data that has units at: (1) the micro level (e.g. students) nested within the (2) macro level (e.g. schools). However, by the nature of the repeated measures design that we applied to the field of psychology, most of the time, the outcome variable (scores) are nested within the participants.

3.2. Multilevel Modelling Instead of Analysis of Variance (ANOVA)

While analyzing the data, in experimental researches, most commonly used technique is accepted as ANOVA. Yet, ANOVA is mostly useful when the predictor (independent) variables are discrete. For the independent variables with repeated measures, where more than one measurement was obtained from a single participant, and the observations were nested within the participants, conducting the analysis within the scope of multilevel modelling, instead of ANOVA provides a set of benefits. First, the homogeneity of regression slopes become no more an issue to be considered. While conducting ANOVA, it was always assumed that, the relationship between covariates and the outcome (dependent) variable is the same across the levels of the predictor variable (Field, Miles, and Field, 2012). Multilevel modelling brings that variability into the regression slopes to overcome the problem. Second, while conducting multilevel analysis, there is no need to be worried about the independence. Regarding nature of the statistics, correlation of the residuals are the indicator of the dependency of the data, and while the levels of the independent variable was examined, even if the similarity *within* one level of the variable is less than the similarity *between* levels of the variable, it threatens the independency. Although, factoring the variables in a hierarchical data structure overcomes that problem, through Intraclass Correlation (ICC). ICC helps the researchers to interpret whether the contextual variable (the variable located at least in level 2) has an effect on the outcome variable and tells about the variability within the levels of a contextual variable; high levels of variability indicates larger ICC. Larger ICC score refers that, variability in the outcome *within* the contextual variable is minimized and variability in the outcome *between* the contextual variables are maximized, in other words, the effect of contextual variable is big on the outcome variable. Third and the most important, the issue of missing data. In repeated measures design, in any case of a single point, that contains missing values, list-wise deletion was made by default. Which means that, that case will no longer included in the analysis, and that type of deletion will lead more and more data to remove. Hence, multilevel analysis ensures case-wise deletion.

In this thesis, hierarchical data structure was constructed over two level: the scores (level 1), nested within the participants (level 2). In order to examine the effect of predictor variables on outcome variable, *fixed effects* (expressed by the regression coefficient, *b*) and *random effects* were introduced to the model first (Snijders, 2005). Main effects (congruency, compatibility, and numerical distance), their two-way interactions (congruency x compatibility, congruency x numerical distance, and compatibility x numerical distance) and the three-way interaction term (congruency x compatibility x numerical distance) was added to the model as the fixed effects, and the intercepts were allowed to be random. To investigate whether including the fixed effects would improve the model fit; first, a baseline model (Model 1) was constructed where only the intercepts vary across the participants. The main consideration by doing this was to assess whether adding fixed effect will improve the fit of the model or not. While assessing the model fit, Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) values should be compared with the previous model. The decreasing trend of the values are accepted as the indicator of improvement in model fit. In order to see whether that change in the value is significant or not, the significance of the likelihood ratio (L-ratio) is the indicator.

3.3. Reaction Time Results

3.3.1. Magnitude Judgment Task

To see whether the data was appropriate to conduct the multilevel analysis or not, variation across the participants was examined. To see that, a baseline model (by including only the intercept) and a model where the intercepts varied across the participants (Model 1) were compared through the AIC and BIC scores. It was found that AIC score declined from 8252.59 to 7730.02, and BIC score declined from 8261.73 to 7743.74 and the variance in intercepts across participants was statistically significant, *SD* = 71.49 (95% CI: -2.71, 4.03), $\chi^2(1) = 524.56$, $p < .0001$. Whole improvements of AIC and BIC scores, and the significant test results indicated to the necessity of conducting the multilevel analysis. Therefore, the data was analyzed by adding fixed effects to the random intercept model.

In order to reach an overall model, fixed effects were added to the empty model one by one, concerning the hypotheses. Thus, first, the main effect of *numerical distance* was added to the model as a fixed effect (Model 2). It was found that, the AIC score decreased to 7539.41, and the BIC score decreased to 7562.27. The Log likelihood ratio also showed that adding numerical distance as a fixed effect significantly improved the fit of the model, $\chi^2(3) = 194.62$, $p < .0001$. Since the numerical distance improved the fit of the model, next, the main effect of *Stroop congruency* was added (Model 3). Both AIC and BIC scores declined to 7525.12 and 7552.57, respectively. When the significance of the change in the values was examined, once again, improvement of the model fit was observed for Model 3, $\chi^2(4) = 16.28$, $p = .0001$. For this reason, the analysis was proceeded by adding another fixed effect, *N-S compatibility* (Model 4). Results indicated that, AIC score increased to 7525.75, and BIC score increased to 7557.76 and the improvement of the model fit was not statistically significant, $\chi^2(5) = 1.38$, $p > .05$.

Despite the Model 4 did not improve the model fit, to examine the interaction effects, constructing the hierarchical model was proceeded with the Model 5, where the first two-way interaction term, *numerical distance x Stroop congruency* was introduced. Results indicated that, the AIC score declined to 7514.91 and the BIC score declined to 7556.07. Log likelihood ratio test revealed that, adding numerical distance x Stroop congruency interaction term improved the fit of the model significantly, $\chi^2(7) = 14.83$, $p < .05$. Hence, the model was further assessed by adding the second two-way interaction, *numerical distance x N-S compatibility* (Model 6). Both the AIC and BIC scores were increased to 7518.06 and 7568.37, respectively, and the test results revealed a non-significant model fit, $\chi^2(9) = .85$, $p > .05$. Yet, the last two-way interaction, *Stroop congruency x N-S compatibility*, was added to the model (Model 7). The AIC score decreased to 7510.80 and BIC score decreased to 7565.69, and the Log likelihood ratio indicated a significant improvement of the model fit, $\chi^2(10) = 9.25$, $p < .05$.

In order to obtain the final model, Model 8, three-way interaction term was added. Both the AIC and BIC scores decreased to 7490.19 and 7554.22, respectively. In addition, the Log likelihood ratio indicated that, adding *numerical distance x Stroop congruency x N-S compatibility* interaction term improved the fit of the model, $\chi^2(12) = 24.61$, $p < .0001$. The model now predicts the reaction time of the participants during Magnitude Judgment task from the included variables (numerical distance, Stroop congruency, N-S compatibility, numerical distance x Stroop congruency, numerical distance x N-S compatibility, Stroop congruency x N-S compatibility, and numerical distance x Stroop congruency x N-S compatibility) and the intercept. The model construction was summarized in Table 1.

Results of the random intercept model indicated that, reaction time of the participants differed in different numerical distances, far-small stimuli compared to far-big stimuli ($b = -22.55$, $t(642) = -6.51$, $p < .0001$) and the close stimuli, compared to far-small and far-big stimuli ($b = -12.32$, $t(642) = -6.18$, $p < .0001$). The negative gradients refer that, the reaction time of the participants was significantly higher for the far-big stimuli compared to far-small stimuli, and the highest reaction time was seen during the stimuli with close distance category (Figure 16). The main effect of N-S compatibility revealed that, reaction time of the participants significantly differed among the compatible and incompatible trials as well, $b = -12.39$, $t(642) = -3.07$, $p < .01$. The reaction time of the participants significantly decreased during incompatible trials, compared to

Table 1. The Included Variables to Obtain an Overall Model that Predicts the Reaction Time of the Participants during Magnitude Judgment Task.

Model	*df*	*AIC*	*BIC*	*Test*	*L-ratio*	*p*
RandomInterceptModel	3	7730.02	7743.74			
RandomIntercept: Distance	5	7539.41	7562.27	1 vs 2	194.62	<.0001***
RandomIntercept: Distance + Congruency	6	7525.12	7552.57	2 vs 3	16.28	.0001**
RandomIntercept: Distance + Congruency + Compatibility	7	7525.75	7557.76	3 vs 4	1.38	.24
RandomIntercept: Distance x Congruency	9	7514.91	7556.07	4 vs 5	14.83	.0006**
RandomIntercept: Distance x Compatibility	11	7518.06	7568.37	5 vs 6	0.85	.65
RandomIntercept: Congruency x Compatibility	12	7510.80	7565.69	6 vs 7	9.26	.0023*
RandomIntercept: Distance x Congruency x Compatibility	14	7490.19	7554.22	7 vs 8	24.61	<.0001***

Note. * $p < .01$; ** $p < .001$; *** $p < .0001$.

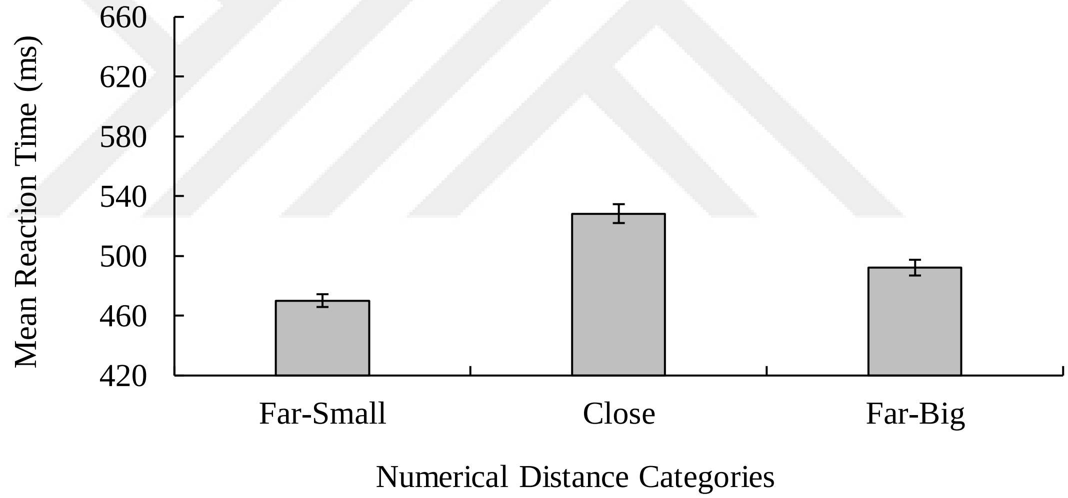

Figure 16. Mean (95% CI) reaction time of the participants for different numerical distance categories.

compatible trials (Figure 17). However, the reaction time of the participants did not significantly differ upon the levels of the Stroop congruency, $b = 3.04$, $t(642) = .76$, $p > .05$.

When the effect of different numerical distance categories (far-small, close and far-big) on the reaction time of the participants by the levels of Stroop congruency was investigated, results of the analysis indicated that, reaction time of the participants for the far-small and far-big stimuli significantly differed during congruent and incongruent trials, $b = 24.99$, $t(642) = 5.07$, $p < .0001$. For the far-small stimuli, participants significantly responded to congruent trials faster than incongruent trials, on the contrary, for the far-big stimuli, the reaction time of the participants decreased non-significantly during incongruent trials compared to congruent trials (Figure 18). However, no significant effect of close stimuli on the reaction time of the participants by the levels of Stroop congruency was found when the far-small stimuli were compared to far-big stimuli, $b = -2.57$, $t(642) = -.90$, $p > .05$. The results of the two-way interactions also revealed that, different numerical distance categories significantly differed across the levels of N-S compatibility. Test results indicated that, reaction time of the participants differed between far-small and far-big stimuli during compatible and incompatible trials ($b = 15.32$, $t(642) = 3.10$, $p < .01$). For the far-small stimuli, participants responded faster during incompatible trials compared to compatible trials, yet, no such significant difference was found for far-big stimuli (Figure 19). In addition, no significant difference in reaction time was found for close stimuli compared to far-small and far-big stimuli across the levels of N-S compatibility, $b = 1.67$, $t(642) = .59$, $p > .05$. The results of last two-way interaction also revealed that, the effect of Stroop congruency was statistically significant across the levels of N-S compatibility, $b = 17.65$, $t(642) = 3.09$, $p < .01$. It was found that, reaction time of the participants significantly increased during incompatible-incongruent trials compared to the incompatible-congruent trials. However, the reaction time of the participants for congruent and incongruent trials did not significantly differ through the compatible and incompatible trials (Figure 20).

A significant three-way interaction was also found between numerical distance x Stroop congruency x N-S compatibility. When the interaction term was broken down by conducting planned contrasts, it was found that the levels of Stroop congruency differed

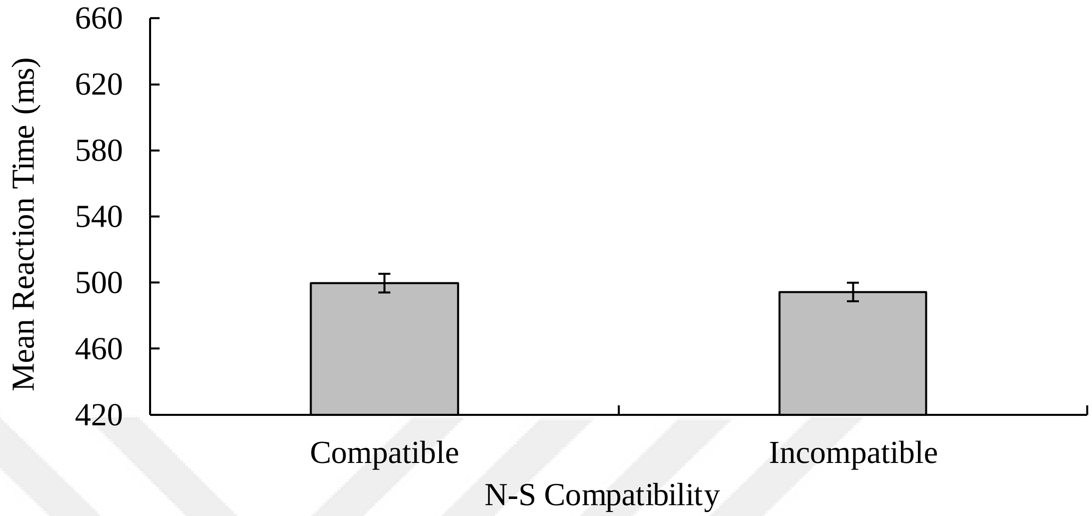

Figure 17. Mean (95% CI) reaction time of the participants for compatible and incompatible trials.

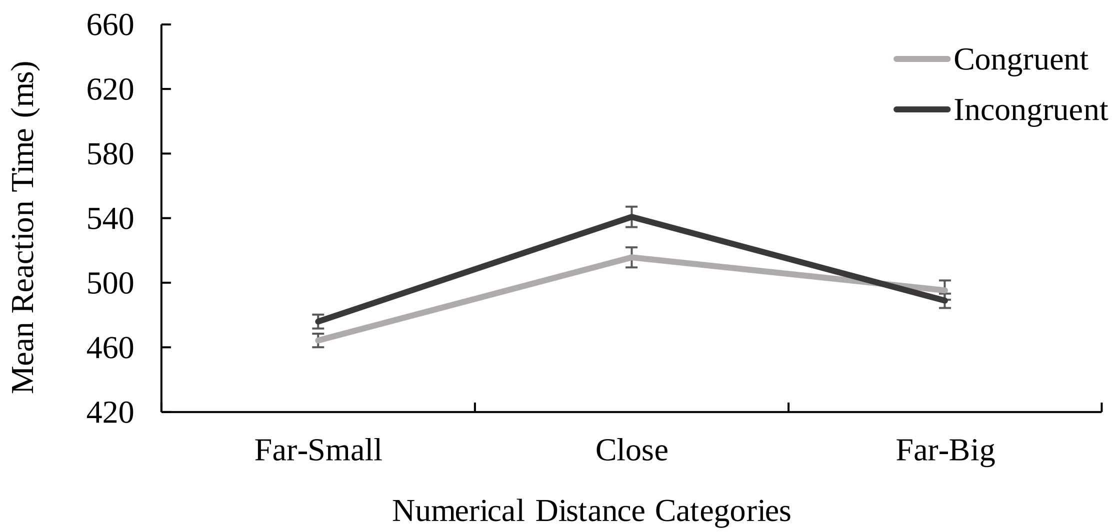

Figure 18. Mean (95% CI) reaction time of the participants for far-small, close, and far-big stimuli in congruent and incongruent trials.

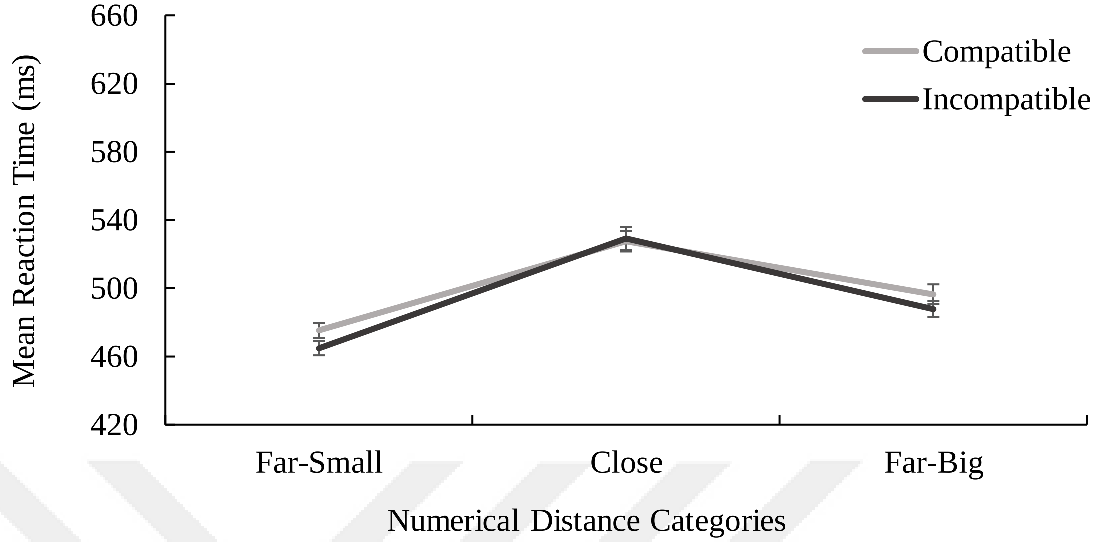

Figure 20. Mean (95% CI) reaction time of the participants for far-small, close, and far-big stimuli in compatible and incompatible trials.

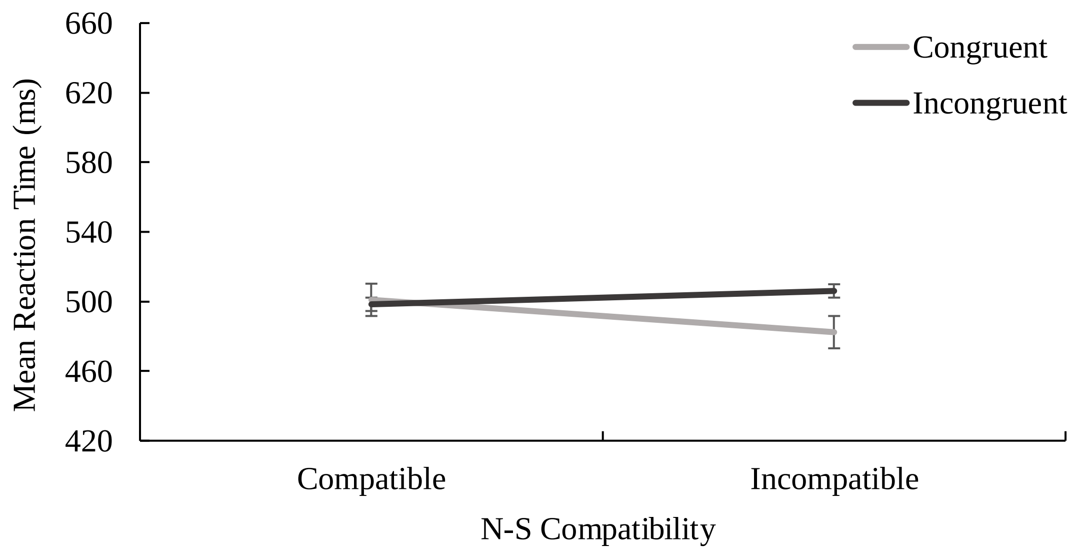

Figure 19. Mean (95% CI) reaction time of the participants for the levels of Stroop congruency by N-S compatibility.

between the levels of N-S compatibility when the data was analyzed within the scope of far-small stimuli compared to far-big stimuli, b = -32. 64, $t(642) = 7.01$, $p < .0001$. While the reaction time of the participants were faster during congruent-incompatible trials compared to congruent-compatible trials, for the incongruent-incompatible trials, the reaction time during far-big stimuli significantly increased compared to far-small stimuli (Figure 21). No such difference was found for the close stimuli compared to far-small and far-big stimuli, b = -6.98, $t(642) = 4.02$, $p > .05$. Table 2 was drawn to summarize the overall results.

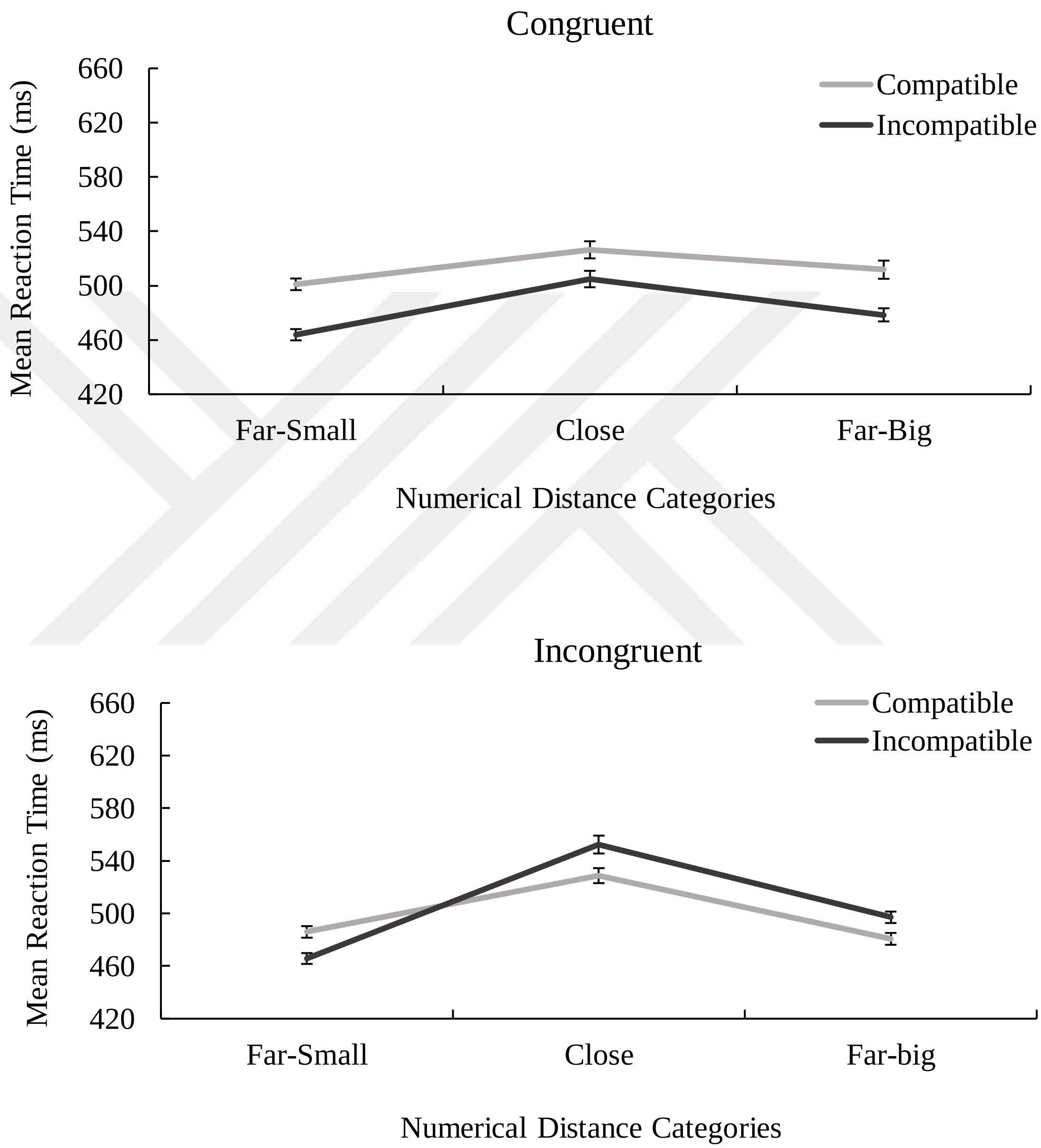

Figure 21. Mean (95% CI) reaction time of the participants for far-small, close and far-big stimuli between the levels of Stroop congruency and the N-S compatibility.

Table 2. Multilevel Analyses of the Effect of Numerical Distance, Stroop Congruency, N-S Compatibility and their Interactions on the Reaction Time Scores for Magnitude Judgment Task.

	b	*SE*	*df*	*t*	*p*
(Intercept)	504.96	9.37	642	53.87	0.00**
Numerical Distance: Far-Small vs Far-Big	-22.55	3.46	642	-6.51	0.00**
Numerical Distance: Close vs Far-Small - Far-Big	-12.32	1.99	642	-6.18	0.00**
Congruency: Incongruent	3.04	4.02	642	0.76	0.45
Compatibility: Incompatible	-12.38	4.03	642	-3.07	0.00*
Numerical Distance: Far-Small vs Far-Big x Congruency: Incongruent	24.99	4.93	642	5.07	0.00**
Numerical Distance: Close vs Far-Small - Far-Big x Congruency: Incongruent	-2.57	2.84	642	-.90	0.37
Numerical Distance: Far-Small vs Far-Big x Compatibility: Incompatible	15.32	4.94	642	3.10	0.00*
Numerical Distance: Close vs Far-Small - Far-Big x Compatibility: Incompatible	1.67	2.84	642	0.59	0.56
Congruency: Incongruent x Compatibility: Incompatible	17.65	5.71	642	3.09	0.00*
Numerical Distance: Far-Small vs Far-Big x Congruency: Incongruent x Compatibility: Incompatible	-32.64	7.01	642	-4.65	0.00**
Numerical Distance: Close vs Far-Small - Far-Big x Congruency: Incongruent x Compatibility: Incompatible	-6.98	4.02	642	-1.73	0.08

Note. * $p < .01$; ** $p < .0001$.

3.3.2. Numerical Judgment Task

To see whether the data was appropriate to conduct the multilevel analysis or not, variation across the participants was examined. In order to see the need for multilevel analysis, a baseline model was fit where only the intercept was introduced, AIC: 9009.57, and BIC: 9018.76. Then, the new model (Model 1) was constructed to allow the intercepts to vary across participants. To assess whether allowing the intercepts across the participants was improved the model fit, AIC and BIC scores were compared. Results indicated that, AIC score declined to 8416.32 and BIC score declined to 8430.10. Finally, the variance in intercepts across participants indicated to the necessity of conducting the multilevel analysis, *SD* = 94.32 (95% CI: -2.85, 5.31), $\chi^2(1) = 48.58$, $p < .0001$. Therefore, the data was analyzed by adding fixed effects to the random intercept model.

As in Magnitude Judgment task, first *numerical distance* was added as a fixed effect to assess the model fit (Model 2). It was found that the AIC score declined to 8398.26 and BIC score declined to 8421.23. When the random intercept model and Model 2 were compared, test results indicated the improvement of the model fit, $\chi^2(3) = 22.05$, $p < .0001$. Hence, the second fixed effect, *Stroop congruency*, was added to the model (Model 3). Both AIC and BIC scores declined to 8265.44 and 8293.01, respectively. To see whether adding the fixed effect significantly improved the previous model or not, test results were examined. It was found that, adding Stroop congruency as a fixed effect significantly improved the fit of the model, $\chi^2(4) = 134.82$, $p < .0001$. Thus, *N-S compatibility* was added as another fixed effect (Model 4). Results of the analysis indicated that, the AIC score slightly increased to 8265.83 and BIC score increased to 8297.99. The Log likelihood ratio test revealed that, adding compatibility as a fixed effect did not improved the model fit, $\chi^2(5) = 1.62$, $p > .05$.

Despite the last fixed effect did not improve the model fit, in order to examine the possible interaction effects, the model was proceeded by including the interaction terms. First, *numerical distance x Stroop congruency* interaction was added to the model (Model 5). It was found that, adding the interaction term provided an improvement to the model fit; AIC: 8264.11 and BIC: 8305.46 and the test results indicated a marginally significant improvement, $\chi^2(7) = 5.72$, $p = .057$. Therefore, the new interaction term was introduced to the model, *numerical distance x N-S compatibility* (Model 6). Unlike the previous model, this time both the AIC: 8267.92 and BIC: 8318.46 scores increased, and test results indicated that adding the interaction term did not improve the model fit, $\chi^2(9) = .19$, $p > .05$. In order to carry on the assessment, the last two-way interaction term was included to the model, *Stroop congruency x compatibility* (Model 7). In a similar vein with the Model 6, Model 7 did not improve the model fit, AIC: 8269.89, BIC: 8325.02, and $\chi^2(10) = .03$, $p > .05$.

To put the model into the final form, three-way interaction term was included, *numerical distance x Stroop congruency x N-S compatibility*. The AIC: 8266.95 and BIC: 8331.27 results indicated a better fit of the model, hence the test results were examined to see whether the improvement was significant or not. It was found that the final model significantly improved the model fit, $\chi^2(12) = 6.94$, $p < .05$. The model now predicts the reaction time of the participants during Numerical Judgment task from the included variables (numerical distance, Stroop congruency, N-S compatibility, numerical distance x Stroop congruency, numerical distance x N-S compatibility, Stroop congruency x N-S compatibility, and numerical distance x Stroop congruency x N-S compatibility) and the intercept. The model construction was summarized in Table 3.

Results of the random intercept model indicated that, both the difference in reaction time between far-small and far-big stimuli ($b = -21.01$, $t(658) = -3.91$, $p < .001$) and close stimuli compared to far-small and far-big stimuli ($b = -6.62$, $t(658) = -2.14$, $p < .05$) significantly differed across the participants. It was found that, participants responded faster to the far-small, compared with the far-big stimuli and highest reaction time score was observed for the close stimuli (Figure 22). In addition, results indicated, the reaction time scores during congruent and incongruent trials differed across the participants, $b = 52.70$, $t(658) = 8.52$, $p < .0001$; faster responses were recorded for the congruent trials, compared with the incongruent trials (Figure 23). For the main effect of compatibility though, no significant effect was found, $b = 4.71$, $t(658) = .76$, $p > .05$.

Results indicated for the numerical distance x Stroop congruency interaction that, reaction time of the participants for far-small and far-big stimuli significantly differed between congruent and incongruent trials, $b = 22.82$, $t(658) = 3.01$, $p < .01$. It was seen that, the reaction time of the participants did not differ during incongruent trials,

Table 3. The Included Variables to Obtain an Overall Model that Predicts the Reaction Time of the Participants during Numerical Judgment Task.

Model	*df*	*AIC*	*BIC*	*Test*	*L-ratio*	*p*
RandomInterceptModel	3	8416.32	8430.10			
RandomIntercept: Distance	5	8398.26	8421.23	1 vs 2	22.05	<.0001**
RandomIntercept: Distance + Congruency	6	8265.44	8293.01	2 vs 3	134.82	<.0001**
RandomIntercept: Distance + Congruency + Compatibility	7	8265.83	8297.99	3 vs 4	1.62	.20
RandomIntercept: Distance x Congruency	9	8264.11	8305.46	4 vs 5	5.72	.057
RandomIntercept: Distance x Compatibility	11	8267.92	8318.46	5 vs 6	0.19	.91
RandomIntercept: Congruency x Compatibility	12	8269.89	8325.02	6 vs 7	0.03	.86
RandomIntercept: Distance x Congruency x Compatibility	14	8266.95	8331.27	7 vs 8	6.94	.0311*

Note. * $p < .05$; ** $p < .0001$.

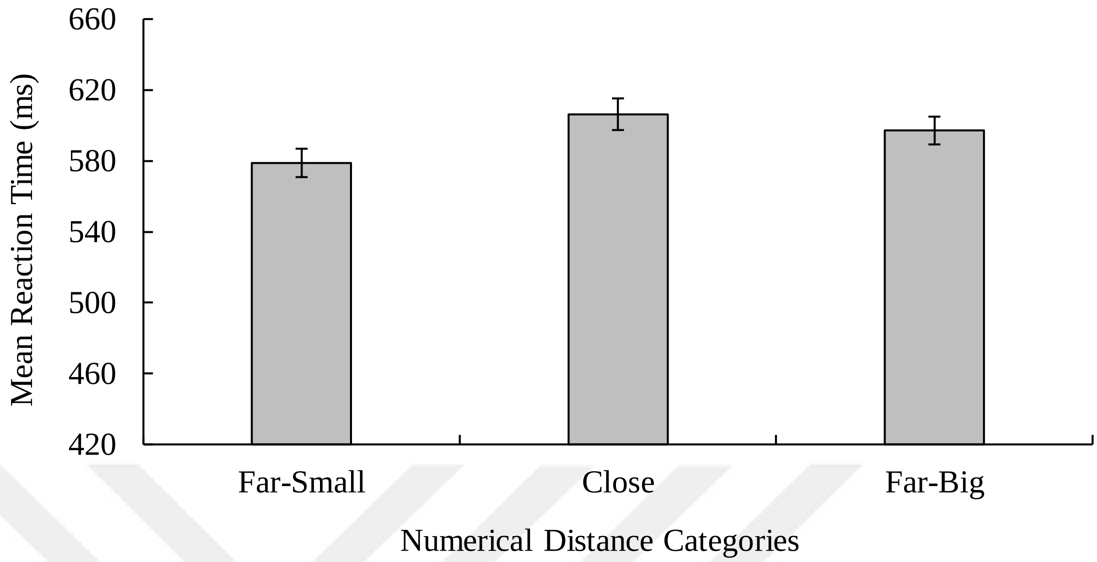

Figure 22. Mean (95% CI) reaction time of the participants for far-small, close, and far-big stimuli.

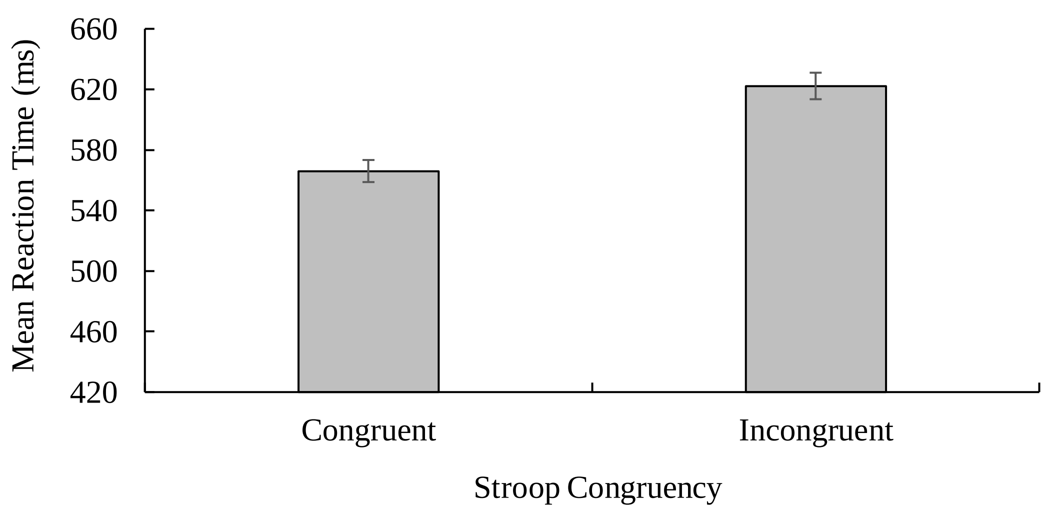

Figure 23. Mean (95% CI) reaction time of the participants for congruent and incongruent trials.

however, during congruent trials, the response time significantly decreased in far-small stimuli compared to far-big stimuli (Figure 24). No significant effect of numerical distance was found between close stimuli compared to the far-small and far-big stimuli regarding the Stroop congruency, $b = 0.20$, $t(658) = .05$, $p > .05$. For the numerical distance x N-S compatibility interaction term, it was found that, whether presenting far-small or far-big stimuli almost significantly differed in the reaction time of the participants during compatible and incompatible trials, $b = 14.43$, $t(658) = 1.90$, $p = .057$; during compatible trials, the reaction time of the participants were slower for far-big stimuli, compared with the far-small stimuli, hence, no such difference was found for incompatible trials (Figure 25). In addition, no significant effect was found between whether presenting close stimuli or far-small and far-big stimuli between the levels of Stroop congruency, $b = -3.52$, $t(658) = -.81$, $p > .05$. Much the same, the effect of Stroop congruency x N-S compatibility interaction also revealed that, incongruent trials, compared to the congruent trials did not significantly affect the reaction time during incompatible trials, compared to the compatible trials, $b = 1.74$, $t(658) = .20$, $p > .05$.

Lastly, results of the three-way interaction revealed that, when the effect of different numerical distance categories was examined regarding far-small and far-big stimuli, the levels of Stroop congruency significantly differed between the levels of compatibility, $b = -24.54$, $t(658) = -2.29$, $p < .05$. During the congruent trials, it was found that, the reaction time of the participants were slower for far-small stimuli throughout the incompatible trials, however, for far-big stimuli, non-significant difference was found between compatible and incompatible trials. Hence, during the incongruent trials, results indicated that, reaction time of the participants did not differ between the levels of compatibility for far-small stimuli, besides, the reaction time of the participants significantly decreased during compatible trials, compared to incompatible trials for far-big stimuli. (Figure 26). No such difference was found when the effect was examined regarding the close stimuli compared with the far-small and far-big stimuli, $b = 7.94$, $t(658) = 1.29$, $p > .05$. The overall results for Numerical Judgment task was visualized in Table 4.

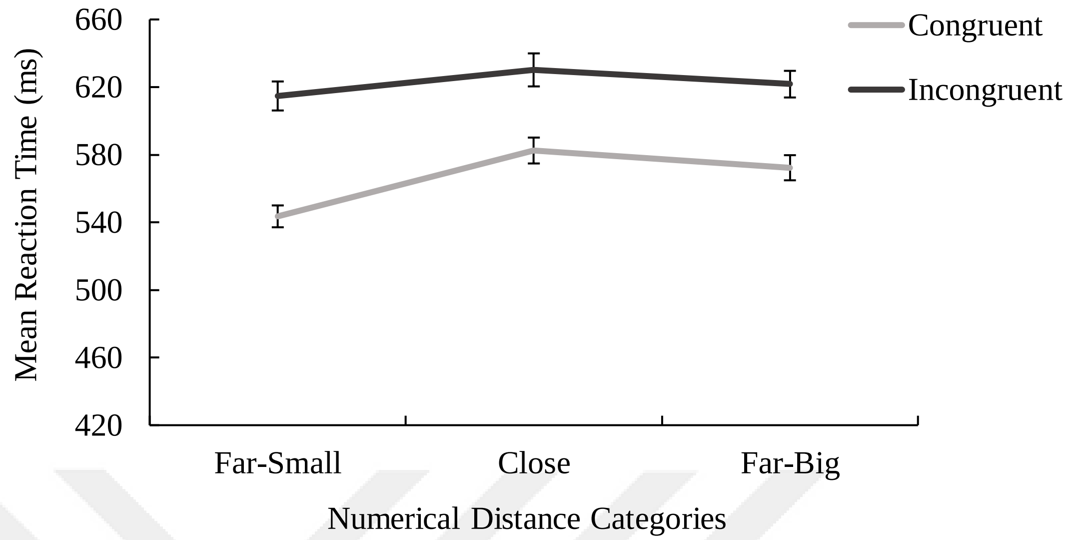

Figure 25. Mean (95% CI) reaction time of the participants for far-small, close, and far-big stimuli in congruent and incongruent trials.

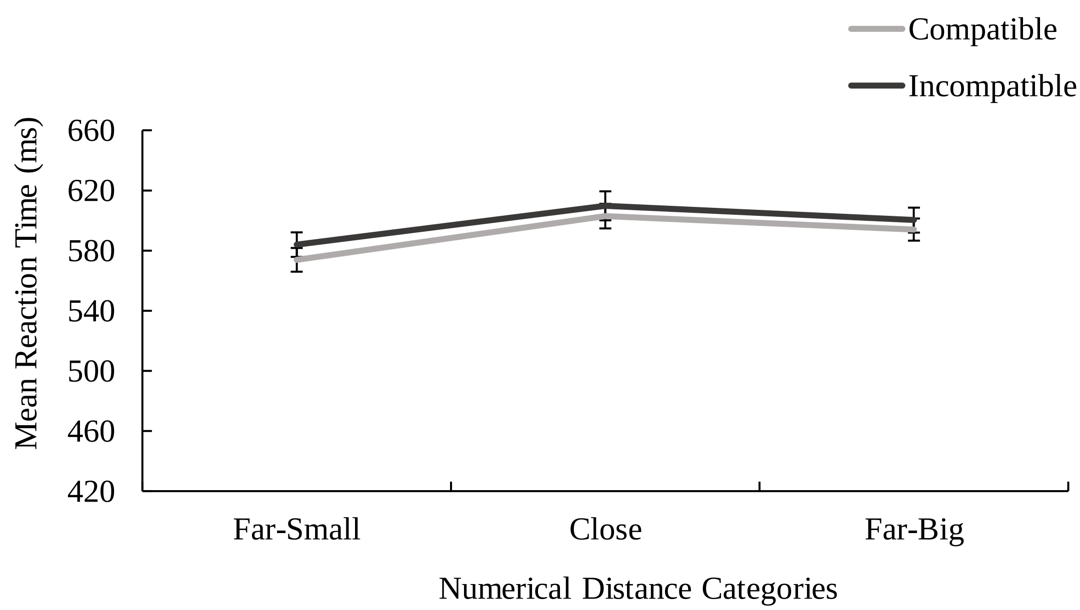

Figure 24. Mean (95% CI) reaction time of the participants for far-small, close, and far-big distance stimuli in compatible and incompatible trials.

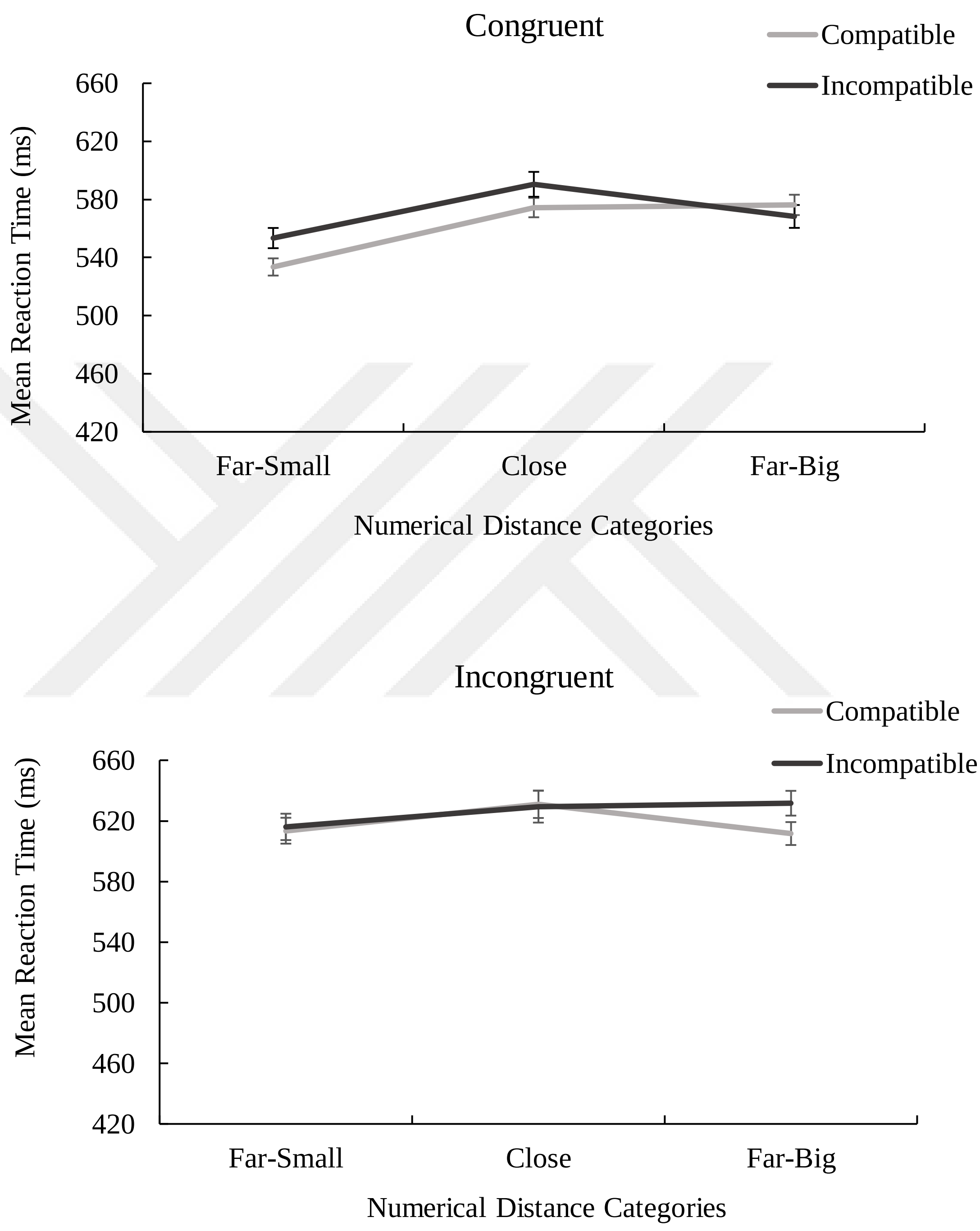

Figure 26. Mean (95% CI) reaction time of the participants for far-small, close and far-big stimuli between the levels of Stroop congruency (congruent and incongruent) and the N-S compatibility (compatible and incompatible).

Table 4. Multilevel Analyses of the Effect of Numerical Distance, Stroop Congruency, N-S Compatibility and their Interactions on the Reaction Time Scores for Numerical Judgment Task.

	b	*SE*	*df*	*t*	*p*
(Intercept)	565.42	12.85	658	44.02	0.00****
Numerical Distance: Far-Small vs Far-Big	-21.01	5.37	658	-3.91	0.00***
Numerical Distance: Close vs Far-Small - Far-Big	-6.62	3.09	658	-2.14	0.03*
Congruency: Incongruent	52.70	6.18	658	8.52	0.00****
Compatibility: Incompatible	4.71	6.18	658	0.76	0.44
Numerical Distance: Far-Small vs Far-Big x Congruency: Incongruent	22.82	7.58	658	3.01	0.00**
Numerical Distance: Close vs Far-Small - Far-Big x Congruency: Incongruent	0.20	4.36	658	0.05	0.96
Numerical Distance: Far-Small vs Far-Big x Compatibility: Incompatible	14.43	7.58	658	1.90	0.057
Numerical Distance: Close vs Far-Small - Far-Big x Compatibility: Incompatible	-3.52	4.36	658	-0.81	0.42
Congruency: Incongruent x Compatibility: Incompatible	1.74	8.75	658	0.20	0.84
Numerical Distance: Far-Small vs Far-Big x Congruency: Incongruent x Compatibility: Incompatible	-24.54	10.73	658	-2.29	0.02*
Numerical Distance: Close vs Far-Small - Far-Big x Congruency: Incongruent x Compatibility: Incompatible	7.94	6.17	658	1.28	0.20

Note. * $p < .05$; ** $p < .01$; *** $p < .001$; **** $p < .0001$.

3.4. Number of Correct Judgments

3.4.1. Magnitude Judgment Task

In order to see the model fit, variation across the participants was examined by comparing the baseline model and Model 1, where the intercepts varied across the participants. Results indicated that, the AIC score decreased from 1547.13 to 1530.22 and the BIC score decreased from 1556.45 to 1544.20 and the variance in intercept was statistically significant across the participants, *SD* = .62 (95% CI: -5.27, 1.42), $\chi^2(1) = 18.91$, $p < .0001$. Decreasing levels of AIC and BIC scores and the significance of the test results indicated the necessity of conducting multilevel analysis. Hence, data was analyzed by including the fixed effects to the random intercept model.

To obtain a full model, first, the main effect of *numerical distance* was introduced (Model 2). It was found that, including main effect of numerical distance significantly improved the model fit: AIC: 1489.86, BIC: 1513.15, and $\chi^2(3) = 44.37$, $p < .0001$. Therefore, *Stroop congruency* was added as a fixed effect (Model 2). Results indicated that, the AIC score declined to 1469.64 and the BIC score declined to 1497.60. The Log likelihood ratio test also revealed that, adding Stroop congruency as a fixed effect significantly improved the model fit, $\chi^2(4) =22.22$, $p < .0001$. Thus, the main effect of *N-S compatibility* was included in the model (Model 3). Both the test results where the Model 2 and Model 3 was compared and the AIC (1471.64) and BIC (1504.25) scores were examined. It was found that, including the main effect of compatibility did not improve the model fit, $\chi^2(5) = .00$, $p > .05$.

Even though including main effect of compatibility did not improve the model fit, in order to see how two-way interaction terms would have an effect, *numerical distance x Stroop congruency* interaction term was included to the model (Model 4). It was found that, the AIC score increased to 1471.01, and the BIC score increased to 1512.95. Increasing values of AIC and BIC were the indicators of poor model fit. Log likelihood ratio test results also revealed that, including numerical distance x congruency interaction did not improve the model fit, $\chi^2(7) = 4.62$, $p > .05$. In order to see the effect of other interaction terms, second two-way interaction, *numerical distance x N-S compatibility* was included (Model 5). Once again, the AIC increased to 1474.96 and the BIC score increased to 1526.22 and the test results showed that adding that interaction term did not improve the fit of the model, $\chi^2(9) = .05$, $p > .05$. Yet, the last two-way interaction term, *Stroop congruency x N-S compatibility* was added (Model 6). Results indicated that, the AIC score decreased to 1467.43, and the BIC score declined to 1523.34. The Log likelihood ratio test showed a significant improve of the fit of the model when Stroop congruency x N-S compatibility interaction was included, $\chi^2(10) = 9.53$, $p < .05$.

In order to see the overall model fit, lastly, three-way interaction term was included to the model (Model 7). Both the AIC and BIC scores decreased to 1460.71 and 1525.94, respectively. Accordingly, test results were examined to see whether the decreased values were significant or not. Results revealed that, including three-way interaction term significantly improved the model fit, $\chi^2(12) = 10.73$, $p < .05$. The model now predicts the number of correct judgments of the participants during Magnitude Judgment task from the included variables (numerical distance, Stroop congruency, N-S compatibility, numerical distance x Stroop congruency, numerical distance x N-S compatibility, Stroop congruency x N-S compatibility, and numerical distance x Stroop congruency x N-S compatibility) and the intercept. The model construction was summarized in Table 5.

The analysis conducted to examine the main effect of numerical distance revealed that, for both far-small and far-big stimuli, and close stimuli compared to far-small and far-big stimuli, significant differences were found: the number of correct judgments of the participants were higher in far-small stimuli, compared to far-big stimuli ($b = .10$, $t(704) = 3.94$, $p < .001$), and the highest number of incorrect judgments were given to close stimuli ($b = .09$, $t(704) = 5.71$, $p < .0001$) (Figure 27). Results also indicated that, the number of correct judgments differed across the levels of congruency, $b = .10$, $t(704) = 4.80$ $p < .0001$: participants respond more accurate during the congruent trials, compared to incongruent trials (Figure 28). Therefore, the difference in number of correct judgments of the participants did not differ across the levels of compatibility, $b = -.00$, $t(704) = -.06$, $p > .05$.

Table 5. The Included Variables to Obtain an Overall Model that Predicts the Number of Correct Judgments of the Participants during Magnitude Judgment Task.

Model	*df*	*AIC*	*BIC*	*Test*	*L-ratio*	*p*
RandomInterceptModel	3	1530.22	1544.20			
RandomIntercept: Distance	5	1489.86	1513.15	1 vs 2	44.37	<.0001**
RandomIntercept: Distance + Congruency	6	1469.64	1497.60	2 vs 3	22.22	<.0001**
RandomIntercept: Distance + Congruency + Compatibility	7	1471.64	1504.25	3 vs 4	.00	.95
RandomIntercept: Distance x Congruency	9	1471.01	1512.95	4 vs 5	4.62	.10
RandomIntercept: Distance x Compatibility	11	1474.96	1526.22	5 vs 6	.05	.97
RandomIntercept: Congruency x Compatibility	12	1467.43	1523.34	6 vs 7	9.53	.0020*
RandomIntercept: Distance x Congruency x Compatibility	14	1460.71	1525.94	7 vs 8	10.73	.0047*

Note. * $p < .05$; ** $p < .0001$

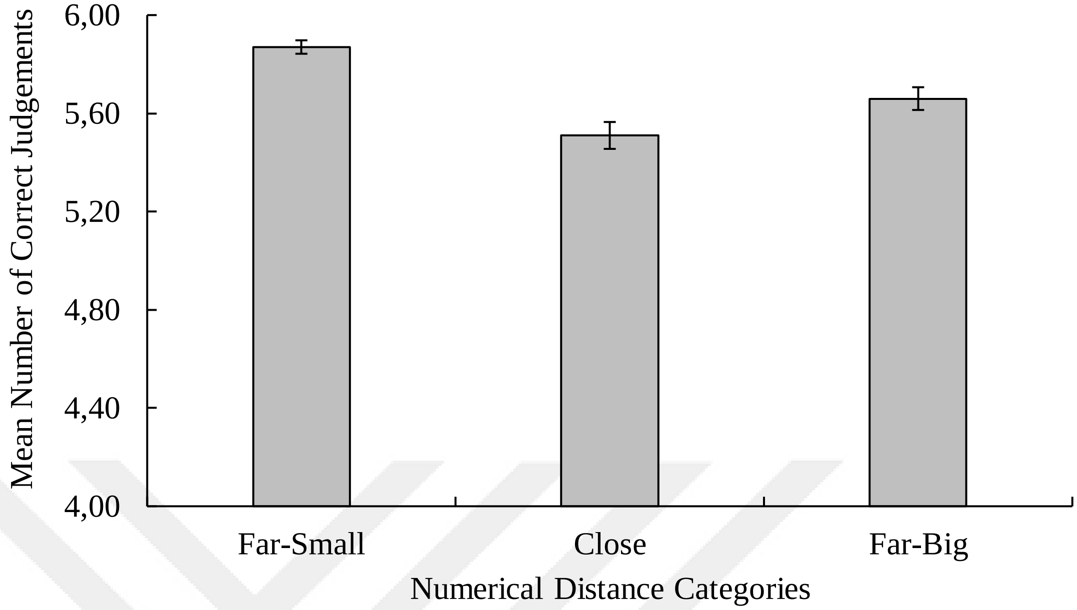

Figure 27. Mean (95% CI) number of correct judgments of the participants for far-small, close, and far-big stimuli.

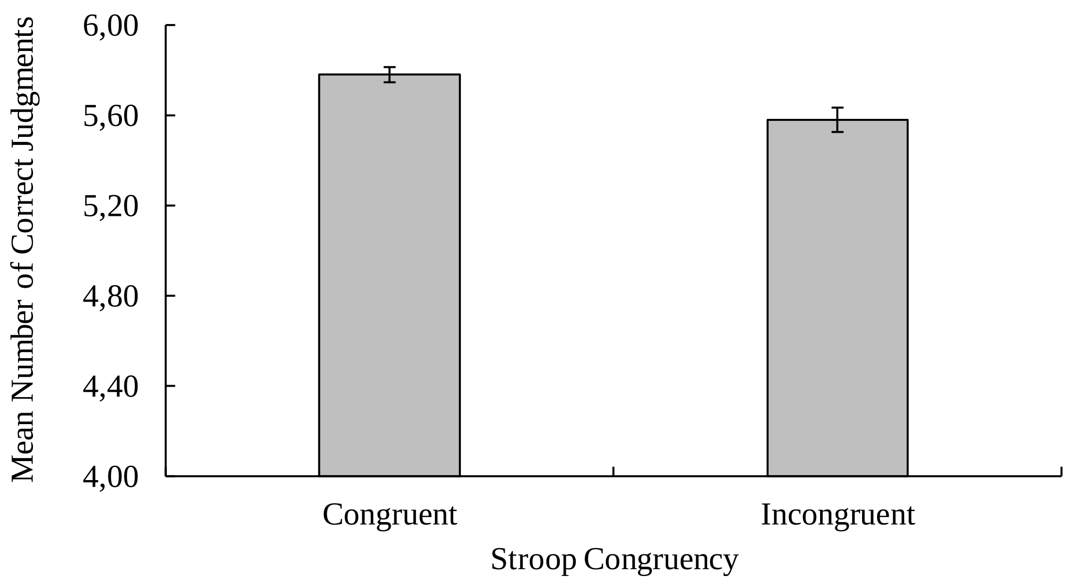

Figure 28. Mean (95% CI) number of correct judgments of the participants for congruent and incongruent trials.

When the effects of numerical distance categories were examined regarding the levels of Stroop congruency, non-significant differences were found between far-small and far-big stimuli (b = -.03, t(704) = -1.26, p > .05), and close stimuli compared to far-small and far-big stimuli (b = -.02, t(704) = -1.76, p > .05). In addition, non-significant difference was found during compatible and incompatible trials, for far-small and big far stimuli (b = .01, t(704) = -.22, p > .05), and close stimuli compared to other numerical distance categories (b = -.00, t(704) = -.04, p > .05. Therefore, it was found that, the number of correct judgments significantly differed between congruent and incongruent trials, during compatible and incompatible trials, b = -.07, t(704) = -3.10, p < .01: during incompatible trials, participants responded significantly more accurate to congruent trials, compared to incongruent trials. Hence, no such significant difference was found within the compatible trials (Figure 29).

Lastly, the three-way interaction effect was examined. Results indicated that, for both: difference between far-small and far-big stimuli (b = .06, t(704) = 2.16, p < .05), and close stimuli compared to far-small and far-big stimuli (b = .05, t(704) = 2.45, p < .05) number of participants differed in the levels of Stroop congruency and N-S compatibility. Results of the analysis revealed that, during the congruent trials, participants responded more accurately to far-small stimuli during compatible trials compared to far-big stimuli. Besides, during incongruent trials, participants respond to far-big stimuli more accurately during compatible trials, yet, no such difference was found for far-small stimuli. In addition, it was found during the congruent trials that, to the close stimuli, compared to other numerical distance categories, correct judgments of the participants were higher during compatible trials and the least number of correct response was recorded for the close stimuli during incongruent-incompatible trials (Figure 30). Table 6 was drawn to summarize the overall results.

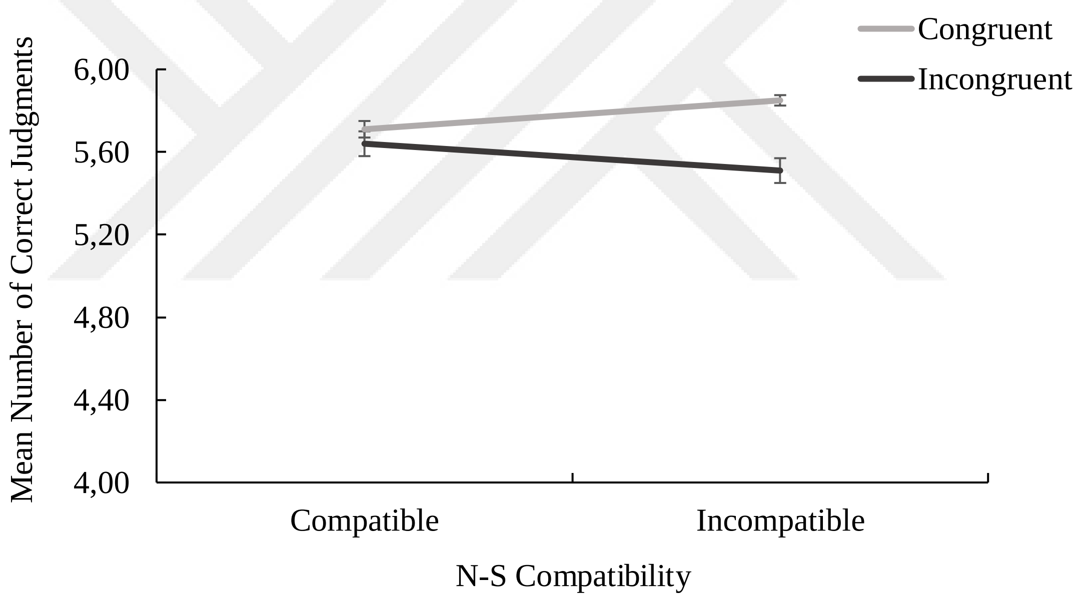

Figure 29. Mean (95% CI) number of correct judgments of the participants between the levels of Stroop congruency and N-S compatibility.

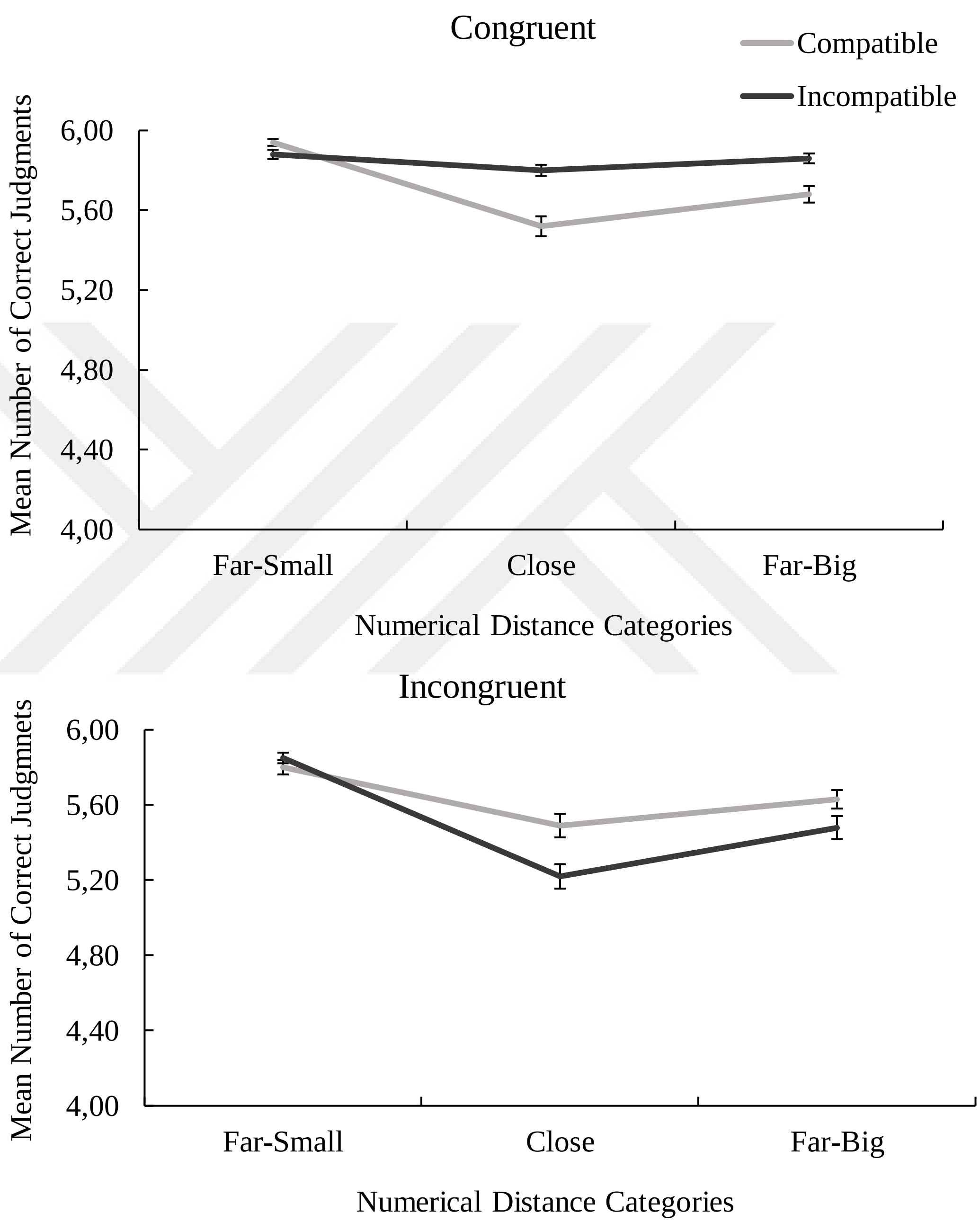

Figure 30. Mean (95% CI) number of correct judgments of the participants for far-small, close and far-big stimuli between the levels of Stroop congruency and N-S compatibility.

Table 6. Multilevel Analyses of the Effect of Numerical Distance, Stroop Congruency, N-S Compatibility and their Interactions on the Number of Correct Judgments for Magnitude Judgment Task.

	b	*SE*	*df*	*t*	*p*
(Intercept)	5.68	0.05	704	175.97	0.00****
Numerical Distance: Far-Small vs Far-Big	0.10	.05	704	3.94	0.00***
Numerical Distance: Close vs Far-Small - Far-Big	0.09	0.02	704	5.71	0.00****
Congruency: Incongruent	0.10	0.06	704	4.80	0.00****
Compatibility: Incompatible	-0.00	0.06	704	-0.06	0.95
Numerical Distance: Far-Small vs Far-Big x Congruency: Incongruent	-0.03	0.07	704	-1.26	0.21
Numerical Distance: Close vs Far-Small - Far-Big x Congruency: Incongruent	-0.03	0.04	704	-1.76	0.08
Numerical Distance: Far-Small vs Far-Big x Compatibility: Incompatible	0.01	0.07	704	0.22	0.82
Numerical Distance: Close vs Far-Small - Far-Big x Compatibility: Incompatible	-0.00	0.04	704	-0.04	0.97
Congruency: Incongruent x Compatibility: Incompatible	-0.07	0.08	704	-3.10	0.00**
Numerical Distance: Far-Small vs Far-Big x Congruency: Incong x Comp: Incomp	0.06	0.10	704	2.16	0.03*
Numerical Distance: Close vs Far-Small - Far-Big x Cong: Incong x Comp: Incomp	0.04	0.06	704	2.45	0.01*

Note. * $p < .05$; ** $p < .01$; *** $p < .001$; **** $p < .0001$.

3.4.2. Numerical Judgment Task

In order to see whether the data was appropriate to conduct multilevel analysis or not, variation across the participants was examined by fitting a baseline model and comparing that model with random intercept model (Model 1), where only the intercept was introduced. When the baseline model was compared with Model 1, it was found that, the AIC score decreased from 2428.89 to 2295.73 and the BIC score decreased from 2438.21 to 2309.71. Additionally, the variance in intercepts across the participants indicated that, there is a need to conduct multilevel analysis, *SD* = .99 (95% CI: -4.32, 2.78), $\chi^2(1) = 135.16$, $p < .0001$. Therefore, the improvement of the model fit was examined by including fixed effects to the random intercept model.

First, *numerical distance* was added to the model as a fixed effect (Model 2). Result of the analysis indicated that, including numerical distance did not significantly improve the fit of the model: AIC: 2298.73, BIC: 2322.21, $\chi^2(3) = 0.81$, $p > .05$. Hence, the second main effect, *Stroop congruency*, was included (Model 3). Both AIC (2213.32) and BIC (2241.28) scores decreased, and the Log likelihood ratio test results indicated a significant improvement of the model fit, $\chi^2(4) = 87.59$, $p < .0001$. Thus, another main effect was included in the model, *N-S compatibility* (Model 4). Results of the AIC: 2213.57, and BIC: 2246.18 scores indicated that, adding main effect of compatibility did not improve the model fit, $\chi^2(5) = 1.75$, $p > .05$.

Since the last fixed effect did not improve the model fit, to see the effect of interaction terms, *numerical distance x Stroop congruency* was added (Model 5). It was found that, again, adding the first interaction term did not improve the model fit, AIC: 2213.76, BIC: 2255.69, $\chi^2(7) = 3.81$, $p > .05$. Hence, the model was proceeded by including the second interaction term, *numerical distance x N-S compatibility* (Model 6). Both the AIC and the BIC scores decreased to 2208.23, and 2359.48, respectively. In order to see the significance of the decreased scores, Log likelihood ratio test was examined. Results revealed that, including the numerical distance x compatibility interaction significantly improved the model fit, $\chi^2(9) = 9.53$, $p < .05$. For this reason, the last two-way interaction term, *Stroop congruency x N-S compatibility*, was included to the model, (Model 7). Results indicated that, including the Stroop congruency x N-S compatibility interaction to the model significantly improved the model fit, AIC: 2201.70, BIC: 2257.61, $\chi^2(10) = 8.52$, $p < .05$.

In order to construct the final model, the three-way interaction term, *numerical distance x Stroop congruency x N-S compatibility*, was included (Model 8). Results indicated that, adding the three-way interaction term to the model ensured a significant model fit, AIC: 2199.46, BIC: 2264.69, $\chi^2(10) = 6.24$, $p < .05$. The model now predicts the number of correct judgments of the participants during the Numerical Judgment task from the included variables (numerical distance, Stroop congruency, N-S compatibility, numerical distance x Stroop congruency, numerical distance x N-S compatibility, Stroop congruency x N-S compatibility, and numerical distance x Stroop congruency x N-S compatibility) and the intercept. The model construction was summarized in Table 7.

Results of the analysis indicated that, the number of correct judgments of the participants did not differ between; far-small and big far stimuli ($b = .04$, $t(704) = .96$, $p > .05$) and close stimuli compared to far-small and far-big stimuli ($b = .00$, $t(704) = .11$, $p > .05$). Hence, the difference between congruent and incongruent trials was statistically significant, $b = .32$, $t(704) = 9.78$, $p < .0001$. It was found that, the number of correct judgments were higher for congruent trials compared to incongruent trials (Figure 31). For the main effect of N-S compatibility, results revealed that, the number of correct judgments significantly differed between compatible and incompatible trials, $b = .04$, $t(704) = 1.34$, $p > .05$.

When the effect of numerical distance categories was examined regarding the levels of the Stroop congruency, no significant interaction effect was found. Results indicated that the number of correct judgments of the participants did not differ between far-small and far-big stimuli ($b = .06$, $t(704) = 1.55$, $p > .05$), and close stimuli compared to far-small and far-big stimuli ($b = .03$, $t(704) = 1.23$, $p > .05$). Moreover, the interaction between numerical distance and N-S compatibility was statistically significant. Planned contrasts revealed that, the nature of the effect relied on the difference between far-small and far-big stimuli, $b = .12$, $t(704) = 2.90$, $p < .001$: the number of correct judgments were higher during the compatible trials compared to incompatible trials for far-small stimuli, besides, for the far-big stimuli, no such difference was examined (Figure 32). In addition,

Table 7. The Included Variables to Obtain an Overall Model that Predicts the Number of Correct Judgments of the Participants during Numerical Judgment Task.

Model	*df*	*AIC*	*BIC*	*Test*	*L-ratio*	*p*
RandomInterceptModel	3	2295.73	2309.71			
RandomIntercept: Distance	5	2298.91	2322.21	1 vs 2	.81	.67
RandomIntercept: Distance + Congruency	6	2213.32	2241.28	2 vs 3	87.59	<.0001***
RandomIntercept: Distance + Congruency + Compatibility	7	2213.57	2246.18	3 vs 4	1.75	.19
RandomIntercept: Distance x Congruency	9	2213.76	2255.69	4 vs 5	3.81	.15
RandomIntercept: Distance x Compatibility	11	2208.23	2259.48	5 vs 6	9.53	.0085*
RandomIntercept: Congruency x Compatibility	12	2201.70	2257.61	6 vs 7	8.52	.0035**
RandomIntercept: Distance x Congruency x Compatibility	14	2199.46	2264.69	7 vs 8	6.24	.0441*

Note. * $p < .05$; ** $p < .01$; *** $p < .0001$.

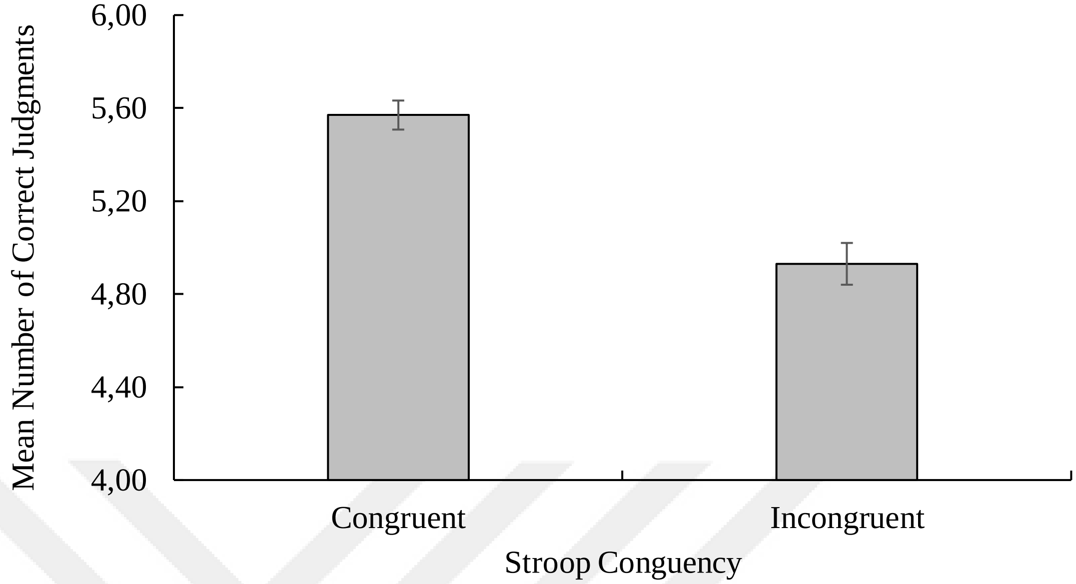

Figure 31. Mean (95% CI) number of correct judgments of the participants for congruent and incongruent trials.

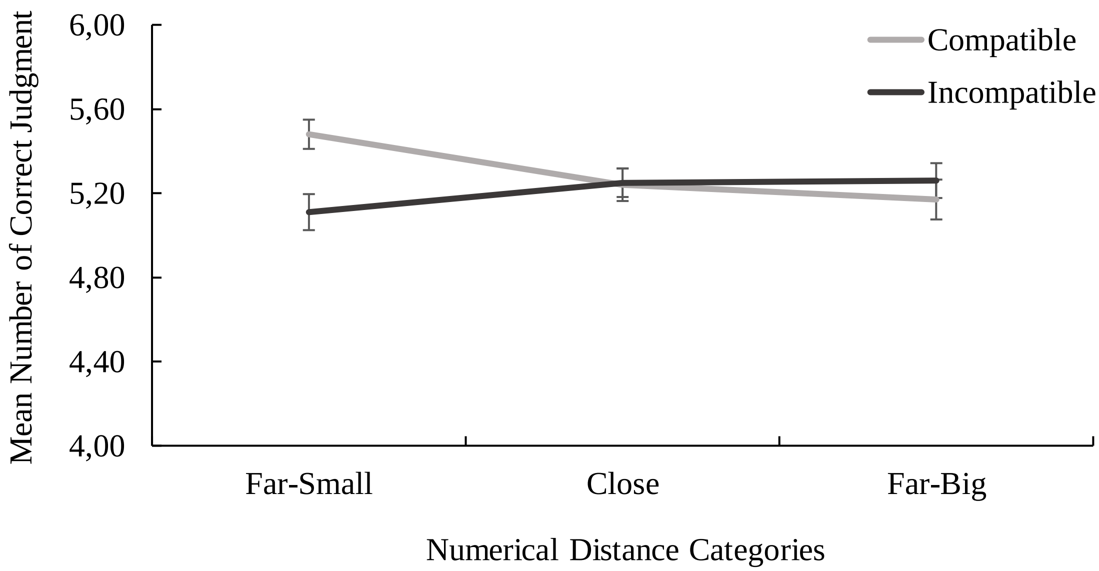

Figure 32. Mean (95% CI) number of correct judgments of the participants for far-small, close, and far-big stimuli in compatible and incompatible trials.

the interaction effect between Stroop congruency and N-S compatibility also revealed significant test results (*b* = -.09, *t*(704) = -2.92, *p* < .001): it was found that, the number of correct judgments were significantly lower in incongruent-incompatible trials compared to incongruent-compatible trials (Figure 33).

The effect of three-way interaction also showed that, the number of correct judgments differed between different numerical distance categories regarding both the levels of Stroop congruency and N-S compatibility. The results of the planned contrasts revealed that, number of correct responses of the participants significantly differed for far-small and far-big stimuli (*b* = .08, *t*(704) = 1.93, *p* = .05): during the congruent trials, the number of correct judgments were higher for compatible trials for far-small stimuli, and lower for far-big stimuli. On the other hand, during the incongruent trials, no such difference was seen between far-small and far-big stimuli compared to close stimuli, (*b* = 0.04, *t*(704) = -1.56, *p* > .05 (Figure 34). Table 8 was drawn to summarize the overall results.

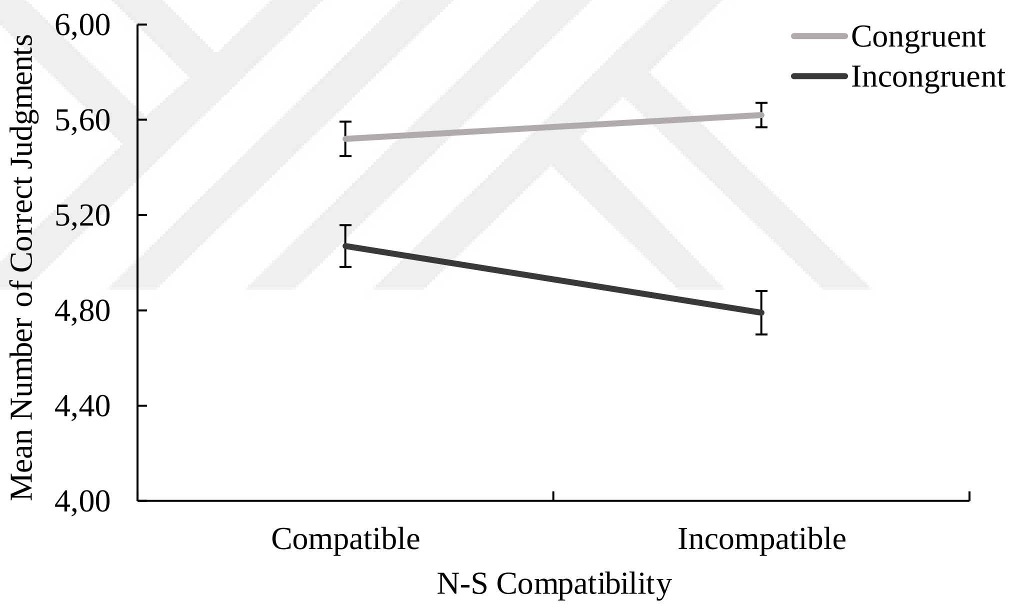

Figure 33. Mean (95% CI) number of correct judgments of the participants between the levels of Stroop congruency and N-S compatibility.

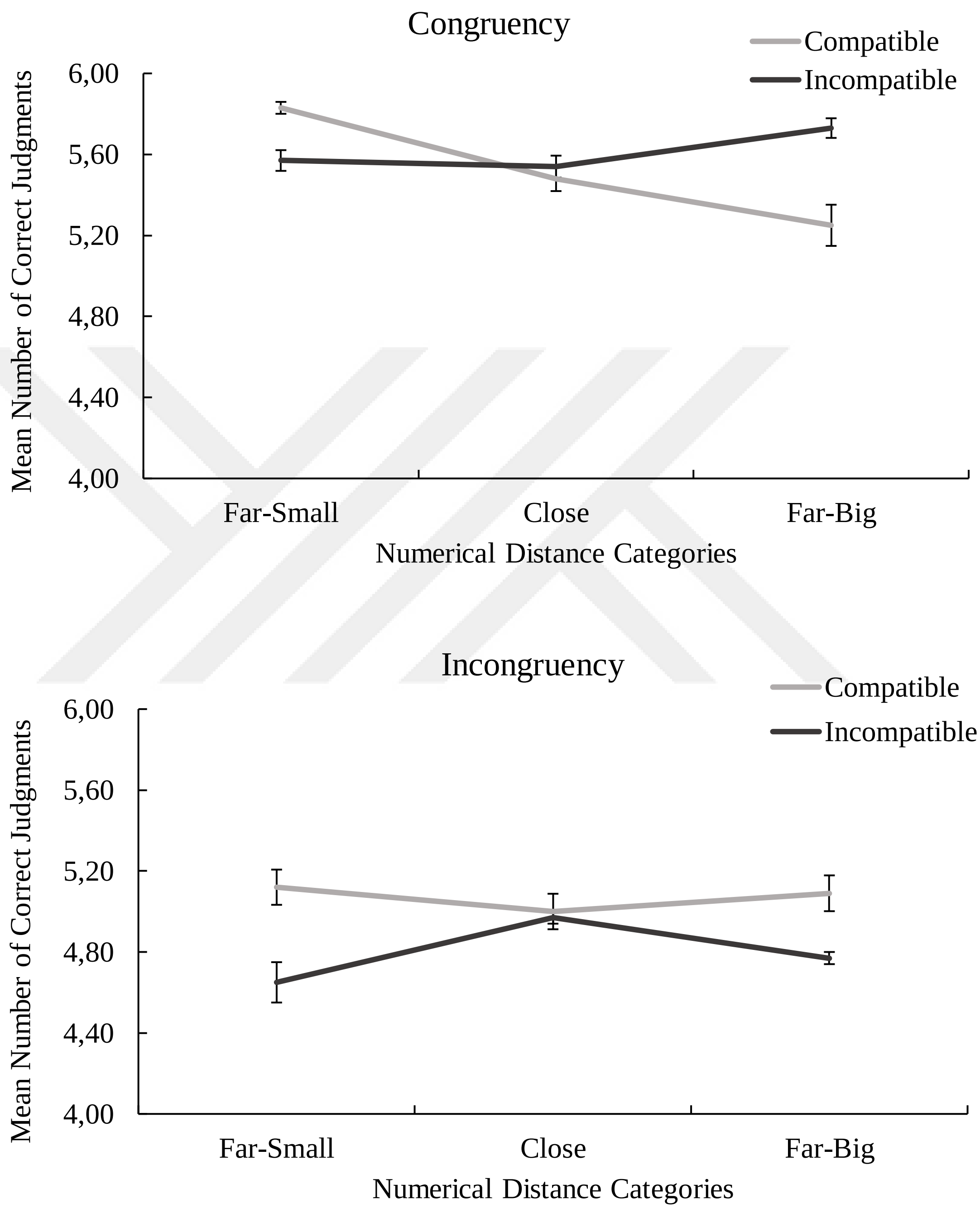

Figure 34. Mean (95% CI) number of correct judgments of the participants for far-small, close and far-big stimuli between the levels of Stroop congruency and N-S compatibility.

Table 8. Multilevel Analyses of the Effect of Numerical Distance, Stroop Congruency, N-S Compatibility and their Interactions on the Number of Correct Judgments for Numerical Judgment Task.

	b	*SE*	*df*	*t*	*p*
(Intercept)	5.25	0.10	704	63.81	0.00***
Numerical Distance: Far-Small vs Far-Big	0.04	0.08	704	0.97	0.33
Numerical Distance: Close vs Far-Small - Far-Big	0.00	0.05	704	0.11	0.91
Congruency: Incongruent	0.32	0.09	704	9.78	0.00***
Compatibility: Incompatible	0.04	0.09	704	1.34	0.18
Numerical Distance: Far-Small vs Far-Big x Congruency: Incongruent	0.06	0.11	704	1.55	0.12
Numerical Distance: Close vs Far-Small - Far-Big x Congruency: Incongruent	0.03	0.07	704	1.23	0.22
Numerical Distance: Far-Small vs Far-Big x Compatibility: Incompatible	0.12	0.11	704	2.90	0.00**
Numerical Distance: Close vs Far-Small - Far-Big x Compatibility: Incompatible	0.03	0.07	704	1.12	0.27
Congruency: Incongruent x Compatibility: Incompatible	-0.09	0.13	704	-2.92	0.00**
Numerical Distance: Far-Small vs Far-Big x Congruency: Incongruent x Compatibility: Incompatible	0.08	0.16	704	1.93	0.05*
Numerical Distance: Close vs Far-Small - Far-Big x Congruency: Incongruent x Compatibility: Incompatible	-0.04	0.09	704	-1.56	0.12

Note. * $p < .05$; ** $p < .01$; *** $p < .0001$.

CHAPTER 4: DISCUSSION

In this thesis, the association between number and space was examined in a modified version of the Numerical Stroop task which was divided in to two tasks (Magnitude and Numerical Judgment) with the given instructions. The primary objective was to investigate whether the currently used tasks, especially the Magnitude Judgment task which was examined for the first time in N-S literature, reveal the Stroop inhibitory processes and whether the N-S association reveals an interaction. Moreover, as is explained in detail during sections **Error! Reference source not found.** and **Error! ference source not found.**the accelerant inhibitory effect of numerical distance (and consequently numerical size -magnitude) was also included as an independent variable in order to demonstrate the processing of the effect. Accordingly, for both tasks, individually, consistent results were obtained with the hypotheses, yet, there are some inconsistencies between them, as expected. The following parts were composed to represent and discuss those findings in conjunction with two tasks and were approached in different sections regarding the literature.

4.1. The NDE and Size Effect in Modified Version of the Numerical Stroop Task

When it was required to make a comparison over the magnitude of two digits, it was found that as the numerical distance between the digits gets smaller (NDE), plus, as the numerical magnitude of those digits gets bigger (size effect), the discriminability between them becomes harder. The first appearance of the effect was recognized in a single-digit Arabic number comparison task (Moyer and Landauer, 1967), and from that day on, in variety of tasks, the significance of the effect was examined, validated and extended in both behavioral (Dehaene and Akhavein, 1995; Duncan and McFarland, 1980; Cohen Kadosh and Henik, 2006; Gertner et al., 2009) and neuronal (Dehaene, 1996; Temple and Posner, 1998; Libertus et al., 2007) states. Despite those studies, some of the implications made a sensation that whether the effect might be task-dependent or not. A study conducted by Goldfarb et al. (2011) acknowledged a significant NDE for comparison task, whereas, when the same stimuli were presented in a standard automatic matching task, non-significant NDE results were obtained. From that time forward, the studies conducted to examine the NDE in one respect were aimed to draw some boundaries of in which case it shows itself, and in which cases it does not. The current results related to NDE revealed substantial evidence at this point.

Based on the information given above, a modified version of the Numerical Stroop task was used to examine how the difference between numerical distance categories show itself when the stimulus presentation was executed regarding N-S compatibility and Stroop congruency rules. Unlike the original Numerical Stroop task (Besner and Coltheart, 1979; Henik and Tzelgov, 1982) -where the physical size of the digits was manipulated to generate the levels of Stroop congruency-, in the modified version, the repetition frequency and the numerical magnitude of the digits were manipulated. In parallel with this, two different judgment tasks were given (1) a numerical magnitude judgment between two digits by omitting the repetition frequency -Numerical Judgment task- (2) a frequency judgment between two digits by omitting the numerical magnitude of those -Magnitude Judgment task-. Accordingly, as it was hypothesized (see hypotheses 1 and 2 in section 0), the number of correct judgments for both tasks and the reaction time results for the Magnitude Judgment task revealed NDE, yet, during the Numerical Judgment task, the reaction time of the participants did not significantly differ between the numerical distance categories. One possible explanation of unexpected reaction time results might be the task difficulty for the number magnitude judgment task. Since the overall reaction time results were examined for different tasks, it was found that the time passes before making judgment upon the frequency of the digits during the Numerical Judgment task (*Mnumerical* = 593.11, *SD* = 96.43) is longer compared to Magnitude Judgment task (*Mmagnitude* = 506.69, *SD* = 77.83). In other words, when it was required to judgment upon the numerical magnitude of the digits, the discriminability between them becomes harder, regardless of the numerical distance.

Another conclusion to be reached based on the significant differences in numerical distance categories is the size effect. When both the differences in reaction time and the number of correct judgments between the far-small and far-big categories were examined, consistent with the 3rd and 4th hypothesis (see section 0), results indicated for a significant size effect for the Magnitude Judgment task. Accordingly, compared with the far-small category, in the far-big distance category, the reaction time of the participants were significantly higher, and the number of errors made were higher too. Moreover, for the Numerical Judgment task, while the reaction time of the participants revealed significant size effect, the accuracy of the response did not differ.

To sum up, for the Magnitude Judgment task, which was examined for the first time over both NDE and size effect, the reaction time of the participants was significantly increased if the two numbers to be compared were numerically close to each other. Moreover, while comparing the two sets of numbers that are in the same distance category, this time, the magnitude of the digits are the determinants of both the reaction time and accuracy of the response (as acknowledged by Moyer and Landauer, 1967). The reason that lies behind the effect was examined by different brain imaging techniques (Kaufmann et al., 2005; Szücs and Soltész, 2007). Accordingly, results indicated that as the distance between the reference number and the probe number decrease, the activation in the parietal regions, especially the IPS gets stronger in both numerical comparison and physical size comparison tasks.

4.2. The Modified Numerical Stroop Task: Magnitude of Stroop Inhibition

J. Ridley Stroop, in 1935, propounded a phenomenon that activates the automatic inhibitory processes for the irrelevant stimulus-response dimension, *the Stroop effect* (Khng and Lee, 2014). The effect was first examined through a color-word naming task in which the interference in the reaction was created through a conflicting stimulus, the name of a color that is printed in another color, The Stroop Color and Word Test (SCWT) (Stroop, 1935). From that study forward, the effect was redesigned and reinvestigated in a variety of formations as (1) warped words Stroop effect, (2) Emotional Stroop effect, (3) Spatial Stroop effect, (4) Auditory Stroop effect, and (5) Numerical Stroop effect (the versions are retrieved from Hilbert et al., 2014). The fundamental point in the working mechanism of the Stroop effect, on which all these versions are based, is to create an incongruent stimulus presentation through simultaneous processing of two different features such as the color-word incongruency in SCWT. Accordingly, what might be the incongruency in a Numerical Stroop task?

The Numerical Stroop task was first propounded by Besner and Coltheart (1979). In parallel with the SCWT, here, the incongruency between features is generated through the physical and semantic size of the presented numbers. Nominately, if the *numerically smaller number* is presented in *relatively smaller type size*, that stimulus presentation is accepted as congruent, yet, if the *numerically smaller* number is presented in a *relatively bigger type size* that is accepted as incongruent. The stimulus presentation is executed from both visual fields and the participants are asked to make a judgment upon either physical or numerical (semantic) size of those numbers. In conjunction with this, in this thesis, a modified version of the Stroop task was used to investigate both the N-S association and the magnitude of the Stroop inhibitory effect, as well. As it was hypothesized (see hypotheses 5 and 6 in section 0), results indicated a significant effect of Stroop congruency for Numerical Judgment task. Accordingly, more delayed and less accurate responses were given during incongruent trials. Besides, for the Magnitude Judgment task, the reaction time of the congruent and incongruent trials differed between the levels of numerical distance categories. To explain those results, once more, it would be better to cross over how the Magnitude Judgment task operates. As it was explained in detail in section 2.2.3. Apparatus and Stimulus Presentation Programin the Magnitude Judgment task, the primary expectation was not related to the processing of numerical magnitude, but an assessment based on the spatial magnitude. Accordingly, at the beginning of the study, the participants were instructed to respond as quickly as possible to the prevented calculation of the frequency of the repetition but only allowed to process which is more or less. Based on this information, the behavior expected from the participants was to make a judgment by focusing on the center of the screen to perceive the density in both visual fields rather than to scan the right and/or left visual field. Therefore, the reaction time might not be the key indicator of the Stroop interference for the Magnitude Judgment task, but the accuracy of the response might be.

Results also indicated that even if the congruency did not show itself, in close distance category, a significant congruency effect was obtained. In other words, when the presented stimuli were in close distance category, it took longer time to respond during incongruent trials, compared to congruent trials. These results were consistent with the results of a series of studies conducted by Santens and Verguts (2011), yet, what could be its underlying mechanisms? For now, it is well known that magnitude information is processed in PC and the abstract representation of the magnitude information is generated in IPS. What about the neural correlates of Stroop congruency? Kaufmann et al. (2005) examined the number-size congruity effect by the means of fMRI scanning and results addressed to the bilateral activation of occipital region, frontal region, and most importantly the area around IPS in parietal region. Moreover, findings also revealed a stronger activation of the corresponding brain region in the parietal lobule during incongruent trials. The reason for the activation in the parietal region is most probably due to the attentional control processing, which includes the functioning of PC and a process what Stroop task aimed to ascertain.

4.3. N-S Association of Inhibitory Processes

What was learned from the N-S association literature is, when the relatively smaller numbers are associated with the left visual field and relatively bigger numbers are associated with the right visual field, the amount of time to respond takes shorter, on the contrary, when the magnitude and the presented visual field are conflicting (smaller on the right, and bigger on the left), the amount of time to respond takes longer. Nevertheless, on one hand, the results of this thesis did not reveal significant N-S association as the main effect (except the reversed effect for Magnitude Judgment task), on the other hand, they generated some very important interactions in the number of correct judgments for the N-S association literature.

Previous studies have shown that the N-S compatibility effect is independent of the Stroop effect when the stimuli were presented in a parity judgment and physical size comparison tasks (Fitousi et al., 2009). However, both the Magnitude Judgment and Numerical Judgment task results revealed a significant interaction between Stroop congruency and N-S compatibility. Accordingly, as it was hypothesized (see hypothesis 8 in section 0), participants made the highest number of errors when the stimulus presentation was conducted as Stroop incongruent / N-S incompatible for both tasks. The underlying mechanisms of those results might be related to the *shared representation* of two different mechanisms (Schwarz & Heinze, 1998). In other words, the information on where the number is located on the space share a common representation during the encoding phase with the information of which digit is bigger or smaller and which repetition frequency is more or less. Thus, in the retrieval phase, those two mechanisms that share the same representation plays an enhancing role in the inhibitory processes (Weis et al., 2018). Or, the reason that lies behind that interaction is, most of the studies that were aimed to ascertain the Stroop inhibitory response effect in N-S association was conducted by examining the inhibition on the N-S paradigm. Yet, in this thesis, the Stroop congruency and the N-S compatibility effects were examined simultaneously through the stimulus presentation procedure. Accordingly the stimulus presentation was conducted as both congruent-compatible, congruent-incompatible, incongruent-compatible, and incongruent-incompatible, within different levels of NDE (far-small, close, far-big). In furtherance, consistent with the expectations for the 7th hypothesis, for the Magnitude Judgement task the reaction time of the participants was the slowest, during incongruent and incompatible trials. However, the Stroop congruency did not reveal an interaction effect with the N-S association during Numerical Judgment task.

Once and for all, one of the most important expectation of this thesis (see hypotheses 9 and 10 in section 0) was to obtain an interaction between Stroop congruency, N-S compatibility and NDE for both Magnitude and Numerical Judgment tasks. Accordingly, results indicated for both tasks that when the stimulus presentation conducted as Stroop incongruent and N-S incompatible, and when the reference number and probe number are numerically close to each other, the slowest and least accurate responses were given. The reason that lies behind that result, in the first step, is based on the strengthening mechanisms between Stroop congruency and N-S compatibility, second is the enhancer inhibitory effect of NDE. Since the existence of the NDE was proved consistently, it is well known now that the association between number and space is not a unitary phenomenon (Moro et al., 2017).

4.4. Limitations, the Importance of this Thesis and Future Implications

4.4.1. Limitations and Importance

One of the potential limitation of this thesis is since the N-S association was investigated through a modified version of the Numerical Stroop task, the stimuli used in the original Numerical Stroop task might also be applied in order to see the reliability of the performance across the original and modified version of the tasks. Further limitation is the performance discriminability issue that arises as the result of the *ceiling effect*, a measurement limitation that occurs when there is a great number of highest possible or close to the highest scores on a test (Gulledge et al., 2020). In this thesis, the stimulus presentation was conducted regarding the Stroop congruency and N-S compatibility rules, thereupon, the presented stimuli were (1) congruent-compatible, (2) congruent-incompatible, (3) incongruent-compatible, and (4) incongruent-incompatible. Accordingly, the fastest and more accurate reaction was obtained during congruent-compatible, and the slowest and less accurate reaction time was obtained during incongruent-incompatible, as it was hypothesized. However, since the congruency in Stroop inhibitory processes and the compatibility of the N-S association were played as an acceleratory role on each other as it was discussed in 4.3. N-S Association of Inhibitory Processes, the majority of the participants responded correctly the congruent-compatible trials, especially when the stimulus presentation was conducted as far-small. The last limitation of this thesis was the non-measured handedness. When the N-S association literature was examined within the scope of the SNARC effect, one of the most important point is the handedness, which is mostly first assessed for each participant, then counterbalanced between the participants (Dehaene et al, 1993). Since this thesis was not aimed to investigate the SNARC effect, participants' dominant hand was not asked. Yet, even if the main consideration is not the SNARC effect, in order to eliminate possible confounding effects -that might played as an accelerator role for either side of the space- which can be caused by the dominant hand, it would be better to control that effect. Nevertheless, the results of this thesis revealed some important findings to the N-S literature regarding the inhibitory processes. In the first place, for both Magnitude and Numerical Judgment tasks, a significant Stroop congruency effect was found. This means that the inhibitory processes are activated through either of the modified version of the Numerical Stoop task, thus, the irrelevant repetition frequency inhibited processing of the numerical magnitude, whereas, the irrelevant numerical magnitude inhibited the processing of repetition frequency. Plus, the modified version can be used in the further studies to investigate the N-S association, since the effect was found significant between the levels of the NDE and there was also a significant interaction effect of the N-S compatibility with the Stroop congruency. The results obtained from three-way interaction for the Magnitude Judgment task is one of the most important finding of this thesis. That is because the information of the numerical comparison between the numbers elicit NDE now widens to a new kind of comparison which is the magnitude judgement, the repetition frequency of the digits.

Secondarily, both Magnitude Judgment and Numerical Judgment results indicated for an NDE. Up to this time, as explained in detail in **Error! Reference source not found.** nd **Error! Reference source not found.**, both the NDE and size effect is accepted as the indicator of the MNL (Restle, 1970). By extension of this knowledge, the results of this thesis also provide an important piece of evidence to the existence of the MNL account.

Finally, when the N-S association was examined within the scope of the excitatory processes, what was nourished is actually the idea of *N-S association is as a result of learning processes*. What about the inhibitory processes? When the tendency was examined regarding the inhibitory processes, what were the findings inferred to? The inhibitory processes were the foremost mechanisms that indicate the N-S association not as a result of a shaped behavior, but as a result of automatic processes that arises because of the aim of the suppressing behavior. Accordingly, what the significant inhibitory processes found for this thesis revealed that N-S association is not a result of some learning mechanisms, but a very fundamental and strong tendency that most probably is an innate mechanism.

4.4.2. Future Implications

The exploration of the space and representing numbers in our mental imagery start with the sensory organs, hence, both the fixating and saccadic eye movements play an important role in the visual perception, more importantly for the mental representation of numbers (Fourtassi et al., 2017). Fourtassi et al. (2017), showed that when the eye movements were examined within the SNARC paradigm, the tendency in behavior shows itself in the eye movements. When the target number is smaller, a faster leftward eye movement, on the contrary when the target stimulus is bigger, a faster rightward eye movement is found. Yet, it should not be forgotten that these eye movements were found in a numerical comparison task, in which the numerical magnitude of the digits was compared. Related with the findings of the current work, the results of the Numerical Judgment task also revealed the congruency effect, however, for the Magnitude Judgment task, the reaction time result did not indicate a congruency effect. Thus, in conjunction with the eye-tracker literature, the results of the Numerical Judgement task could be related to the eye movements. But, what about the Magnitude Judgment? The relatively faster reaction while judging the frequency of the digits and no significant difference between the levels of the Stroop congruency evoked the question of, what if the participants did not look the peripheral areas while making judgment upon the repetition frequency of those digits?

In accordance with the MNL account, while we are making judgement upon the magnitude of two digits, rather than calculating the exact difference, mostly we tend to approximate as an automatic process. When we look from the viewpoint of the MNL account in a repetition frequency judgment, most probably what we do is rather than calculating how many times the number is repeated, is just make a simple more or less comparison. From this standpoint, the eye movements would provide further evidence of the underlying mechanism of those results.

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APPENDIX A

KATILIMCI İZİN FORMU

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

Tarih: Araştırmacının İmzası:

..... / ..... / ....

....

Çalışmanın amacı ve içeriği hakkında açıklamaların yer aldığı "Katılımcı Bilgilendirme 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 İmzası:

..... / ..... / ....

....

APPENDIX B

KATILIMCI BİLGİLENDİRME FORMU

Bu çalışmanın amacı, zihinsel sayı dizisinin, sayıların rakamsal değeri ve miktara (tekrar sayısı) ilişkin değerlendirmeler üzerindeki etkisini görmektir.

Çalışma boyunca bilgisayar ekranının sağ ve sol yarısından sunulacak uyarıcılardan, yönergeler aracılığıyla istenen görevlere uygun şekilde tercih yapılması beklenecektir.

Çalışma kapsamında katılımcılardan elde edilen veriler, çalışma başında verilecek olan katılımcı numarası dolayısıyla, isim kullanılmaksızın analizlere dâhil edilecek ve raporda yer alacaktır.

Katılımınız araştırma hipotezinin test edilmesi ve yukarıda açıklanan amaçlar doğrultusunda literatüre sağlayacağı katkılar bakımından oldukça önemlidir.

Çalışmaya katılmanız 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.

Araştırmacının iletişim bilgileri:
Günce Yavuz
İzmir Ekonomi Üniversitesi Psikoloji Laboratuvarı
E-mail: gunce.yavuz@ieu.edu.tr

Okudum, kabul ediyorum.

APPENDIX C

KATILIMCI BİLGİ FORMU

Cinsiyet:……………………………………….

Yaş:…………………………………………….

İletişim Bilgileri:

e-mail:………………………………………….

Telefon:……………………………………………

1. Herhangi bir ciddi görme bozukluğunuz var mı?

o Evet

o Hayır

Eğer yanıtınız evet ise lütfen konulan tanıyı belirtiniz……………………………..

2. Daha önce psikiyatrik bir rahatsızlık tanısı aldınız mı?

o Evet

o Hayır

Eğer yanıtınız evet ise lütfen konulan tanıyı belirtiniz……………………………..

3. Herhangi bir ilaç kullanıyor musunuz?

o Evet

o Hayır

Eğer yanıtınız evet ise lütfen konulan tanıyı belirtiniz……………………………..

ETHICS COMMITTEE APPROVAL

SAYI : B.30.2.İEÜ.0.05.05-020-*096* **02.06.2020**

KONU : Etik Kurul Kararı hk.

Sayın Prof. Dr. Seda DURAL ÇETİNKAYA,

"Sayı-Uzamsal Konum Uyumunun Stroop Görevi Kapsamında Test Edilmesi" başlıklı projenizin etik uygunluğu konusundaki başvurunuz sonuçlanmıştır.

Etik Kurulumuz 12.05.2020 tarihinde sizin başvurunuzun da içinde bulunduğu bir gündemle toplanmış ve projenin incelenmesi için bir alt komisyon oluşturmuştur. Projenizin detayları alt komisyon üyelerine gönderilerek görüş istenmiştir. Üyelerden gelen raporlar doğrultusunda Etik Kurul 02.06.2020 tarihinde tekrar toplanmış ve raporları gözden geçirmiştir.

Sonuçta 02.06.2020 tarih ve 110 numaralı Etik Kurul **"Sayı-Uzamsal Konum Uyumunun Stroop Görevi Kapsamında Test Edilmesi"** konulu projenizin etik açıdan uygun olduğuna oy birliği ile karar verilmiştir.

Gereği için bilgilerinize sunarım.

Saygılarımla,

Prof. Dr. Filiz Başkan

Etik Kurul Başkanı