Five- to 8-Year-Old Turkish Children's

Number Sense and Cognitive Flexibility

by

Meryem Söğüt

Thesis submitted to the

Institute for Graduate Studies in the Social Sciences

in partial satisfaction of the requirements for the degree of

Master of Arts

in

Psychology

Koç University

April, 2019

STATEMENT OF AUTHORSHIP

This thesis contains no material which has been accepted for any award or any other degree or diploma in any other university or institution. It is affirmed by the candidate that, to the best of her knowledge, this thesis contains no material previously published or written by another person, except where due references are made in the text of the thesis.

Signed Meryem Söğüt

Abstract

Executive functions (EFs) are top down cognitive processes that are associated with the regulation of behaviors as well as emotions. EFs include three core interrelated components: working memory, inhibition, and cognitive flexibility. Among them, cognitive flexibility is defined as the ability to flexibly switch between different perspectives and adjust to the changing conditions. The present study investigated the magnitude of relationship between cognitive flexibility and number sense as part of conceptual thinking. It was expected that children will be affected by the age and the criteria used in the cognitive flexibility tasks. This relationship was measured with Penn Conditional Exclusion Test (PCET) and Wisconsin Card Sorting Test (WCST). The Early Numeracy Test (ENT) was used for number sense assessment. One hundred and fourteen 5- to 8-year-old Turkish students attending preschool, first, and second grade of elementary school participated in the study. Results suggested that the PCET and the WCST have components in common: concept formation and perseveration. The concept formation scores in two EF tests were correlated, but perseveration factors were distinct from each other. ENT was also significantly correlated with 4 scores of the WCST and 5 scores of the PCET, indicating a significant relationship between EF and number sense. Finally, age was a significant covariate for only concept formation factors of both the WCST and PCET, in addition to the ENT scores from age of 5 to 6. Effects of gender, years spent in pre-school, and type of school were not statistically significant for any of the EF and ENT measures, except the effect of preschool on the concept formation in the WCST. This finding point to a further need to investigate the use of symbols in the task switching measures in pre-school period.

Key words: number sense, concept formation, cognitive flexibility, task-shifting, Wisconsin card sorting test, Penn conditional exclusion test

Özet

Meryem Söğüt, “5-8 Yaş Türk Çocuklarında Sayı Bilgisi ve Bilişsel Esneklik“

Yönetsel beceriler davranış ve duygu düzenlemesi ile ilişkili tepeden aşağı bilişsel süreçlerdir. Yönetsel beceriler işler bellek, ket vurma ve bilişsel esneklik olmak üzere birbiriyle ilişkili üç temel parçadan oluşmaktadır. Bilişsel esneklik, farklı bakış açıları arasında esnek bir şekilde gidip gelebilme ve değişen durumlara uyum sağlayabilme becerisi olarak tanımlanmıştır. Bu çalışmada kavramsal düşünme becerisi temelinde bilişsel esneklik ve sayı bilgisi arasındaki ilişki incelenmiştir. Yaş ve bilişsel esneklik testlerinde kullanılan sıralama ölçütlerinin çocukların performanslarını etkileyeceği öngörülmüştür. Bu iki değişken arasındaki ilişki Penn Durumsal Ret Testi ve Wiskonsin Kart Eşleme Testi kullanılarak ölçülmüştür. Sayı bilgisini ölçmek için Erken Sayı Bilgisi Testi kullanılmıştır. Çalışmaya anaokulu, birinci ve ikinci sınıfa giden 5-8 yaş arası yüz on dört çocuk katılmıştır. Bulgular WKET ve PDRT testlerinin “kavram formasyonu” ve “sürdürme” olmak üzere iki ortak bileşene sahip olduğunu göstermiştir. İki yönetsel beceri testindeki kavram formasyonu skorları arasında anlamlı bir ilişki varken sürdürme faktörü skorları arasında anlamlı bir ilişki olmadığı görülmüştür. Erken Sayı Bilgisi Testi skorlarının, 4 WKST ve 5 PDRT skoruyla anlamlı bir ilişkiye sahip olduğu gösterilerek yönetsel beceriler ve sayı bilgisi arasındaki anlamlı ilişki örneklenmiştir. Son olarak, yaş değişkeni kavram formasyonu ve Erken Sayı Bilgisi Testi skorları üzerinde anlamlı bir etkiye sahipken; cinsiyet, okul öncesi eğitim geçmişi ve okul türü değişkenlerinin hiçbir skor üzerinde anlamlı bir etkiye sahip olmadığı görülmüştür. Bu bulgu, erken yaş dönemi çocuklar için hazırlanan bilişsel esneklik testlerindeki sembol kullanımının etkilerinin araştırılması gerektiğini ortaya koymaktadır.

Anahtar sözcükler: sayı bilgisi, kavram formasyonu, bilişsel esneklik, WKST, PDRT

Acknowledgements

Foremost, I would like to thank Dr. Ayşe Altan Atalay for her invaluable guidance, support, and encouragement throughout my academic life in Koç University. I thank you from my heart for the knowledge and experience you provided since two years, for all of your directions during my thesis period, for your soothing and heartening presence whenever I feel anxious. Many thanks to Dr. Tilbe Göksun for her vital suggestions and contributions. Her ideas, directions, and support were invaluably helpful for me in achieving this goal.
Many heartfelt thanks to Zehra İlgen Şeker for always being near by me in every step of my life for two years with her endless care as a special “colleague”. She has an irreplaceable place in my heart, and has a significant role in my professional life with her genuine interest in humans, and her endless generosity, constancy and love. Her contributions to me are beyond all words. I would like to thank my great siblings Şahadet, Ahmet, Tahsin and Yasin for their supportive and entertaining presence in my life for years, and for making my “study times” more tolerable and efficient! Special thanks to my beloved friends Elif Girgin and Hanan Fael for always listening and soothing my anxious questions, and clearing up my mind with their brilliant ideas. Their endless friendship is a very special gift to me. Many thanks to my special friend, İrem Nur Kaya, for her loving and caring encouragements in good and bad.

I also thank my other special friends Rukiye Eşki, Canan Kapucu, Eslem Günaydın, Berna Sena Civan and Emine Safi for their presence that make the thesis process more valuable and enjoyable. I thank Prof. Dr. Lemis Önkol since she has provided the Early Numeracy Test and gave me the permission to use it in this study. Many thanks to my friends from Boğaziçi University, who helped me with the data collection process. Finally, I would like to express my deepest gratitude to my parents for their endless love, patience and support, and their respect and faith in me throughout my life. This thesis is dedicated to my family.

Table of Contents

List of Tables

List of Figures

Chapter 1. Introduction

Development of Executive Functions and Its Correlates

Executive functions (EFs) are defined as higher order mental processes used to regulate cognitive processes such as attention, inhibition or flexibility in a controlled fashion (Carlson, 2005; Diamond, 2013). EFs enable one to change perspective, focus on tasks, and it is imperative in inhibition of maladaptive prepotent responses (Diamond, 2013; Lehto et al., 2003). EF has been conceptualized as an umbrella term that includes cognitive flexibility, planning, judgment, decision making, inhibition, and shifting (Miyake et al., 2000; Strauss, Sherman, & Spreen, 2006). Various empirical studies suggest that these higher order cognitive processes are significantly associated with various aspects of cognitive functioning including problem solving (Ropovik, 2014), regulation of emotions, and avoidance of long-term problems (Sulik et al., 2015), academic achievement (Best, Miller, & Naglieri, 2011), and ability in mathematics and literacy (Bull & Lee, 2014; Clements et al., 2016; Verdine et al., 2014) — specifically— cardinal number knowledge and print related skills (Purpura et al., 2017). Executive functions are also associated with some environmental variables such as parent's level of education (Conway, Waldfogel, Wang, 2018). Other researchers also provide evidence for the effect of socioeconomic status especially for language, reading and executive functions (Noble et al., 2015). Because, the children of higly educated parents have more likelihood to be raised in an intellectually stimulating environment (as cited in Ardila & Roselli, 2005).

More recent work provides evidence for the multi componential nature of EF (Miyake, Friedman, Emerson, Witzki, Howerter, & Wager, 2000). Miyake et al. (2000) proposed a three-factor model of EF, conceptualizing EF as composed of independent components that are still related to one another. Using a factor analytical approach, Miyake et al. (2000) identified components of EFs as the shifting, inhibition, and updating of working memory representations. Inhibition requires one to inhibit a pre-potent response and activate a conflicting response, whereas updating is found to be load onto tasks such as track keeping, tonemonitoring, and letter memory (Miyake et al., 2000). In other words, updating refers to the coding of incoming information and keeping track of its relevancy by actively manipulating the working memory (Miyake et. al, 2000). Lastly, shifting is defined as the capacity for switching between different mental sets (Diamond, 2013), as compared to inhibition, which requires one to ignore a single pre-potent response (Best & Miller, 2010). Earlier studies have also obtained similar results with Miyake et al.'s model of unity and diversity of EF (Hughes, 1998; Welsh, Pennington, & Groisser, 1991) and later studies (Senn, Espy, & Kaufmann, 2004), and the same model was replicated with younger participants (Lehto et al., 2003). EFs are also found to contribute to children's numerical development (Doebel & Zelazo, 2015). Because, understanding the distinction between conceptual numerical relationships and procedural strategies require one to switch from one dimension to another (as cited in Cragg et al., 2017).

It is very difficult to identify a general trajectory of EF development from the literature, due to its multi-componential nature. That is, different components show a tendency to follow their own developmental trajectories and reach maturity at different ages (Brydges et al., 2014; Lerner & Lonigan, 2014). Specifically, cognitive flexibility shows a rapid development between the ages of 2 and 5 in parallel with the improvements in other cognitive processes such as inhibition and language (Deak, 2003). Once children start going to school, they are subjected to complex environments to which they are expected to adapt. Some situations require an efficient response to familiar problems whereas others require flexible responses to novel problems and each child displays different levels of mastery in these complex situations (Deak, 2003). Therefore, examining the development of flexible cognition after 5 years of age through different measures is vital to understand the increased variance among the children especially in transition to school period. Greater cognitive flexibility is associated with favorable outcomes throughout the lifespan such as better math abilities in school years (Bull & Scerif, 2001). However, a main challenge is the narrow age ranges. Few studies have examined developmental sequences and mechanisms, although EFs are found to develop most rapidly during infancy, preschool, and primary school years (Best, Miller, & Johns, 2009; Davidson, Amso, Anderson, & Diamond, 2006). Therefore, the present study examined the relationship between the EF and number sense during preschool and early school years, with a specific focus on cognitive flexibility. Specifically, the study investigated whether there were differences in specificity and sensitivity of two EF measures in a Turkish sample depending on age and number sense.

1.1. Development of Cognitive Flexibility

Cognitive flexibility, also known as shifting, is one of the core components of EF skills (Malooly et al., 2013; Miyake et al., 2000; Zelazo & Carlson, 2012). It is defined as the ability to switch between two or more tasks (Miyake et al., 2000), thinking about multiple things simultaneously (Cartwright, 2008) or modifying thought processes based on a change in rules or demands in a task (Deak, 2003; Hund & Foster, 2008). Miller and Cohen (2001) noted that this ability is vital for adjusting to new conditions in life. In other words, one of the vital elements of success in life is the ability to replace habitual behaviors with the new ones, an ability that develops gradually (Munakata et al., 2012).

The capacity to switch between different mental sets and flexibly shift the focus of attention begins to develop in infancy (Anderson, 2008; Ionescu, 2012). Starting from 4 to 6 months of age, infants can switch between two different objects. This ability transforms into a more complex structure later during the preschool period, which enables children to shift between internal and external stimuli (Ruff & Rothbart, 2001). The ability to shift between internal stimuli in the mind and external stimuli in the environment is the core structure allowing toddlers to have a knowledge of self in the mirror and to use pretend play between 18 and 24 months of age (Nielsen & Dissanayake, 2004). It is development of the anterior attention system that allows the baby to gain control over attention at the end of 1st year. For example, Garon et al. (2008) assessed cognitive flexibility of infants teaching them to reach a certain location and then told them to switch to another location. Results showed that the switching ability is evident early in infancy. However, an infant's ability of switching according to task demands is constrained by external factors such as novelty of the stimulus cards (Garon et al., 2008). This ability to perform voluntary control over shifts of attention starts to develop during the preschool period (Colombo, 2001; Johnson, Posner, & Rothbart, 1994). Thus, it is important to track the developmental changes in cognitive flexibility capacity depending on the context and age (Anderson, 2002; Wecker & Kramer et al., 2005).

One widely cited example regarding the cognitive flexibility is the A-not-B error. In the standard A-not-B task, a toy is hidden in the same location for several trials. Then, the infant is expected to retrieve the place of the toy after it is hidden in another location. This task requires infants to hold a certain response set in the memory (choose the A side) and then shift to a new response set (switch to the B side). According to Piaget (2013), infants between 8 to 10 months of age fail to search for an object whose place has been changed from one location to another, although they see the person while changing its place. Piaget explains this failure with the developmental pattern of object permanence. However, more recent studies offered different explanations for this behavioral pattern. For example, Diamond (1988) explained it as a consequence of difficulty in changing the already existing motoric response style while thinking of the place of an object. In other words, this behavioral pattern can be related to impairments in "representational flexibility," which is an EF component. Zelazo and Frye (1998) claimed it as a lack of ability to make comparative relations that leads to failure in their switching flexibility in a single situation.

Recent research examining flexibility has also highlighted marked developmental gains starting from infancy. Munakata et al. (2012) explained three key transitions in the development of flexible behavior. Their main claim is that development of abstract goal representation is the key factor in the development of more flexible behavior. In the first phase, they argued that infants gradually become better at knowing the place of the hidden toy in parallel with the improvements in abstract representation. In other words, they start using flexible goal-oriented behaviors over habitual ones due to signals from the environment. Adjusting the behavior to the changing situations in order to achieve a goal requires the use of cognitive control. In the second phase, the use of cognitive control in infants gradually become less externally driven. During the last stage, cognitive control becomes less reactive providing the infant with an ability to maintain abstract goals over a long period. Jacques and Zelazo (2001) have also further investigated the developmental changes in cognitive control using the DCCS task in a cross-sectional sample of children between the ages of 2 and 5 years. In the DCCS task, children sort cards based on one dimension (color) and then switch to a second dimension (shape). The study revealed that children do not develop the ability to represent the entire set and to understand the higher order relations until the age of 5. The same improvement in cognitive flexibility was also documented for 3 to 5 years of age on other tasks such as the Preschool Attentional Switching Task (Chevalier & Blaye, 2008) and experimental versions of DCCS task (Doebel & Zelazo, 2015).

In an earlier study, Zelazo et al. (2003) revealed age related differences in cognitive flexibility across nine different experiments using different versions of DCCS task in each experiment. One of the experiments, called the Total Change Version, refers to using different colors and shapes in pre and post switch trials. In this version, 3-year-old children were much more likely to sort the new cards correctly on post switch trials compared to the original version. When a 3-year-old child presented with a red truck and focused on the "redness" in the pre-switch trial, it was very hard for the child to switch to another dimension and evaluate if the same object presented as a truck in the post switch trial. Only by age of 4 to 5 years, most children can realize the existence of different dimensions and switch between sorting dimensions on the DCCS task (Diamond, 2002). Thus, the results of the experiments revealed that 3- and 4-year-olds can use different rules to sort cards unless there is a rule conflict requiring formulation of a higher order rule. However, children develop the ability to switch flexibly in each trial only after the age of 7 (Diamond, 2013). The findings indicate that children's perseveration is not only related to limitations in children's memory capacity but they experience difficulty while disengaging attention from a previous rule set (Kirkham & Diamond, 2003).

Taken together, it seems that there are task and age-related differences in the perseveration on the EF tasks (e.g., Zelazo, Frye, & Rapus, 1996). Therefore, tasks that differ from one another in terms of stimuli, responses, number of switches, and goal-setting determine the failure or success of the child in the EF test (Cragg & Chevalier, 2012). Deficits in goal-setting capacity seem to increase the probability of failure for children younger than 4 years of age. Some measures require the child to comprehend the task rule and switching time without any reminder whereas some tasks explicitly define and remind the rules to the child throughout the task.

Although there is extensive research showing age related differences in children between ages of 3 and 5, fewer studies have been conducted with children older than 5 years of age (Cragg & Chevalier, 2012; Garon, Bryson, & Smith, 2008; Isquith, Gioia, & Espy, 2004). Thus, based on the earlier findings regarding the description of EF components and age differences (Garon, Bryson, & Smith, 2008; Lehto et al., 2003; Miyake et al., 2000; Zelazo et al., 2001), the present study investigated the development of cognitive flexibility of children between 5 and 8 years of age to see whether there was a significant change regarding EF scores especially in the beginning of school years (Best & Miller, 2010). This age period is extremely important from a developmental perspective because it marks the transition to school age, where EF capacities become more important in keeping up with the school work and function independently from the close control that was once provided by the parents and teachers (Hughes, Ensor, Wilson, & Graham, 2011; Zelazo & Carlson, 2012). Moreover, studies show that examination of some EF components in early childhood would not yield accurate results using the current tasks. For example, Senn et al. (2004) reported that differentiation of shifting is not evident in preschoolers, based on the findings of their study that inhibition and WM were interrelated and predicted complex task performance; however, shifting was unrelated to inhibition and WM. In other words, the currents tasks may not be age appropriate to identify these non-differentiated components. Thus, it is assumed that more complex tasks are suitable for older children and adolescents (Best & Miller, 2010).

In that sense, WCST is one of the most widely used complex task of cognitive flexibility that does not include any verbal command regarding the rule change (Heaton, Chelune, Taley, Kay, & Curtiss, 1993). WCST was first generated as a task for adult populations suffering from various psychological conditions. However, similarities between the EF capacities of children and adults suffering from especially psychotic disorders made clinicians and researchers use WCST as an assessment tool for younger populations. Although certain researchers such as Heaton et al. (1993) and Ardilla et al. (2005) suggested WCST to be suitable for populations as young as age 5 ½, the tasks' reliability in this age group is still subject to discussion. Nevertheless, there are only a few studies conducted with typically developing children in school age years (Yeniçeri & Altan-Atalay, 2011; Best, Miller, & Jones, 2009**).** The WCST requires participants to sort cards that are different from each other based on a certain criterion (color, shape or number). The test-taker is shown four cards and is expected to match one additional card to the main four cards. The participant is not informed about the sorting rule, but only given feedback about the accuracy of the responses. If the test taker achieves ten consecutive correct responses, the sorting category automatically changes, without informing the test taker. After the change, the test-taker should understand that the rule has changed and figure out the new sorting rule on his own, based on the feedback presented following each trial. Willcutt and colleagues (2005) related the performance on the WCST to the ability to keep a rule in memory and then display cognitive flexibility while switching to a new rule after the incorrect feedback is given.

WCST taps onto different EF and non-EF processes such as response modality, visuospatial demands, the need for timed responses or motor and perceptual ability (Hughes, Ensor, Wilson, & Graham, 2011; Miyake et. al, 2000). For example, the WCST is used by Levin et al. (1991) as a measure of "Perseveration/ Disinhibition" whereas Pennington (1997) employed it to measure "Cognitive Flexibility" (as cited in Zelazo, David, & Müller, 2002). It is also a test of categorical thinking (Maruish & Moses, 2013). The use of WCST in the assessment of other variables than cognitive flexibility stems from the fact that cognitive flexibility (CF) is accepted as the most complex one of the EF components (Diamond, 2013; Diamond, Carlson, & Beck, 2005). Response inhibition (RI) and working memory (WM) are thought to be prerequisites for the development of CF. For example, inhibition of previous rules (RI) and at the same time maintaining new information (WM) are basic steps needed for a child to effectively shift between rule sets and tasks (CF) (Dajani & Uddin, 2015). This problem of multidimensionality is defined as task impurity and results in complexity while interpreting the data in terms of nonexecutive variance depending on only one EF task (Miyake et. al, 2000). Many EF tasks including WCST might not be sensitive only to that process, indicating the task impurity problem in nearly all measures of cognitive flexibility (Snyder, Miyake, & Hankin, 2015). For example, Garon et al. (2008) states that many of the complex response inhibition tasks also involve a shifting process between two different response sets. Researchers apply different solutions regarding the problem of task impurity. First, some suggest implementation of multiple assessment tools in the assessment of EFs (Stuss & Levine, 2002). On the other hand, others prefer measuring only one construct for convenience (Miyake et al., 2000), although EF tasks necessitate the coordination of multiple processes (Asato, Sweeney, & Luna, 2006).

Although some studies indicate multidimensional nature of EFs, others show that EF components can be partially distinct. More specifically, developmental studies provide further evidence regarding the distinction between cognitive flexibility and other EF domains (Dajani & Uddin, 2017). For example, Brydges et al. (2014) conducted a longitudinal study to identify the critical ages when the changes in the structure of EFs take place**.** They found that the structural changes were more pronounced between the ages of 9 and 10. Furthermore, there was a change in the factor model as well, showing that memory has differentiated from inhibition and shifting. They argue that it is not possible to differentiate individual EFs until the age of 9. Thus, children mostly employ general executive abilities until the age of 9 rather than specific executive abilities. Taken together, previous research reveal different findings regarding the developmental trajectories of EF components, especially for cognitive flexibility. Therefore, the degree of unity or diversity is subject to change based on the developmental period (Goschke, 2000).

Another problem in the assessment of EF constructs is related to large age ranges. Researchers employ different measures depending on the age of children (Hughes, 1998). However, ensuring the uniformity of the tasks used across an age range seems crucial for the comparisons across age groups (Klenberg, Korkman, & Lahti-Nuuttila, 2001). From this perspective, WCST seems to be a suitable measure to document age related changes on cognitive flexibility since WCST norms exist for children as young as age of 5 ½ (Heaton et al. 1993). Although WCST was used with adults in earlier studies, researchers later focused on revising the instrument for children (Roselli & Ardila, 1993). However, Chelune and Baer (1986) suggested that children reach adult levels of performance in WCST only by age 10. Supportingly, Yalcın and Karakas (2007) found that age 11 is where the significant differences in terms of WCST performance emerge. Therefore, there is still controversy regarding the use of revised and shortened versions for younger children (Fletcher & Taylor, 1984), since children are found to present different behavioral preferences depending on the age and context in terms of dimension of sorting tests (Brown & Campione, 1974). For example, 3- and 4-year-olds have more tendency to categorize food items on the basis of color whereas they prefer categorizing the toys based on the shape (Macario, 1991). To put it differently, task variations such as the order of the rules, stimuli, responses, number of switches, and goal-setting affect the difficulty level of completing the task (Cragg & Chevalier, 2012; Zelazo & Doebel, 2015). For example, Bujoreanu and Willis (2008) found that WCST performance differed in each trial depending on the sequence of the number sorting criterion and age. The completed number of categories would have increased for 6-year-olds, if the number was presented as the last criterion in the test sequence. This finding might stem from the fact that number dimension as compared to color or shape dimension on WCST is a relatively abstract concept for younger children due to children's numerical inefficiency (Prevor & Diamond, 2005). Roselli and Ardila (1993) also found a developmental change in terms of difficulty in understanding sorting criteria on the WCST.

Taken together, although WCST is a valid measure of set-shifting for older age groups, presenting a "number" criterion in the test sequence transforms it into a task for numerical abilities (Bujoreanu & Willis, 2008**).** In other words, the performance of the children on WCST may confound with their numerical abilities. Thus, Senturk et al. (2014) also emphasized the need for a developmentally appropriate cognitive flexibility task for children between ages 6 and 8. In this sense, various novel instruments have been developed to assess children's EFs (Diamond, Carlson, & Beck, 2005; Kurtz et al., 2004; Zelazo, Müller, Frye, & Marcovitch, 2003). The Penn Conditional Exclusion Test (PCET) is one of the new measures of EF and proposed as a measure that can be used for assessing abstract thinking and cognitive flexibility. To our knowledge, there is no study conducted with children younger than 8 years old using PCET. PCET requires participants to sort cards based on the odd man out paradigm. It shows correlation with total errors and categories achieved on the WCST (Kurtz et al., 2004). Different than the WCST, it does not include number as a sorting criteria. The use of number criterion on switching tasks is reported to lower the performance of younger children due to their numerical inefficiency (Prever & Diamond, 2005). Thus, the present study included both PCET and WCST as a measure of cognitive flexibility to be able to compare the results of the two tests and prevent the bias regarding their multicomponential nature.

1.2 Development of Number Sense

The roots of symbolic number representation and mathematical concepts have been a topic of interest for researchers (Starr, Libertus, & Brannon, 2013). Studies regarding the number concept development throughout lifespan can be categorized under two major theoretical backgrounds for the interest of the present study. First one roots back to the studies of Piaget and Cook (1952), which claims that the numerical knowledge is not fully developed until the concrete operational stage. According to Piaget's logical foundation model, the ability to classify, to conserve number, to make one to one correspondence, seriation, and to succeed in asymmetrical relation operations are necessary components of numerical concept development (Piaget, 1953). In other words, although a child might choose the right answer in a number task, that does not indicate the existence of logical understanding of the numbers. There are extensive critics of Piagetian understanding of number development in conjunction with logical reasoning, claiming that counting exists in early childhood as an indicator of number sense (Gelman & Gallistel, 1978; Wynn, 1992). Yet, the whole theory of constructivism is not refuted (Dehaene, 1997). The conservation of number is defined as the ability to understand the stability in the quantity despite the change in physical qualifications such as density, length row or shape. According to Piaget, 5-year-old children succeed in primitive conservation tasks. However, the ability to understand more advanced levels of conservation tasks, such as conservation of weight develops around 6 years of age. Moreover, one to one correspondence and seriation are reported to develop starting from age 5 (Sophian, 1988), while classification ability is expected to improve from age 6.

Second, theoretical background is mostly based on the innate and non-verbal cognitive capacities of children as suggested by Dehaene (1997), rooted back in the Bayesian approach. Dehaene (1997) began his attempts to identify the development of number sense with the question of the way mind creates mathematics. He argues that the number sense is evident both in animals such as chimps, rats, and newborn infants. The number sense is defined as the ability to process, understand, and estimate numbers (Dehaene, 1997). The term “number sense” not only includes the ability to subitize and count, but also to compare and estimate quantities, to use derived fact strategy, to link abstract number knowledge with real world quantities, and to switch between different numerical formats based on context and purpose (Berch, 2005; Gersten, Jordan, & Flojo, 2005; Jordan et al., 2007).

It is claimed that the preverbal, non-symbolic numerical capacities exhibited by human infants in the first year of life serve as a conceptual basis for learning to count and acquiring symbolic mathematical knowledge (Izard, Sann, Spelke, & Streri, 2009). This idea of innateness is mostly criticized by the constructionist perspective (Dehaene, 1997). However, the innateness of the number sense is supported by the studies using infants’ gaze direction, gaze duration and brain waves (Hyde & Spelke, 2011; Libertus & Brannon, 2010). For example, Libertus and Brannon (2010) conducted a study with 6-month-old infants. They presented both pictures of changing and constant number of dots to the infants. They found that infants pay more attention to the changing image.

The number sense includes both nonverbal and verbal understanding (Brannon & Szkudlarek, 2017). Verbal understanding of number concept is not evident in infants and young children and starts to develop later in life with the development of certain cognitive and language mechanisms (Feigenson, Dehaene, & Spelke, 2004). However, preverbal intuitive number sense is stated to be prevalent in the first year of life, before the development of symbolic number understanding and counting (Starr, Libertus, & Brannon, 2013).

Dehaene and Cohen (1994) argued that there are two dissociable stages in the development of nonverbal number concept. The existence of Approximate Number System (ANS) and subitizing, two different innate non-symbolic number systems, both in human and animal species are further shown in different studies (Cantlon, 2012; Cantlon & Brannon, 2006; Feigenson, Dehaene, & Spelke, 2004; Rugani, Vallortigara, & Regolin, 2014, 2015). The subitizing system is responsible for the representation of small numbers up to 4, while the ANS is involved only with numbers larger than 4 (Cantlon, Platt, & Brannon, 2009; Dehaene, 1997; Feigenson et al., 2004). Small numbers are accepted as easily enumerated without counting which is called subitizing. Subitizing derives from the Latin word “sudden” and it is acknowledged in five or six tenths of a second (Dehaene, 1997). On the contrary, larger numbers can only be approximated or estimated. Our perception of large numbers relies on the density of items, the area they occupy, and the regularity of their distribution in the space (Dehaene, 1997). This system of number sense is known as Approximate Number System (Liberta, Feigenson, & Halberda, 2011). The Approximate Number System (ANS) is defined as the ability to approximately represent numbers without verbal counting or the involvement of numerical symbols (He et al., 2016). The ANS is stated to act upon distance and size effects. The distance effect is based on the idea that discriminating between two numbers that are further apart in numerical distance (3 vs. 9) is easier compared to numbers that are closer to each other (6 vs. 9). The size effect points to the fact that discriminating between smaller numbers (3 vs. 9) is easier compared to larger numbers (33 vs. 39) at the same distance. These effects are derived from Weber's law which claims that the difficulty in discriminating any two numbers is dependent on the ratio between them, rather than their absolute difference.

There are several studies conducted to show the presence of ANS early in infancy. The violation of expectancy paradigm suggests that infants also keep track of objects over addition and subtraction events (Wynn, 1992). In another study conducted by McCrink and Wynn (2004), infants were shown impossible events such as 5 + 5 = 5 or 5 + 5 = 10 and it was found that they looked longer to the impossible ones. Another study conducted by Cordes and Brannon (2009) also suggest that infants selectively attend to the numerical attributes. For a 7-month-old infant to display a novelty effect, there is a need for a 1:2 ratio change in numerosity. Additionally, the ANS is stated not to only include the approximate representation of numerical values, but also mental transformations across those representations. These transformations include arithmetic operations, ordinal relationships, and proportional reasoning in human infants and nonhuman primates. For example, McCrink and Wynn (2007) examined the ratio differentiation of 6-month-old infants. They presented the same ratio repeatedly to the infants in the first phase. After several trials, infants are shown both new ratios and new examples of the old ratio. They had the ability to discriminate ratios but only to a certain extent. For example, they were successful when two ratios differed by a factor of 2, however failed in the ones which differed by a factor of 1.5. Therefore, it is concluded that infants are able to discriminate between ratios in different test trials through the use of old information in the new conditions. However, there are susceptive findings regarding the infant's numerical abilities as well (Cohen, & Marks, 2002) claiming that familiarization and the presence of numerical abilities are totally distinct processes.

There is extensive research showing that the ANS is positively correlated with later mathematics achievement in different age groups, including adulthood (Agrillo, Piffer, & Adriano, 2013; DeWind & Brannon, 2012); middle childhood (Geary, Hoard, Nugent, & Rouder, 2015; Pinheiro-Chagas et al., 2014); early childhood (Gilmore et al., 2010), and preschool children (Keller & Libertus, 2015, Chu, vanMarle, & Geary, 2015; Libertus, Feigenson, & Halberda, 2013). Significant correlations between the ANS performance and math ability are even more pronounced when recent meta-analytic studies are examined (Chen & Li, 2014; Fazio, Bailey, Thompson, & Siegler, 2014; Schneider et al., 2016). Additionally, the difference in ANS acuity of typically developing children and children with dyscalculia also supports this notion (Bugden & Ansari, 2015; Mazzocco et al., 2011; Piazza et al., 2010).

Landerl (2013) conducted a longitudinal study with 42 children with age-adequate arithmetic development and 41 children with dyscalculia over a 2-year period from grade 2 to grade 4 to examine the developmental trajectories of numerical processing. They found that children with dyscalculia needs longer time to respond and have difficulty with placing numbers in a line and solving problems using two-digit numbers. Nevertheless, there are also conflicting findings (Göbel, Watson, Lervåg, & Hulme, 2014; Kolkman, Kroesbergen, & Leseman, 2013). That is, although developmental studies recently started to concentrate on understanding this ability, studies regarding the development of ANS in different age groups still are being debated.

The difference in results stems from several reasons. First, the use of different tasks both for within and between age groups makes the comparison of the data unlikely (Sasanguie, Göbel, et al., 2013; Xu & Spelke, 2000). Second, the term “number sense” is described differently by researchers based on their theoretical background (Berch, 2005; Dehaene, 1997; Gersten, Jordan, & Flojo, 2005; Jordan et al., 2007; Piaget, 2013). For example, Dehaene (1997) states it as an inborn capacity whereas Piaget rejects the possession of number sense in children until age of 5 (Sousa, 2008). Also, previous studies show variance in terms of the specific age groups they investigated. As an example of age differences, in a study conducted by Halberda and Feigenson (2008), 64 children whose ages range from 3 to 6 years and 16 adults were used to examine the developmental trajectory of numerical acuity. They used a computerized numerical discrimination task where they presented participants with a video screen showing two different items simultaneously. On each trial, the participants were asked to press either a yellow or blue button based on the quantity of pizzas in the both items. They also made a manipulation giving more total surface area to the trials with larger numerosity which they named as area correlated trials in the first half of the procedure, and they used a larger surface area for trials with smaller numerosity which is called as area anti-correlated trials in the other half of the procedure.

According to the results, age differences were evident in the findings including that a major part of the discriminations were not age appropriate for 3- and 4-year- olds. Thus, they used a higher percentage of guessing. However, 5- and 6-year-olds were found to correctly respond to even to the most difficult discrimination tasks. Nevertheless, Lee and Sarnecka (2010) proposed a theory known as number knower-levels theory which is composed of three basic assumptions. First assumption is that cardinal meanings of the numbers are learned by children one at a time in order. Secondly, learning the cardinality principle enables children to understand all higher number word meanings and thirdly, children do not know the meaning of numbers before they learn the cardinality principle.

Based on this theory, in a study examining the age ranges for the number sense, socioeconomic background explained a higher proportion of the variance compared to age (Negen & Sarnecka, 2012, Sarnecka & Gelman, 2004). Although a positive correlation was found between level of number knowledge and age, individual variation was so pronounced that level of the same age group children ranged from pre-knower to CP knower (Sarnecka, Goldman & Slusser, 2015). The effect of several different variables on the development of ANS acuity continues until early adolescence (Halberda & Feigenson, 2008). Specifically, changes in executive functioning affect numerical abilities. There are improvements in both inhibition and cognitive flexibility in the preschool and early elementary school years (Happaney, Zelazo, & Stuss, 2004). These variables are associated with math performance in tasks which require symbolic reasoning (Espy et al., 2004; McClelland, Acock, & Morrison, 2006; McClelland et al., 2007). Therefore, it is vital to investigate the potential sources of ANS acuity development during early childhood.

Furthermore, several studies were conducted on the development of numerical conceptualization in Turkish children in line with the evolutionary view on the number sense. The studies are mostly focused on the educational programs that are implemented with the purpose of improving numerical conceptualization ability which contradicts with the Piagetian view of number sense. For example, Önkol (2012) reviewed several studies conducted in Turkey and indicated that majority of such studies have used an experimental design with only 20 to 60 numbers of students between ages of 4 to 7 years. Thus, no study has examined the process following the transition to elementary school and during the first few years of elementary school where the children get exposed to more complicated tasks that require them to engage in computations. Given the paradoxical findings regarding the developmental trajectory of ANS acuity (Libertus & Brannon, 2010; Sasanguie et al., 2014; Sasanguie, Göbel, et al., 2013; Xu & Spelke, 2000), the current study attempted to identify the developmental trajectory of number sense between ages of 5 to 8 by applying a wide measure of number sense (ENT) to identify both the specific strengths and weaknesses.

1.3 The Current Study

There is variation in terms of children's knowledge of numbers. Since several research yielded important findings related to the predictive role of number knowledge to later school achievement (Duncan et al., 2007; Jo Van Hoof et al., 2017; Razza & Blair, 2007), the primary aim of the present study was to investigate the variables affecting the task performance in executive functioning measures, specifically cognitive flexibility.

Previous research found a positive association between children's EF skills and mathematics performance (Bull & Scerif, 2001; Clark, Pritchard, & Woodward, 2010; Clark et al., 2013). Deficits in EFs are shown to hinder children's numerical development (Steele et al., 2012). In other words, EFs are shown to account for the differences in numerical skills of children (Friso-van den Bos, Kolkman, Kroesbergen, & Leseman, 2014; Navarro et al., 2011). Because, as Siegler and Araya (2005) stated, understanding the distinction between conceptual numerical relationships and procedural strategies requires one to switch from one dimension to another using EF skills (as cited in Cragg et al., 2017). Thus, EF deficits might have negative effects on children's numerical development (Doebel & Zelazo, 2015). Cragg et al. (2014) stated the lack of research which examines the role of shifting in numerical performance although a meta-analysis of Yeniad et al. (2013) reveals a positive relationship between shifting ability and performance in numeracy problems. On the contrary, Mazzocco, Chan and Bock (2017) argued that positive correlations between arithmetic ability and EFs do not guarantee concordance among all members. Instead, it is possible that a small but meaningful number of children may have good mathematical ability regardless of EF skills.

Therefore, the present study also examined the performance of children in a numeracy measure in addition to their cognitive flexibility performances. History of psychological research examining the relationship between numerical skills and EF mostly dates back to the last ten years (Clark et al., 2010) and empirical research on the developmental relations between cognitive flexibility and its correlates stated in the literature during pre and primary school years remains sparse (Cragg et al., 2014). Hence, the present study specifically aimed to investigate the relationship between EF and number sense in children between ages 5 and 8 using two different EF tasks to see whether task related differences have an effect on their performance.

Heaton et al. (1993) implemented the WCST only to children younger than 5.5 years of age. However, the study conducted by Best, Miller, and Jones (2009) revealed controversial results regarding the WCST performances of children between ages of 6 and 7**.** It is also claimed that there is no proper measure to assess cognitive flexibility between ages of 5 and 7 (Carlson, 2005; Garon et al., 2008). Therefore, WCST may not be an appropriate assessment task for this age group despite what the early studies indicated. The present study aimed to examine whether the depressed performance presented by this age group was associated with numerical thinking ability or not and identify the possible reasons of poor performances in the 5- to 8-year-old children.

Next, based on the literature related to the effects of sorting criteria and sorting order on the performance scores, it seems that the use of number as a sorting criterion in the WCST makes the task extremely difficult for specific age groups, and thus the sensitivity of the test for this specific age group is questionable (Prevor & Diamond, 2005). To address this issue, the present study employed a measure of EF (PCET) that did not include number as a sorting criteria in addition to WCST that requires numerical conceptual thinking abilities. In other words, this study examined the extent to which differences in number sense accounts for the differences in cognitive flexibility for the specific tasks. In the light of available literature,

1- It is expected that significant improvements will be observed in children's performances on cognitive flexibility and number sense tasks with increasing age.
2- It is predicted that individuals' scores on numeracy test and EF tests will be associated with one another providing support for a role of EF in the development of numerical knowledge.
3- It is expected that both EF tests will composed of different components which may be correlated with one another.

Chapter 2. Method

2.1 Participants

One hundred and fourteen Turkish students from 2 public schools and 2 private schools in Istanbul participated in the present study. 38 of them were preschoolers, 30 of them were first grade students, and 46 of them were second graders. The participants' ages ranged from 5.0 to 8.2 years (M= 77.48, S.D= 10.44). As reported by their parents, none of the participants had any diagnosis of a psychological or neurological disorder. This age group was chosen for the present study based on the following reasons. First, at this age, there is evidence of a significant developmental improvement in terms of EF (Chan & Morgan, 2018). Second, studies mostly focus on children between ages of 3 and 5 years, which indicates a lack in the examination of EF and number sense for older children (Blair & Razza, 2007; Zelazo, Müller, Frye, & Marcovitch, 2003). Eleven children were not included in the data analysis due to missing information.

2.2 Measures

2.2.1 Cognitive flexibility.

The child's ability to shift was assessed through the Wisconsin Card Sorting Test (WCST) and Penn Conditional Exclusion Test (PCET).

2.2.1.1 Wisconsin Card Sorting Test (WCST).

Participants were assessed through the computerized WCST test (WCST-CV4) with the standard administration procedure (Heaton et al., 1993). The basic idea of the WCST is that participants match response cards to key cards according to a non-specified matching rule (number, shape or color), which changes every time when 10 (out of a maximum of 128) response cards have been sorted correctly in each category.

Several studies have found no differences between the manual and computer-based versions of the WCST in their sample in the neuropsychological assessment of EFs (Schatz &

Browndyke, 2002; Tien et al., 1996). Therefore, we used the Berg Card Sorting Test, which is one of the tests in The Psychology Experiment Building Language Battery for the computerized version with a few syntax changes regarding the randomized order of the rules as number, shape, and color.

The standard order of the rules was ensured to achieve the same test conditions for all participants. Several variables were included for the data analyses:

1. *Perseverative errors* occur when the participant persists in responding to a stimuli characteristic that is incorrect (Heaton et al., 1993).
2. *Perseverative responses* are defined as a response that has been correct in the previous category, but it is no longer correct in the current category.
3. *Non-perseverative errors* occur when there are incorrect responses that do not match the perseverated-to principle (Heaton et al., 1993).
4. *Failure to maintain the set* occurs when a client makes five or more consecutive correct matches but then makes an error before successfully completing the category (Heaton et al., 1993).
5. *Number of Categories Completed* (NCC) is the number of categories client successfully completed during the test (Heaton et al., 1993).
6. *Trials to Complete First Category (TFC)* represents the total number of trials a person required to complete the first sorting rule and gives an indication of the initial conceptualization a person gained of the sorting (Heaton et al., 1993)
7. *Conceptual Level Responses* are defined as consecutive correct responses occurring in runs of three or more (Heaton et al., 1993).
8. *Unique Errors* refers to errors that are not correct by another rule (Heaton et al., 1993).

Greve, Stickle, Love, Bianchini, and Stanford (2005) reviewed 17 explanatory factor analytic (EFA) studies of the WCST and results indicated that it was best represented by a three-dimensional model including the response inflexibility (factor 1), ineffective hypothesis-testing strategy (factor 2), and set maintenance (factor 3).

2.2.1.2 Penn Conditional Exclusion Test (PCET).

The PCET is a measure of abstraction in EF related to the WCST scores of categories achieved and total errors**.** It is a computerized test battery where participants must decide what object out of four objects does not belong to the other three. There are three criteria given in standard order for choosing an object: line thickness, shape, and size. The criterion change is based on achieving 10 consecutive correct answers for each principle. The participant is not informed about the sorting principle and has to determine the unrelated card on his own**.** After clicking on the card, there is an automatic feedback indicating whether the decision is correct or not. The feedback that appears on the screen provided orally in Turkish since the test instructions are in English. On average, each version of the PCET takes 10 minutes to complete. If the participant is unable to achieve a single category, the test ends after 144 trials.

The test is scored based on the number of correct or incorrect responses as well as the accuracy and efficiency scores. Accuracy score in the PCET is defined as the proportion of correct responses compared to total scores in each category (Gur et al., 2010), whereas efficiency score is to be able to give accurate responses as fast as possible. Additionally, perseverative errors and perseverative correct responses scores were included for the data analysis. *Perseverative Errors* occur when 3 consecutive incorrect responses based on a previous criterion are made without any intervening responses in between that match any other criterion. *Correct Perseverative Responses* are responses based on a perseverative criterion but which also match the correct sorting principle for the trial.

Positive correlations between the PCET and a measure of abstraction, abstraction subtest of the AIM, was evidence of the convergent validity. Divergent validity was confirmed by low, nonsignificant correlations between the PCET and measures of facial emotion recognition, word and face memory, visuospatial function, and verbal reasoning (Kurtz et al., 2004).

2.2.2 Number sense.

The Early Numeracy Test-Revised is a task-oriented test which attempts to measure the level of early mathematical competence. The test was developed for preschoolers, first and second graders. The ENT-R consists of two parallel versions (Version A and version B) of 45 items each. The test consists of in total of nine components: comparing, linking quantities, one to one correspondence, arranging, using numerals, synchronous and shortened counting, resultative counting, applying knowledge of numbers and estimating.

We used the Turkish adaptation of Early Numeracy Test (Önkol, 2012) to measure level of early mathematical competence of children between ages of 5 to 8. Önkol (2012) used 768 children from 25 public and private primary schools in different regions of Istanbul. After the translation of the original forms, reliability coefficients were found to range from .84 to .93.

The raw total score refers to the total number of correctly answered items in the test. The test score of the child was converted in a standardized score. This competence score indicates the level of child's early mathematical competence**.** The meaning of the competence score was derived by comparing it with the scores of children in the sample. Sample items are presented in Appendix C.

2.2.3 Demographic information form.

A Demographic Information Form (DIF) was prepared for this study. Participants' birthdate, number of siblings, current medical condition, and parental educational level and occupation were asked in this form *(Appendix B).*

2.3 Procedure

The official permission from the Ministry of the National Education of Turkey was obtained in order to conduct this research in the selected elementary schools in Istanbul. Afterwards, the examiner contacted with the principals of elementary schools. Finally, the present study was conducted in 4 elementary schools, of which 2 are public schools, and 2 are private. All of the administrations were held on school grounds during children's class time.

A consent form, explaining the aim and the procedure of the study, and the DIF were sent to the parents at least one week before the administrations. The ones who agreed their child to participate in the study filled out both the consent form and the DIF. Copies of the consent form and the DIF were presented in Appendix A and Appendix B, respectively. Later, the preschool background was added to the information taken from the parents.

Four undergrad students from psychology and education departments of Boğaziçi University collected the data from different schools simultaneously. All of them were trained in terms of test implementations to ensure the reliability of the results. First of all, they received a theoretical training from the researcher of the present study. In addition, they had a whole day implementation process under the supervision of the researcher. Individual administrations included the Penn Conditional Exclusion Test (PCET), the Wisconsin Card Sorting Test (WCST), and the Early Numeracy Test (ENT), which were applied one by one to each child separately. The order of all measures was counterbalanced. Participants were informed that none of these tests had time limits. The necessary instructions were provided in the beginning of each test, and no further information or guidance was given. Individual administrations lasted at most 45 minutes with each child.

2.4 Analyses

The relationships among EF and number sense were explored through Pearson product-moment correlations among scores of the WCST, PCET, and ENT. Multivariate analysis of variance (MANOVA) was applied to examine whether there was a statistically significant difference between the mean scores of WCST, PCET, and ENT scores depending on the age factor. In addition, post hoc analyses were performed using Bonferroni test to make comparisons among the age groups for significant F values ($p < .05$). Two exploratory factor analyses (EFAs) were conducted for the PCET and WCST scores separately in order to investigate the internal structures of two EF tests. In this regard, principal components analysis (PCA) command of SPSS 23.0 was used. In each EFA, direct oblimin rotation with a criterion of eigenvalues greater than 1.0 was used. Rotated factor solution and the total variance explained with the observed factors were indicated in results. Variance proportions and eigenvalues for each factor were illustrated.

In order to detect changes with respect to age between indicated factors, three sets of one-way ANOVAs for the WCST and two sets of one-way ANOVAs for the PCET were performed. The univariate F values and partial eta squares (η2) were illustrated in the results. Finally, hierarchical multiple regression analyses were conducted to examine which ENT variables predicted the WCST and the PCET scores, when the impact of demographic (age, sex, and maternal education) variables were controlled. Before the regression analyses, factor scores for each factor in WCST and PCET were derived through the Bartlett, a method of estimating factor score coefficients. (Bartlett, 1935).

Chapter 3. Results

3.1 Descriptive Statistics

3.1.1 Descriptive statistics for the sample

The ages of the participants ranged from 5 to 8 years. The sample was categorized into 3 categories based on their ages (5-year-old, 6-year-old and 7-year-olds) (Table 1). Thus, the first group included children aged between 5.0 and 5.11, (M=5.6, SD=3.23). The second group (6-year-old children) included children aged between 6.0 years and 6.11 years, (M=6.6, SD=3.69). The third group (7-year-old children) consisted of those aged from 7.0 to 7.9 years, (M=7.7, SD=4.08). Frequencies in terms of ages and gender are presented in Table 1.

Table 1
The Frequency Distribution According to Age Groups and Gender

		Gender		
		Female	Male	Total
Age	5-year-olds	15	21	36
	6-year-olds	26	20	46
	7-year-olds	13	19	32
	Total	54	60	114

The information regarding parental education was obtained from the Demographic Information Form (DIF). To begin with the years spent in preschool, sample of the present study included 8 participants who did not have any preschool experience. Additionally, there were 47 children with one year of experience, 47 children with 2 years of experience, and 12 children with 3 years of experience (M=1.55, SD=.77). Secondly, parents were categorized into low, middle, and high education groups according to their education level. Parents who gave up their education before completing the primary school (literate parents) and those who completed primary education of 8 years were grouped into low education group. Middle education group includes parents with a high school degree and high education group involves parents with a university or graduate degree (master or doctorate) (Maternal, M=2.27, SD=.85, Paternal, M=2.46, SD=.90).The number of siblings for this sample of children range from 0 to 3 (M=1.04, SD=.72). The frequency distributions in terms of mothers, father's education, school type, grade, and number of siblings are presented in Table 2.

Table 2
Cross tabulation

		Age			
		5	6	7	Total
Maternal Education	*Low*	*8*	*8*	*9*	*25*
	Middle	9	20	9	38
	High	19	18	12	49
Paternal Education	Low	5	4	10	19
	Middle	11	17	7	35
	High	20	25	13	58
Number of Siblings	No sibling	11	7	9	27
	1 sibling	19	23	12	54
	2 or more siblings	6	16	9	31
School Type	Private	30	35	11	76
	State	6	11	19	36
Grade	Preschool	32	6	0	38
	1st Grade	3	25	2	30
	2nd Grade	1	15	28	44
Years Spent in Preschool	0 year	3	2	3	8
	1 year	19	17	22	58
	2 years	14	20	6	40
	3 years	0	6	2	8

3.1.2 Descriptive statistics for the test variables.

Participants' performances on the Wisconsin Card Sorting Test (WCST), the Penn Conditional Exclusion Test (PCET) and the Early Numeracy Test (ENT) are observed with respect to the specific scores of the test variables. The raw scores were used in the statistical analyses. The mean scores, standard deviations, and minimum and maximum values for the test variables are presented in Table 3.

Table 3

Means, Standard Deviations, Minimum and Maximum Values

Test Variables	*N*	*Minimum*	*Maximum*	*M*	*SD*
WCST-PE	114	0	37	9.2	6.17
WCST-NPE	113	0	50	11.5	10.4
WCST-CC	114	0	5	2.05	1.3
WCST-CLR	113	0	65.6	36.01	13.2
WCST-T1stC	113	0	60	16.2	12.7
WCST-FMS	113	0	10	1.3	1.4
WCST-UE	113	0	23	2.4	4.4
PCET ACC2	113	.08	3.6	1.6	1.1
PCET EFF	113	0	.3	.12	.12
PCET CAT1	70	10	46	18.3	9.6
PCETCR	113	4	84	37	16.5
PCETER	113	3	88	28.6	18.1
PCET PER_ER	113	0	43	8.6	10.5

Note. WCST: Wisconsin Card Sorting Test, PE: Perseverative Errors, NPE: Nonperseverative Errors, CC: Categories Completed, CLR: Conceptual Level Responses, TC1stC: Trials to Complete the First Category, FMS: Failure to Maintain Set, UE: Unique errors, PCET: Penn Conditional Exclusion Test, ACC2: Accuracy 2, EFF: Efficiency, CAT1: Number of Trials in PCET Using Sorting Principle 1, CR: Correct Responses, ER: Incorrect Responses, PER_ER: Perseverative Errors

3.2 Zero-Order Correlations

The Pearson product-moment correlation coefficients were calculated to examine the relationships between the WCST, PCET and ENT scores. The correlation coefficients are displayed in Tables 4, 5, and 6. Additional correlation analysis were conducted to examine the relationship between the ENT scores and Bartlett scores as shown in Table 7. Lastly, the relationship between the demographics and test variables were examined as presented in Table 8.

First, all variables in the ENT significantly correlated with 4 scores of the WCST, which are WCST-NPE, WCST-CC, WCST-CLR, and WCST-UE. In addition, four scores of WCST correlated with none of the variables in the ENT, which are WCST-PE, WCST-PR, WCST-FMS, and WCST-T1stC. Correlation coefficients regarding the ENT and WCST scores are given in the Table 4.

Second, considering correlations among the WCST and the PCET scores**,** the total correct score of the PCET significantly correlated with only one score of the WCST, that is unique errors (WCST-UE) [r = -.30, $p < .01$]. In addition, ACC2 score of the PCET significantly correlated with 4 scores of the WCST, that are nonperseverative errors (WCST-NPE) [r = -.35, $p < .01$], conceptual level responses (WCST-CLR) [r = .43, $p < .01$], categories completed (WCST-CC) [r = .45, $p < .01$], and unique errors (WCST-UE) [r = -.31, $p < .01$]. Furthermore, efficiency score of the PCET also significantly correlated with 4 scores of the WCST, that are nonperseverative errors (WCST-NPE) [r = -.34, $p < .01$], conceptual level responses (WCST-CLR) [r = .41, $p < .01$], categories completed (WCST-CC), [r = .43, $p < .01$], and unique errors (WCST-UE) [r = -.28, $p < .01$]. On the other hand, none of the variables in the PCET significantly correlated with 4 scores in the WCST that is perseverative errors (WCST-PE), perseverative responses (WCST-PR), trials to complete the first category (WCST-T1stC), and failure to maintain set (WCST-FMS). The correlation coefficients regarding the PCET and WCST scores can be seen the Table 5.

Finally, regarding the correlation between the ENT and the PCET, incorrect responses (ER) score of the PCET significantly correlated with 7 scores in the ENT, which were comparison (ENT-COM) [r = -.24, $p < .05$], classification (ENT-CLASS) [r = -.26, $p < .01$], seriation (ENT-SER) [r = -.26, $p < .01$], using numerals (ENT-NUM), [r = -.31, $p < .01$], synchronous and shortened counting (ENT-SS_C) [r = -.22, $p < .05$], applying knowledge of numbers (ENT-APP_N) [r = -.25, $p < .01$], estimation (ENT-EST) [r = -.18, $p < .05$]. High number of incorrect responses was associated with lower performance in the ENT. The number of Trials Using Sorting Principle 1 (CAT1_TR) score of the PCET was found to be correlated with 3 scores in the ENT that are classification (ENT-CLASS) [r = -.32, $p < .01$], seriation (ENT-SER) [r = -.42, $p < .01$], applying knowledge of numbers (ENT-APP_N) [r = -.24, $p < .05$]. Lower performance in the ENT was associated with more trials to complete the first category. Correlation coefficients regarding the ENT and PCET scores are presented in the Table 6.

Table 4. *Correlation Matrix for the Test Variables of the WCST and ENT*

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13
1-ENT-COM	1												
2-ENT-CLASS	.21*	1											
3-ENT-COR	.27**	.48**	1										
4-ENT-SER	.31**	.52**	.62**	1									
5-ENT-NUM	.19*	.43**	.49**	.63**	1								
6-ENT-SS_C	.30**	.51**	.55**	.62**	.67**	1							
7-ENT-RES-C	.18*	.49**	.60**	.59**	.65**	.71**	1						
8-ENT-APP_N	.19*	.47**	.57**	.60**	.65**	.66**	.53**	1					
9-ENT-EST	.28**	.24*	.35**	.32**	.44**	.35**	.36**	.53**	1				
10-WCST-CC	.30**	.41**	.28**	.30**	.24*	.39**	.31**	.33**	.24*	1			
11-WCST-CLR	.40**	.40**	.17	.33**	.23*	.36**	.29**	.27**	.32**	.65**	1		
12-WCST-NPE	-.28**	.-34**	-.17	-.28**	-.19*	-.24**	-.21*	-.15	-.22*	-.75**	-.74**	1	
13-WCST-UE	-.23*	.-32**	-25**	-.34**	-.32**	-.28**	-.23*	-.27**	-.34**	-.41**	-.54**	.56**	1

Note. * p< .05, ** p< .01 (two tailed). WCST: Wisconsin Card Sorting Test, NPE: Nonperseverative errors, CLR: Conceptual level responses, CC: Categories completed, UE: Unique Errors, ENT: Early Numeracy Test, Comp: Comparison, Class: Classification, Corr: Correspondence, Ser: Seriation, Num: Using Numerals, Sync: Synchronous Counting, Res: Resultative Counting, App: Applying knowledge of numbers, Est: Estimating.

Table 5. ***Correlation Matrix for the Test Variables of the PCET and WCST***

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	**16**
1-WCST-CC	1															
2-WCST-PR	.49**	1														
3-WCST-NPE	-.75**	-.73**	1													
4-WCST-UE	-.41**	-.26**	.56**	1												
5-WCST-T1stC	-.07	-.04	-.10	-.06	1											
6-WCST-FMS	-.25**	-.19*	-.08	-.07	.13	1										
7-WCST-CLR	.65**	.19*	-.74**	-.54**	.13	.08	1									
8-WCST-PE	.19*	.90**	-.46**	-.08	-.01	-.22*	-.12	1								
9-PCET-ER	.16	.03	-.11	-.30**	.001	.03	.13	-.04	1							
10-PCET-CR	-.26**	-.03	.24**	.18*	-.08	-.03	-.30**	.10	.17	1						
11-PCET-CAT	.45**	.10	-.35**	-.30**	.04	-.03	.40**	-.08	.59**	-.30**	1					
12-PCET-CAT1	-.23	.07	.06	.15	-.11	.14	-.10	.12	.52**	.37**	-.15	1				
13-PCET-PER_ER	.06	.008	.001	-.14	-.04	-.04	-.006	.01	.62**	.73**	.29**	.25*	1			
14-PCET-PER-RES	.07	.008	-.003	-.14	-.04	.,04	-.003	.01	.63**	.71**	.30**	.24*	.99**	1		
15-PCET-ACC2	.45**	.07	-.35**	-.31**	.05	.,01	.43**	-.12	.49**	-.52**	.96**	-.23	.07	.08	1	
16-PCET-EFF	.43**	.07	-.34**	-.28**	.05	-.02	.41**	-.12	.47**	-.48**	.97**	-.21	.10	.10	.99**	**1**

Note. * p< .05, ** p< .01 (two tailed). WCST: Wisconsin Card Sorting Test, CC: Categories completed, PR: Perseverative Responses, NPE: Nonperseverative errors, UE: Unique Errors, T1stC: Trials to Complete the First Category, FMS: Failure to Maintain the Set, CLR: Conceptual level responses, PE: Perseverative Errors, PCET: Penn Conditional Exclusion Test, ER: Incorrect Responses, CR: Correct Responses, CAT: Categories Achieved, CAT1: Number of Trials Using Sorting Principle 1, PER_ER: Perseverative Errors, ACC2: Accuracy 2, EFF: Efficiency.

Table 6. *Correlation Matrix for the Test Variables of the PCET and ENT*

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1-ENT-COM	1														
2-ENT-CLASS	.21*	1													
3-ENT-COR	.27**	.48**	1												
4-ENT-SER	.31**	.52**	.62**	1											
5-ENT-NUM	.19*	.43**	.49**	.62**	1										
6-ENT-SS_C	.28**	.51**	.55**	.62**	.67**	1									
7-ENT-RES-C	-.24*	.49**	.60**	.58**	.65**	.71**	1								
8-ENT-APP_N	.19*	.46**	.57**	.60**	.64**	.65**	.53**	1							
9-ENT-EST	.28**	.24**	.34**	.32**	.44**	.34**	.36**	.53**	1						
10-PCET-ER	-.24*	-.26**	-,15	-.26**	-.31**	-.22*	-.12	-.25**	-.18*	1					
11-PCET-CR	.19*	.29**	.37**	.33**	.27**	.32**	.31**	.31*	.21*	.17	1				
12-PCET-CAT1	-.21	-.32**	-.18	-.42**	-.08	-.12	.006	-.24*	.19	.37**	.52**	1			
13-PCET-ER_ER	.07	.10	.23*	.20*	.05	.15	.18*	.10	.04	.73**	.62**	.25*	1		
14-PCET-ACC2	.41**	.48**	.48**	.52**	.37**	.39**	.35**	.47**	.26**	-.52**	.49**	-.23	.07	1	
15-PCET-EFF	.39**	.46**	.47**	.50**	.34**	.36**	.32**	.45**	.24**	-.48**	.47**	-.21	.10	.99**	1

Note. * p< .05, ** p< .01 (two tailed). ENT: Early Numeracy Test, Comp: Comparison, Class: Classification, Corr: Correspondence, Ser: Seriation, Num: Using Numerals, Sync: Synchronous Counting, Res: Resultative Counting, App: Applying knowledge of numbers, Est: Estimating PCET: Penn Conditional Exclusion Test, CR: Correct Responses, ER: Incorrect Responses, CAT1: Number of Trials Using Sorting Principle 1, PER_ER: Perseverative Errors, ACC2: Accuracy 2, EFF: Efficiency

Table 7. *Correlation Matrix for the Test Variables of the ENT and Bartlett Scores*

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1-ENT-COM	1													
2-ENT-CLASS	,215*	1												
3-ENT-COR	,275**	,483**	1											
4-ENT-SER	,314**	,523**	,625**	1										
5-ENT-NUM	,191*	,432**	,493**	,627**	1									
6-ENT-SS_C	,298**	,510**	,552**	,621**	,670**	1								
7-ENT-RES-C	,186*	,492**	,602**	,589**	,653**	,713**	1							
8-ENT-APP_N	,194*	,468**	,576**	,603**	,647**	,659**	,533**	1						
9-ENT-EST	,280**	,240*	,348**	,326**	,440**	,349**	,365**	,536**	1					
10-ENT-TOT	,240*	,471**	,643**	,710**	,624**	,694**	,620**	,668**	,481**	1				
11-W-CF	,410**	,477**	,493**	,521**	,359**	,379**	,346**	,466**	,255**	,309**	1			
12-W-PSV	,043	,076	,201*	,146	,021	,126	,162	,078	,032	,133	,111	1		
13-P-CF	,408**	,476**	,492**	,517**	,357**	,378**	,344**	,466**	,255**	,308**	1,000**	,110	1	
14- P-PSV	,085	,110	,232*	,201*	,053	,160	,185	,106	,044	,155	,159	,988**	,156	1

Note. * p< .05, ** p< .01 (two tailed). ENT: Early Numeracy Test, Comp: Comparison, Class: Classification, Corr: Correspondence, Ser: Seriation, Num: Using Numerals, Sync: Synchronous Counting, Res: Resultative Counting, App: Applying knowledge of numbers, Est: Estimating, Tot: Total; WCST: Wisconsin Card Sorting Test, CF: Concept Formation, PSV: Persevaration; PCET: Penn Conditional Exclusion Test, CF: Concept Formation, PSV: Persevaration.

Table 8. *Correlation Matrix for the Demographics and Test Variables*

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1-Age	1													
2-PS	,276**	1												
3-TS	,455**	-,208*	1											
4-Grade	,818**	,266**	,312**	1										
5-CC	,353**	,669**	,137	,390**	1									
6- NP	-,276**	-,469**	-,147	-,266**	-,750**	1								
7- UE	-,395**	-,334**	-,135	-,393**	-,413**	,562**	1							
8- CLR	,380**	,374**	,183	,361**	,654**	-,740**	-,542**	1						
9-PCET-EFF	,435**	,275**	,103	,480**	,435**	-,341**	-,284**	,419**	1					
10-ENT-CLASS	,403**	,310**	,026	,466**	,415**	-,342**	-,320**	,396**	,469**	1				
11-ENT-COR	,405**	,248**	,039	,441**	,287**	-,168	-,255**	,171	,474**	,483**	1			
12-ENT-SER	,485**	,234*	,025	,540**	,298**	-,279**	-,343**	,330**	,503**	,523**	,625**	1		
13-ENT-SS_C	,543**	,271**	,199*	,624**	,391**	-,244**	-,279**	,363**	,363**	,510**	,552**	,621**	1	
14-ENT-APP_N	,536**	,212*	,179	,627**	,328**	-,157	-,272**	,268**	,456**	,468**	,576**	,603**	,659**	1

Note. * p< .05, ** p< .01 (two tailed). WCST: Wisconsin Card Sorting Test, CC: Categories Completed, NP: Nonpersevrative Errors, UE: Unique Errors, CLR: Conceptual Level Responses; PCET: Penn Conditional Exclusion Test, EFF: Efficiency; ENT: Early Numeracy Test, Class: Classification, Corr: Correspondence, Ser: Seriation, SS_C: Synchronous Counting, App: Applying knowledge of numbers.

3.3 Age Related Differences in the WCST, PCET and ENT Scores

A series of Multivariate Analysis of Variances (MANOVA) were conducted to examine whether there was a statistically significant difference between the mean scores of the WCST, PCET, and ENT depending on the demographic variables (age and sex). First MANOVA was conducted using age (5-, 6- and 7-year-olds) and sex (males and females) as independent variables, and 8 scores of the WCST (PR, PE, NP, CLR, UE, CC, FMS and TC1st) as dependent variables. The main effect of the age was found to be significant, $F(8,100) = 1.73$, $p < .01$ $\eta^2 = .121$. F values and partial eta squares (η^2) for the multivariate tests are presented in Table 9.

Table 9

Multivariate Tests Results of MANOVA for the WCST

Variables	*Pillai's Trace*	*F*	*df*	Error *df*	η^2
Age	.002**	1.73	8	100	.121
Sex	.101	2.52	16	202	.166
Age*Sex	.754	.73	16	202	.055

Note. *$p < .01$.

Additionally, univariate ANOVAs were used to interpret the significant main effects for each dependent variable. Tests of between subjects effects revealed that age had a significant main effect for CC, UE, and CLR scores of the WCST, $F(2,107) = 7.02$, $p < .01$ $\eta^2 = .116$; $F(2, 107) = 10.34$, $p < .001$, $\eta^2 = .162$; $F(2,107) = 7.77$, $p < .01$, $\eta^2 = .127$, respectively. The details are presented in Table 10.

Table 10

Age-related differences in the children's WCST performances

WCST	5 Years		6 years		7 years		F	*P*
	Mean	S.D	Mean	S.D	Mean	S.D		
CC	1.33	.89	2.28	1.45	2.53	1.36	8.69	.000**
PR	18.36	11.67	17.39	8.51	17.5	7.68	.12	.88
PE	11.11	7.88	8.43	5.31	8.25	4.77	2.5	.08
NPE	14.82	10.74	10.56	10.33	9.43	9.74	2.6	.07
T1st	17.54	13.93	14.93	11.73	16.68	13.06	.43	.64
FMS	1.22	1.23	1.58	1.80	1.28	1.05	.72	.48
CLR	28.87	12.60	38.07	12.42	40.84	12.32	8.7	.000**
UE	5.17	5.85	1.60	3.58	.84	1.66	11.2	.000**

Note. WCST: Wisconsin Card Sorting Test, CC: Categories completed PR: Perseverative responses, PE: Perseverative errors, NPE: Nonperseverative errors, TC1st: Trials to complete the first category, FMS: Failure to maintain set, CLR: Conceptual level responses, UE: Unique errors.

Post hoc analyses were performed using Bonferroni tests to make comparisons among the variables for significant F values ($p < .05$). Post hoc comparisons regarding the age using the Bonferroni test indicated that the mean scores for the 5-year-olds (WCST-CC, M = 1.33, SD = .88, WCST-UE, M = 5.17, SD = 5.85, WCST-CLR, M = 28.87, SD = 12.6) was significantly different than 6-year-olds (WCST-CC, M = 2.28, SD = 1.45, WCST-UE, M=1.60, SD = 3.58, WCST-CLR, M = 38.07, SD = 12.42). However, 6-year-olds did not significantly differ from 7-year-olds (WCST-CC, (M = 2.53, SD = 1.36, p =1), WCST-UE, (M =.84, SD = 1.66, p=1), WCST-CLR, (M= 40.84, SD = 12.32, p =1)). Another MANOVA conducted with grades rather than age acting as the dependent variable. Similar results were achieved when grade was used as the factor variable. The mean scores of preschool children (WCST-NP, M = 15.49, SD = 1.68, WCST-UE, M = 5.18, SD = .64, WCST-CLR, M = 29.28, SD = 2.04) were significantly different from 1st graders (WCST-NP, M = 10.64, SD = 1.88, WCST-UE, M = 1.67, SD = .73, WCST-CLR, M = 36.94, SD = 2.29). But there was no statistical difference between 1st graders and 2nd graders for any of the scores, $p > .05$. Table 11 show the results of the post hoc analyses in greater detail.

Table 11

The results of Post-hoc Bonferroni Analyses for WCST

WCST	5 and 6 Years		6 and 7 years		Post-Hoc (Bonferroni)	
	Mean	S.D	Mean	S.D	5 and 6 Years	6 and 7 years
CC	-.94	.28	-.24	.29	.003*	1
PR	.96	2.09	-.10	2.16	1.000	1.000
PE	2.67	1.36	.18	1.40	.155	1.000
NPE	4.26	2.31	1.12	2.37	.204	1.000
T1st	2.60	2.87	-1.75	2.95	1.000	1.000
FMS	-.36	.32	.30	.33	.826	1.000
CLR	-9.20	2.79	-2.76	2.86	.004*	1.000
UE	3.56	.91	.76	.93	.001*	1.000

Note. WCST: Wisconsin Card Sorting Test, CC: Categories completed PR: Perseverative responses, PE: Perseverative errors, NPE: Nonperseverative errors, TC1st: Trials to complete the first category, FMS: Failure to maintain set, CLR: Conceptual level responses, UE: Unique errors.

Overall, children's performance on the test improve as the age increases. The means and standard deviations for significant F values of age groups are displayed in Table 7. In sum, 6 and 7-year-olds made more conceptual level responses, completed more categories, and made less unique errors on the WCST than 5-year-olds. However, there is no statistical difference between 6- and 7-year-olds on any of these scores. In terms of PE, PR, FMS and T1stC scores, results of post-hoc analyses showed that there were no age differences between the three age groups. 5-year-olds did not differ significantly from both 6 and 7-year-olds. In addition, no significant difference was found between 6- and 7-year-olds on these scores.

Another MANOVA, using age and sex as independent variables was performed for the PCET scores. Results indicated that the main effect of age was significant, $F(2, 45) = 3.37$, $p < .05$, $\eta^2 = .091$. However, other main effects and interactions were not significant. F values and partial eta squares (η^2) for the multivariate tests are illustrated in Table 12.

Table 12

Multivariate Tests Results of MANOVA for the PCET

Variables	*Pillai's Trace*	*F*	*Df*	Error *df*	η^2
Age	.000**	.4.89	14	204	.251
Sex	.065	1.98	7	101	.121
Age*Sex	.540	.92	14	204	.059

Note. *$p < .01$.

Finally, since the main effect of age was significant in the multivariate test results ($p = .000$), the univariate test results for this interaction were considered. The main effect of age was statistically significant for PCETCR, $F(2, 107) = 9.58$, $p < .001$, η^2=152; PCET-ER, $F(2, 107) = 10.48$, $p < .001$, η^2= .164; PCET_CAT, $F(2, 107) = 20.9$, $p < .001$, η^2= .281; PCET_ACC2, $F(2, 107) = 24.35$, $p < .001$, η^2= .313; PCET_EFF, $F(2, 107) = 21.18$, $p < .001$, η^2= .284. Univariate ANOVA results are presented in Table 13.

Table 13

Univariate ANOVA Results for the PCET

P-CET	5 Years		6 years		7 years		F	*p*
	Mean	S.D	Mean	S.D	Mean	S.D		
CR	27.52	16.84	40.68	13.44	42.53	15.91	10.3	.000
ER	38.66	19.46	25.57	16.80	21.65	13.58	9.8	.000
CAT	.47	.81	1.91	1.20	2.06	1.29	22.1	.000
PER_ER	7.11	12.50	9.80	9.51	8.65	9.67	.64	.527
PER_RES	7.6	13.3	10.6	10.3	9.7	10.88	.67	.514
ACC2	.65	.60	2	1.11	2.18	1.13	25.5	.000
EFF	.02	.05	.16	.11	.18	.12	22.2	.000

Note. PCET: Penn Conditional Exclusion Test, CR: Correct Responses, ER: Incorrect Responses, CAT: Number of Categories Achieved, CAT1_TR: Number of Trials in PCET Using Sorting Principle 1, PER_ER: Perseverative Errors, PER_RES: Perseverative Responses, ACC2: Accuracy 2, EFF: Efficiency

Post hoc analyses were performed using Bonferroni test to make comparisons among the variables for significant F values ($p < .05$). Table 14 shows the results of the post hoc analyses in greater detail. Post hoc comparisons using the Bonferroni test indicated that the mean scores for the 5-year-olds (PCET-CR, (M=27.52, SD=16.8), PCET-ER, (M=38.6, SD=19.4), PCET-CAT, (M=.47, SD=.81), PCET-ACC2, (M=.65, SD=.60), PCET-EFF, (M=.02, SD=.05) was significantly different than 6-year-olds (PCET-CR, (M=40.68, SD=13.44), PCET-ER, (M =25.5, SD =16.8), PCET-CAT, (M=1.9, SD=1.2), PCET-ACC2, (M =2, SD=1.11), PCET-EFF, (M=.16, SD=.11)). However, 6-year-olds did not significantly differ from 7-year-olds (PCET-CR, (M=42.5, SD=15.9, *p* =1), PCET-ER, (M=2.06, SD=1.29, *p*=1), PCET-CAT, (M=40.84, SD=12.32, *p*=1), PCET-ACC2, (M=2.18, SD=1.13, *p*=1), PCET-EFF, (M=.18, SD=.12, *p*=1)).

Table 14

The results of Post-Hoc Bonferroni Analyses for the PCET

PCET	5 and 6 Years		6 and 7 years		Post-Hoc (Bonferroni)	
	Mean	S.D	Mean	S.D	5 and 6 Years	6 and 7 years
CR	-13.16	3.42	-1.84	3.53	.001	1.000
ER	13.08	3.77	3.92	3.90	.002	.953
CAT	-1.43	.25	-.15	.25	.000	1.000
CAT1_TR	7.85	3.20	-4.44	2.45	.050	.224
PER_ER	-2.68	2.36	1.14	2.45	.777	1.000
PER_RES	-2.95	2.57	.93	2.66	.761	1.000
ACC2	-1.34	.22	-.18	.22	.000	1.000
EFF	-.13	.02	-.01	.02	.000	1.000

Note. PCET: Penn Conditional Exclusion Test, CR: Correct Responses, ER: Incorrect Responses, CAT: Number of Categories Achieved, CAT1_TR: Number of Trials in PCET Using Sorting Principle 1, PER_ER: Perseverative Errors, PER_RES: Perseverative Responses, ACC2: Accuracy 2, EFF: Efficiency

Post-hoc analyses showed that children's performance on the test improve, as the age increases. In sum, 6 and 7-year-olds made more total correct responses, more, completed more categories, made fewer errors on the PCET than 5-year-olds. However, there was no statistical difference between 6- and 7-year-olds on any of these scores.

Another MANOVA, using age and sex as independent variables, was performed for ENT scores. Results indicated that main effect of age was significant, $F(18, 200) = 5.26$, $p < .01$ $\eta^2 = .322$. However, other main effects and interactions were not significant F values and partial eta squares (η^2) for the multivariate tests are illustrated in Table 15.

Table 15

Multivariate Tests Results of MANOVA for the ENT

Variables	Pillai's Trace	*F*	*Df*	Error *df*	η^2
Age	.000**	5.26	18	200	.322
Sex	.667	.74	9	99	.063
Age*Sex	.902	.59	18	200	.051

Note. ***p* < .01.

Univariate ANOVAs were used to interpret the significant main effects for each dependent variable. Results revealed significant differences among age groups for 9 scores of the ENT, ENT-COM, $F(2,107)=6.95$, $p < .01$, $\eta^2=.115$; ENT-CLASS, $F(2,107)= 13.91$, $p < .001$, $\eta^2=.206$; ENT-COR, $F(2,107)= 18$, $p < .001$, $\eta^2=.252$; ENT-SER, $F(2,107)= 29.49$, $p < .001$, $\eta^2=.355$; ENT-NUM, $F(2,107)= 31.51$, $p < .001$, $\eta^2 =.371$; ENT-SS_C, $F(2,107)=28.71$, $p < .001$, $\eta^2=.35$; ENT-RES_C, $F(2,107)=21.1$, $p < .001$, $\eta^2=.283$; ENT-APP_N, $F(2,107)=30.1$, $p < .001$, $\eta^2=.36$; ENT-EST, $F(2,107)= 8.19$, $p < .001$, $\eta^2 =.133$. The means and standard deviations for significant F values of age groups are displayed in Table 16.

Table 16

Univariate ANOVA Results for the ENT

ENT	5 Years		6 years		7 years		F	*p*
	Mean	S.D	Mean	S.D	Mean	S.D		
COM	4.31	.63	4.67	.47	4.71	.45	6.95	.001
CLASS	2.74	.88	3.71	1.22	4.09	1.11	13.91	.000
COR	3.37	1.08	4.41	.83	4.46	.71	18	.000
SER	2.51	1.29	4.28	1	4.18	.96	29.49	.000
NUM	1.85	1.33	3.47	1.37	4.25	.95	31.51	.000
SS_C	2.31	1.15	3.80	1.14	4.28	.99	28.71	.000
RES_C	2.82	1.50	4.04	1.09	4.65	.65	21.1	.000
APP_N	2.28	1.54	3.73	1.18	4.53	.67	30.1	.000
EST	2.14	1.51	2.89	1.35	3.53	1.01	8.19	.000

Note. ENT: Early Numeracy Test, COM: Comparison, CLASS: Classification, COR: One to One Correspondence, SER: Seriation, NUM: Using Numerals, SS_C: Synchronous and Shortened Counting, RES_C: Resultative Counting, APP_N: Applying Knowledge of Numbers, EST: Estimation.

In addition, post hoc analyses were performed using Bonferroni test to make comparisons among the variables for significant F values ($p < .05$). Table 17 show the results of the post hoc analyses in greater detail.

Post hoc comparisons using the Bonferroni test indicated that the mean scores for the 5-year-olds (ENT-COM, ENT-CLASS, ENT-COR, ENT-SER, ENT-NUM, ENT-SS_C, ENT-RES_CC, ENT-APP_N, ENT_EST) was significantly different than 6 year-olds. Six-year-olds significantly differ from 7-year-olds on only two scores (ENT- NUM, (M=4.25, SD=.95, *p* =.026), ENT-APP_N, (M=4.53, SD=.67, *p*=.015).

Table 17

The results of Post-Hoc Bonferroni Analyses for the ENT

ENT	5 and 6 Years		6 and 7 years		Post-Hoc (Bonferroni)	
	Mean	S.D	Mean	S.D	5 and 6 Years	6 and 7 years
COM	-.35	.11	-.044	.12	.008	1.000
CLASS	-.97	.24	-.37	.25	.000	.419
COR	-1.04	.19	-.05	.20	.000	1.000
SER	-1.76	.24	.09	.25	.000	1.000
NUM	-1.62	.28	-.77	.28	.000	.026**
SS_C	-1.49	.24	-.47	.25	.000	.193
RES_C	-1.21	.25	-.61	.26	.000	.066
APP_N	-1.45	.26	-.79	.27	.000	.015**
EST	-.74	.29	-.63	.30	.039	.114

Note. ENT: Early Numeracy Test, COM: Comparison, CLASS: Classification, COR: One to One Correspondence, SER: Seriation, NUM: Using Numerals, SS_C: Synchronous and Shortened Counting, RES_C: Resultative Counting, APP_N: Applying Knowledge of Numbers, EST: Estimation.

In sum, the results showed that children's performance on the test improves as the age increases. Six- and 7-year-olds had higher scores on all of the categories than 5-year-olds. There was a statistically significant difference between 6- and 7-year-olds only in two scores, ENT-NUM, M=-.77, SD=.28, p < .01, ENT-APP_NUM=-.79, SD=.27, $p < .01$.

3.4 Principal Components Analyses

The Principal component analyses were conducted to explore the factor structure of the WCST and PCET and to identify the different dimensions of these tests for a group of Turkish children between the ages 5 and 8 years.

3.4.1 Wisconsin card sorting test.

WCST provides 15 scores, and some of them are redundant in the presence of others. Because some of the scores are derived from other scores (Greeve et al., 2005). Therefore, 8 scores of the WCST, which are categories completed (CC), perseverative responses (PR), perseverative errors (PE), nonperseverative errors (NPE), conceptual level response (CLR), unique errors (UE), trials to complete first category (TC1st), and failure to maintain set

(FMS), were chosen. Greeve et al. (2005) stated that use of orthogonal rotation instead of oblique rotation bias the results since major variables in the WCST are interrelated.

Eight scores of the WCST subjected to principal components analysis (PCA) with a direct oblimin rotation for a sample of 114 participants. With a criterion of eigenvalues greater than 1.0, there found a three-factor solution explaining 77.5% of the variance. The first factor, accounting for 42.5% of the variance, had loadings from CC, NPE, UE, and CLR scores. This factor refers to the concept formation. The second factor, explaining 21% of the variance, consisted of PE and PR scores, representing the perseveration tendency. The third factor, explaining the 14% of the variance had loadings from TC1st and FMS scores. This factor is named as "Set Maintenance". Factor loadings are displayed in Table 18.

Table 18

Principal Components Analysis of the WCST

	Factor		
	1	2	3
CC	.822	.104	-.340
PR	.210	.911	-.051
PE	-.152	1.013	.009
NPE	-.771	-.437	-.130
UE	-.724	.000	-.122
CLR	.953	-.205	.063
T1stC	.003	.129	.740
FMS	.035	-.169	.732
Variance Proportion	42	21	14
Eigenvalue	3.40	1.76	1.12

Note. The extraction method was principal component analysis. The rotation method was direct oblimin with Kaiser normalization. WCST: Wisconsin Card Sorting Test, CC: Categories completed PR: Perseverative responses, PE: Perseverative errors, NPE: Nonperseverative errors, TC1st: Trials to complete the first category, FMS: Failure to maintain set, CLR: Conceptual level responses, UE: Unique errors.

3.4.2 Penn Conditional Exclusion Test (PCET).

Seven scores of the PCET, which are correct responses, categories achieved, perseverative errors, perseverative responses, incorrect responses, accuracy and efficiency, from all 114 subjects were entered into a PCA with varimax rotation. Two factors, explaining

93.2% of the variance, emerged with eigenvalues greater than 1.0. The first factor accounted for 51.9% of the variance, and had loadings from categories achieved, accuracy 2 and efficiency scores. Low scores on these variables indicate inefficient rule-use, which is related to the poor concept formation. Therefore, this factor is called concept formation. The second factor explained 41.2% of the variance, and had loading from correct responses, incorrect responses, perseverative errors and perseverative responses, representing poor set shifting. Hence, the second factor is considered as the perseveration tendency (Table 19).

Table 19

Principal Components Analysis of the PCET

	Factor	
	1	2
CR	.539	.618
CAT	.963	.145
PE	.077	.977
PR	.087	.976
ER	-.537	.837
ACC2	.998	-.081
EFF	.991	-.056
Variance Proportion	52	41
Eigenvalue	3.63	2.885

Note. The extraction method was principal component analysis. The rotation method was direct oblimin with Kaiser normalization. PCET: Penn Conditional Exclusion Test, CR: Correct Responses, ER: Incorrect Responses, CAT: Number of Categories Achieved, CAT1_TR: Number of Trials in PCET Using Sorting Principle 1, PER_ER: Perseverative Errors, PER_RES: Perseverative Responses, ACC2: Accuracy 2, EFF: Efficiency

3.4.3 Group comparisons with factor scores.

To detect changes with respect to age between indicated factors, three one-way ANOVAs for the WCST and two one-way ANOVAs for the PCET were performed. Before the ANOVAs, scores for each WCST and PCET subscales were converted into Bartlett factor scores. First ANOVA was conducted with WCST-Concept Formation serving as dependent variable and age as the independent variable. Second ANOVA was performed for WCST-Perseveration as outcome variable and age as the predictor. Third ANOVA included WCST-

Set Maintenance as outcome variable and age as the predictor. The same procedures were repeated separately for PCET-Concept Formation and PCET-Perseveration as outcome variables and age as the predictor. Results showed a lack of significant difference among age groups in Perseveration in both the WCST, *F*(2.110)=1.71, *p*=.185, and the PCET, *F*(2,110)=.643, *p*=.528. In addition, no significant difference was found between age groups in the Set Maintenance of the WCST, *F*(2,110)=.035, *p*=.965, factors. However, ANOVA performed with Concept Formation factor as the dependent variable yielded significant results, both in the WCST *F*(2,110)=12.08, *p*=.000, and the PCET, *F*(2,110)=23.83, *p*=.000. As can be seen in Figure 6, concept formation improves with increasing age whereas perseverative tendencies decrease.

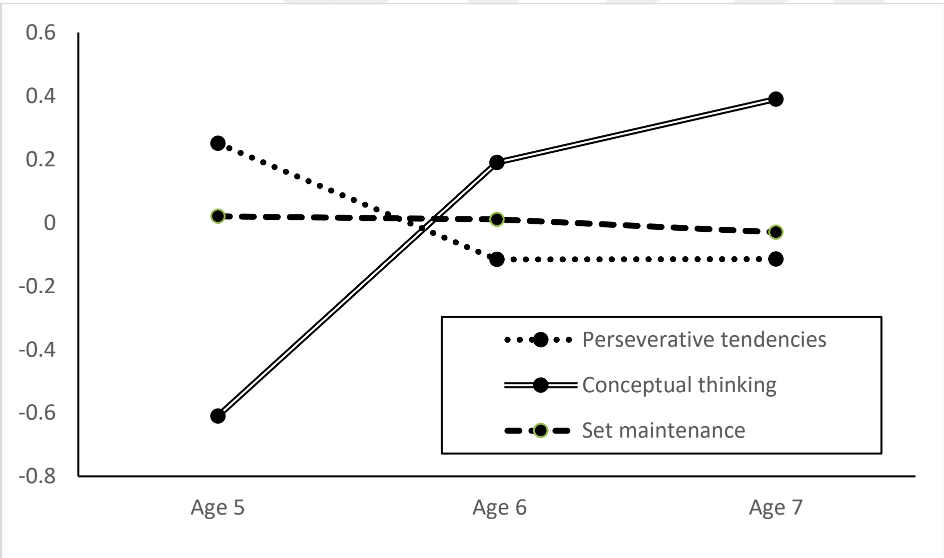

Figure 1. The Standardized Bartlett scores of CF, PSV, and FMS as a function of age

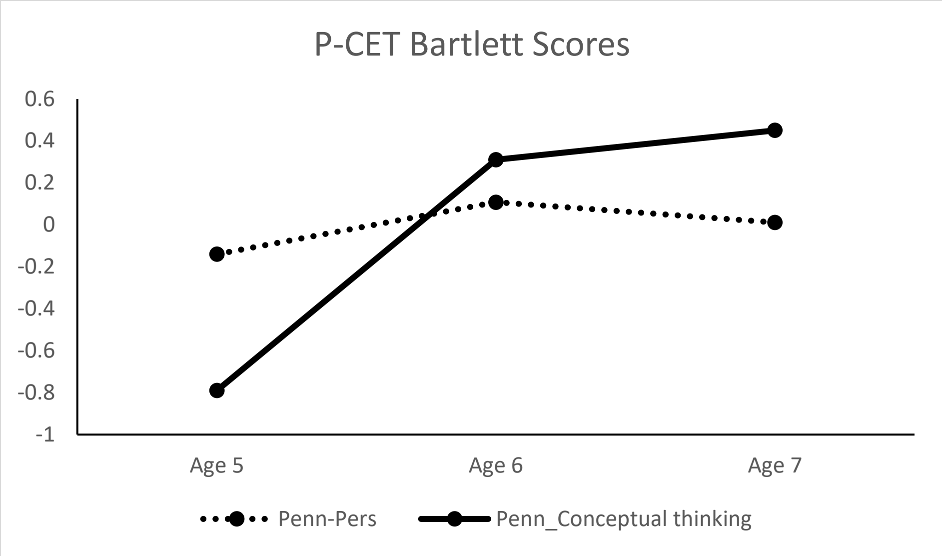

Figure 2. The Standardized Bartlett scores of CF and PSV as a function of age

3.5 Association of ENT Sub-scores with Concept Formation, Perseveration, and Set Maintenance in the WCST

Hierarchical multiple regression analyses were conducted to examine which ENT variables predicted the WCST and the PCET component scores, when demographic (age, sex and maternal education) variables were controlled. Before the regression analyses, factor scores for each factor in the WCST and PCET were derived through the Bartlett (Bartholomew, Deary, & Lawn, 2009). The predictor variables were entered into the equation for the first step as follows: mother's education, age, grade, preschool background, type of school and sex. For the second step, ENT variables were entered into the equation.

First, a series of hierarchical regression analyses were conducted using the first principal component as the criterion variable, which included the WCST-CC and WCST-UE and WCST-CLR scores. The results of step 1 indicated that the variance accounted for (R^2) with the first six independent variables (age, sex and maternal education, grade, preschool background, type of school) was .28, $F(6,205)= 6.70$, $p < .001$). Grade, β= .31, t =2.06, $p < .05$, and preschool background, β= .28, t =2.4, $p < .05$, were the only statistically significant independent variables, indicating a positive relationship. In other words, as grade and years spent in preschool increase, there was an increase in the scores of WCST-Concept Formation as well. In step 2, ENT variables were entered into the regression equation. The change in variance accounted for (ΔR^2) was equal to .19, which was significantly different from zero, $F(9,96)= 3.83$, $p < .001$). Comparison, β= 2.3, t =2.70, $p < .05$, classification, β= .29, t =3.11, $p < .05$, and estimation, β= 2.2, t =2.33, $p < .05$, were only statistically significant variables. In sum, only two of the demographics and three of the ENT scores contributed significantly to the explanation of Concept Formation in the WCST. There was a positive relationship between the concept formation and all other variables except maternal education (β=-.17) which was not a significant predictor.

The second dependent variable was the perseveration factor of the WCST which includes WCST-PR and WCST-PE scores. The results of step 1 indicated that six variables (age, sex and maternal education, grade, preschool background, type of school) entered on the first step explained 4 % of the variance, which was not significantly different from zero $F(6.205)=.653$, $p=.688$). None of the predictors in Step 1 significantly contributed to the regression model. In step 2, ENT variables were entered into the regression equation. The change in variance accounted for (ΔR^2) was equal to .08, which was not significantly different from zero, $F(9,96)= .47$, $p=.890$). Neither the first model (demographic variables) nor the second model (demographics plus ENT variables) predicted scores on the Perseveration in the WCST to a statistically significant degree. In addition, all of the variables were positively related to Perseveration except type of school (β=.047). However, none of them was significant.

The third dependent variable was the set maintenance factor of the WCST which includes WCST-FMS and WCST-T1stC scores. Variables entered on the step 1 (age, sex, maternal education) did not predict the scores on the set maintenance factor of the WCST to a statistically significant degree, $F(6,105) = .64$, $p = .697$. Introducing the ENT variables explained an additional 6% of variation in Set Maintenance and this change in R^2 was significant, $F(9,96) = 2.22$, $p < .05$. Estimation was the only statistically significant predictor, $\beta = .30$, $t = 2.57$, $p < .05$. In addition, all of the variables were negatively related to Perseveration except type of school ($\beta = .21$, $t = .64$, $p > .05$) and preschool background ($\beta = .19$, $t = 1.09$, $p > .05$). The unstandardized regression coefficients (*B*) and intercept, the standardized regression coefficients (β), for the full model are reported in Table 20.

Table 20

Hierarchical Regression Analyses for the WCST Scores

WCST Scores	*B*	S.E-*B*	β	*T*	*p*	Rsquare	Fchange
Concept Formation							
Step 1					.000**	.28	6.7
Demographics							
Sex	.27	.17	.14	1.62	.108		
Age	.01	.01	.11	.65	.514		
Maternal Education	-.20	.10	-.17	-1.85	.066		
Grade	.36	.17	.31	2.06	.041*		
Preschool Background	.36	.15	.28	2.4	.018*		
Type of school	.30	.28	.14	1.09	.277		
Step 2					.000**	.47	3.83
ENT variables							
Comparison	.42	.156	2.3	2.70	.008*		
Classification	.24	.08	.29	3.11	.002*		
Estimation	.16	.07	2.2	2.33	.022*		
Perseveration							
Step 1					.688	.04	.653
Demographics							
Sex	-.099	.19	-.05	-.51	.611		
Age	-.004	.019	-.04	-.22	.828		
Maternal Education	-.18	.12	-.16	-1.52	.130		
Grade	-.063	.20	-.05	-.31	.754		
Preschool Background	-.001	.174	-.001	-.007	.99		
Type of school	.047	.32	.022	.146	.88		
Step 2					.89	.08	.472
ENT variables							
Set Maintenance							
Step 1					.697	.035	.64
Demographics							
Sex	-.083	.19	-.04	-.43	.670		
Age	-.03	.12		-.30	.488		
Maternal Education	.097	.12	.082	.79	.430		
Grade	-.24	.20	-.20	-1.19	.236		
Preschool Background	.19	.17	.14	1.09	.277		
Type of school	.21	.32	.098	.64	.520		
Step 2					.027*	.20	2.22
ENT variables							
Synchronous Counting	-.23	.12	-.31	-1.88	.062		
Estimation	.21	.08	.30	2.57	.012*		

Note. * $p< .05$, ** $p< .01$ (two tailed).

3.6 Association of ENT Sub-scores with Concept Formation and Perseveration in the PCET

The same analyses were conducted this time with concept formation and perseveration factors of the PCET serving as the dependent variable. The first dependent variable was the concept formation factor of the PCET which is composed of PCET-CAT, PCET-ACC2, and PCET-EFF scores. The results of step 1 indicated that the variance accounted for (R^2) with the first six independent variables (age, sex and maternal education, grade, preschool background, type of school) equaled .26.4, which was significantly different from zero, $F(6,105)=6.29$, $p < .001$). Grade was the only statistically significant independent variable, β=.32, t =2.13, $p < .05$. In step 2, ENT variables were entered into the regression equation. The change in variance accounted for (ΔR^2) was equal to .21, which was significantly different from zero, $F(9,96)= 4.24$, $p < .001$). Comparison, β= .25, t =3.01, $p <$ .05, and classification, β=.20, t =2.23, $p < .05$, were only statistically significant variables. In addition, age, (β=.024), maternal education, (β=.024), and grade, (β=.37), were positively related to PCET-Concept Formation whereas preschool background, (β=-.033), type of school, (β=-.30), and sex, (β=-.08), were negatively associated. Overall, only one of the demographics (age) and two of the ENT scores (ENT-COM and ENT-CLASS) contributed significantly to the explanation of Concept Formation in the PCET.

The second dependent variable was the perseveration factor of the PCET which includes PCET-PER_ER and PCET-PER_RES scores. The results of step 1 indicated that the variance accounted for (R^2) with the first six independent variables (age, sex and maternal education, grade, preschool background, type of school) equaled .088, which was not significantly different from zero, F(6,105)=1.68, $p > .05$). None of the predictors in Step 1 significantly contributed to the regression model. In step 2, ENT variables were entered into the regression equation. The change in variance accounted for (ΔR^2) was equal to .075, which was not significantly different from zero, $F(9,96)= .96$, $p > .05$). Lastly, age, (β=-.002), and type of school, (β=-.42), were negatively related to PCET-Perseveration whereas maternal education, (β=.08), sex, (β=.34), grade, (β=.13), preschool background (β=.04), were positively related. In other words, more years spent in preschool and being in a higher grade make a non-significant increase in the PCET-Perseveration scores. However, neither the first model (demographic variables) nor the second model (demographics plus ENT variables) predicted scores on the Perseveration in the PCET to a statistically significant degree.

The unstandardized regression coefficients (*B*) and intercept, the standardized regression coefficients (*β*), for the full model are reported in Table 21.

Table 21

Hierarchical Regression Analyses for the PCET Scores

PCET Scores	*B*	S.E-*B*	Β	*t*	*p*	Rsquare	Fchange
Concept Formation							
Step 1					.000**	.26	6.3
Demographics							
Age	.024	.016	.25	1.49	.138		
Maternal Education	.024	.10	.020	.22	.823		
Sex	-.08	.17	-.04	-.46	.643		
Grade	.37	.17	.32	2.13	.035*		
Preschool Background	-.033	.15	-.026	-.21	.828		
Type of school	-.30	.28	-.14	-1.07	.283		
Step 2					.000**	.47	4.24
ENT Variables							
Comparison	.46	.15	.25	3.01	.003		
Classification	.17	.078	.20	2.23	.028		
Perseveration							
Step 1					.132	.09	.1.68
Demographics							
Age	-.002	.018	-.016	-.086	.931		
Maternal Education	.08	.12	.072	.705	.482		
Sex	.34	.19	.17	1.8	.075		
Grade	.13	.20	.11	.69	.492		
Preschool Background	.04	.17	.03	.24	.810		
Type of school	-.42	.31	-.20	-1.35	.179		
Step 2					.476	.16	.96
ENT Variables							

Note. * p< .05, ** p< .01 (two tailed).

Chapter 4. Discussion

The present study aimed to investigate the nature of and the relationship between two tests of cognitive flexibility and developmental trends in cognitive flexibility in a group of 5- to 8-year-old children as measured by these tasks. The study also aimed to examine the two cognitive flexibility tasks in terms of their appropriateness for this developmental period as well as their association with developments in the ability to quickly understand, approximate, and manipulate numerical quantities. The major goals of the study can be examined under four headings, (a) the factor structures of the two EF tests to explore children's developmental trajectories on each indicated executive domain, (b) the extent of relationship between the two EF tests, (c) the relationship between executive functioning and number sense, and (d) grade and age-related differences in children's EF and numerical performances. Results will be discussed by addressing these main targets of the study.

4.1 Developmental Trends in Cognitive Flexibility Tasks

One of the primary aims of the present study was to track the developmental trajectories of two EF tests namely the WCST and PCET in a sample of 5- to 8-year-old children. The results in our sample show a regular improvement in performance in each of the most relevant variables of the WCST and PCET with an increasing age. However, the general trend in both tasks indicated a significant improvement only in concept formation scores between ages 5 and 6, but this trend is less sharp after age of 6. In other words, finding that 5-year-old participants completed fewer categories than 6- and 7-year-old participants supports previous research on the WCST performance across different developmental levels and ages (Chelune & Baer, 1986; Heaton et al., 1993; Roselli & Ardila, 1993; Seidman et al., 2005; Shu, Tien, Lung, & Chang, 2000; Willcutt et al., 2005). In fact, significant changes in cognitive flexibility ability with an increasing age was also documented when cognitive flexibility capacity was assessed with other tasks (Blaye & Bonthoux; 2001; Chen, 1999; HermerVazquez, Moffet, & Munkholm, 2001; Zelazo, Frye, & Rapus; Deak, 2003).

These age-related changes might originate from several reasons. First, the age related difference may be related to a general immaturity of different perceptual systems (Benedek, et al., 2003; Jeon, et al., 2010; Skoczenski & Norcia, 2002), attentional mechanisms (Johnson, 2002; Farzin, et al., 2010, 2011), inhibitory capacity (Diamond, 2002) or visual working memory capacity (Cowan, et al., 2011; Simmering, 2012; Wilson, et al., 1987), and multiple object tracking (O'Hearn, Landau, & Hoffman, 2005). However, none of these areas were the topic of interest in the present study. It is not possible to conclude whether the poor performance was related with a general immaturity or immaturity specific to cognitive flexibility.

In support of this argument, studies show that regarding the specific ages at which cognitive flexibility capacities show a rapid improvement. Although the ability to generate concepts and classify objects appears between the ages of 3 and 4, these abilities manifest a significant progress around the ages of 4 and 5, which enables children to observe two sorting criteria in the same group of objects (Smidts, Jacobs, & Anderson, 2004). However, the ability to define a third classification criterion improves only after ages of 5 (Luciana & Nelson, 1998; Smidts, Jacobs, & Anderson, 2004). Children younger than age of 7 years still experience difficulties in more complex tasks that require identification of categories (Smidts et al., 2004). All in all, the present study reveals that 5 to 6 years of age is the period when a significant improvement occurs for this specific sample of children. To be able to fully understand the underlying mechanisms of this age group, there is a need for studies with larger sample of children in the future.

Second, lower scores of younger children may be related to task characteristics, more specifically the cognitive demands of tasks and younger children's inability to meet even the basic demands of these tasks. The WCST require participants to sort cards based on three different criteria (color, shape, and number respectively) and flexibly adapt when the sorting rule is changed without being informed. However, PCET applies an odd man out paradigm where the child has to choose one card that does not belong to other three cards based on three different criteria (line thickness, shape and size). For a successful performance in these tests, there might be a threshold for the maturation of the required cognitive capacities regarding the concept formation between ages of 5 and 6. In other words, although there is a consensus regarding the developmental changes in the executive function (Bujoreanu & Willis, 2008; Kohli & Kaur, 2006; Somsen, 2007), critical ages at which these changes occur are still a matter of debate. The significant difference between 5- and 6-year-olds obtained from the current study might indicate a differential maturation process of certain brain regions for this sample of children.

Third, additional regression analyses with age and grade being included revealed that the grade is able to predict the changes in the concept formation scores of both the PCET and WCST over and above age. For this sample of children, 5-year-old children were the ones who attend to preschool whereas 6- and 7-year-olds were in formal schooling. Thus, the difference might be related with the effects of formal schooling in addition to age. The performances of first and second graders did not differ on any of the measures in the present study except the two scores in the ENT while there was a significant difference between preschoolers and first graders for concept formation scores in both the WCST and PCET but not for perseveration or set maintenance. In line with this argument, it was claimed that children of similar ages might vary in their skills, strategies and cognitive structures employed during the EF tasks due to malleability of the brain (Segalowitz & Davies, 2004). In other words, depending on the age, children have the chance to improve the required skills needed in the EF tasks which creates variability among same age children. Other researchers also provide evidence for the vital effect of intervention programs and experience with problem solving in real-world situations while interpreting the results of card sorting tests in addition to age and general intelligence (Chan, Lam, Wong, & Chiu, 2003; Olesen, Westerberg, & Klingberg, 2004; Rueda, Rothbart, Saccamanno, & Posner, 2005; Zelazo, Müller, Frye, & Marcovitch, 2003). An earlier study by McCrea, Mueller, and Parrila (1999) found that children between ages of 7 to 9 years who attend to school perform better on the executive function tasks, revealing a small to moderate effect of schooling experiences on executive function. A more recent study with preschool children in transition to school examined schooling and age effects on inhibition and working memory (Burrage et al., 2008). They revealed that there was a significant influence of school related experiences on the memory whereas these effects were not significant for inhibition. Hence, these studies provide evidence for related but separable influences of age and formal schooling on the development of executive function in preschool and early elementary school children. Furthermore, for the sake of the present study, the significant effect of grade on the concept formation rather than perseveration and set maintenance might be related to the fact that each subfactor in the EF tasks follows a different developmental trajectory.

Moreover, the present study also made a crucial contribution to the literature by providing evidence for the view that years spent in preschool is a significant predictor for concept formation scores. Researchers also highlighted the difference between the children who attend to preschool to those who did not. They emphasized that children who have a preschool background have higher scores on concept formation tests compared to others who have no preschool background (Akman et al., 2000; Çelik, 2005; Hayran, 2010; Schwartz et al., 1975). Education might have a positive effect on the performance of children through providing them with better working memory, verbal reasoning and spatial processing skills, as well as better memory accuracy and faster motor speed (Moore et al., 2015). Hence, the preschool background might be one of the factors that may have contributed to EF development.

Further analyses did not reveal any significant differences between public and private school children. These results may stem from several reasons. First, the number of children in the present study was small. Second, the public schools that were used for the data collection were not in a deprived socioeconomic status and they had good physical conditions as well. However, this finding might be a hint for the effect of several different variables related with the schooling on children's performance such as teacher quality, curriculum and materials.

Consistent with the previous findings on the WCST (Ardila et al., 2005; Patterson, Bock, Pasnak, 2015; Shu et al., 2000; Yeniad, 2009), the current study did not reveal any sex difference on the PCET and WCST scores. Nevertheless, literature lacks studies on the PCET regarding the sex difference. Hence, further studies should explore these effects on the PCET performances of children.

Moreover, the current results showed no significant effect of parental education level on variables related to both conceptual thinking and perseveration. This result is in contrast with the literature indicating a strong association between parents' educational level and children's cognitive performances (Ardila, Roselli, Matute, & Guajardo, 2005; Gur et al., 2010; Kagitcibasi, Bekman, & Goksel, 1995; Klenberg, Korkman, & Lahti-Nuuttila, 2001). In addition, the present study did not reveal any effect of maternal education on the ENT scores as well, which is consistent with the previous research (Önkol, 2012). These results suggest that the difference in the PCET and WCST scores depended on some conditions other than maternal education. Several studies emphasize the role of maternal depression (Hughes, Roman, Hart, Ensor, 2012), affective quality of the mother–child relationship (Bernier et al., 2010; Estrada, Arsenio, Hess, & Holloway, 1987), general environmental stress and chaos (Rhoades, Greenberg, Lanza, & Blair, 2011) on executive functions. However, why the education level of mothers did not predict the WCST and PCET scores still needs to be investigated.

4.2 Assessment of Executive Functions: Internal Structures of Measures

Another goal of the present study was to explore the relationship between the scores of two EF tests namely as the the Wisconsin Card Sorting Test and the Penn Conditional Exclusion Test. It was expected that both EF tests will composed of different components which may be correlated with one another. The results of the study showed that both executive function (EF) measures, the WCST and the PCET, have two overlapping factors, namely concept formation and perseveration (or cognitive inflexibility) in a sample of 5- to 8-year-old children. However, the WCST has an additional factor named as set maintenance in the present study. Hence, the results are in line with the argument that some of the EF measures requires more than one cognitive capacity (Baron, 2004). To be more specific, the present study supports previous findings that indicated specific WCST scores load on different factors rather than being categorized under a single factor (Greve et al., 1998; Greve et al., 2002; Greve et al., 2005; Koren et al., 1998; Lee et al., 2004; Yeniçeri & Altan Atalay, 2011). The internal structures of these tests are discussed here separately with respect to consistencies and inconsistencies with the previous research.

4.2.1 Factor structures of the executive function tests.

Despite the controversy in the previous research, the results of this study support three factor structures (Greve et al., 2005). Additionally, the present study is the first study investigating the factor structure of the PCET in children younger than 8 years old and revealed a two factor structure tapping on to concept formation and perseveration. This finding is in line with the study conducted by Silver and Bilker (2013) who examined the factor structure of the PCET in a group of adults. Nevertheless, there is a need for further studies conducted with children to be able to make better comparisons.

The first factor, named concept formation, was composed of conceptual level responses (CLR), categories completed (CC), nonperseverative errors (NPE), and unique errors (UE) scores for the WCST whereas it included accuracy, efficiency and categories completed scores for the PCET. Similar names have been used in previous studies such as conceptualization, concept formation, learning, reasoning, and problem solving (Senturk, Yeniceri, Ercan, Altan-Atalay, 2014; Yalçın & Karakaş, 2008; Karakaş, 2004; Yeniçeri, Altan-Atalay, 2011). The scores on the WCST reflect the ability to recognize the possible sorting concepts and problem solving (Greeve, Kevin, Bianchini, 1998) and poor performance on the WCST in this specific factor may implicate the difficulties in task conceptualization. However, it reflects an underlying process of abstraction, taking the speed and accuracy trade off into consideration for the PCET. In other words, for the WCST, error number may increase as a result of difficulties in generating a new conceptual pattern. Specifically, lower scores on the number of categories completed score is accepted as an indicative of conceptual problems. Different than the WCST, accuracy score of the PCET is related with correct responses achieved in each category whereas efficiency includes both accuracy and speed scores. Specifically, high speed and less errors (accuracy) mean that the child has correctly understood the rule of the task and is working on the task efficiently. Thus, it is not surprising that both the WCST and PCET scores are an indicator of concept formation for the present study.

The second factor, perseveration (or cognitive inflexibility), is comprised of scores that seem to measure the inability to shift from an incorrect response set. This factor includes perseverative responses and perseverative errors (PE) scores for the WCST whereas it is composed of correct responses, incorrect responses, perseverative errors and perseverative responses scores for the PCET. This factor reflects deficiencies in mental set shifting (Kongs, Thompson, Iverson, & Heaton, 2000). Perseverative performance on the WCST can be explained in relation to problems in cognitive flexibility (Zelazo, 2006) which is also called as set shifting (Davidson et. al, 2006). Zelazo and Müller (2002) distinguished two types of cognitive inflexibility as the root of the perseverative behavior in children. One is related with the concept formation while the second one concerns the failure to inhibit the inappropriate responses. Consistent with the second argument, set-shifting process is claimed to better function if one is able to inhibit the old rule (Dillon & Pizzagalli, 2007) and this ability of set shifting makes a robust development after age of 8 (Crone et al., 2006). In sum, inhibition of irrelevant responses and the ability to flexibly shift to a new context significantly determine the number of perseverations in the WCST.

The third factor, set maintenance, emerged as a factor only in the WCST and it is composed of trials to complete first category (TC1st) and failure to maintain set (FMS) scores. FMS was emerged as a distinct factor in several studies (Greve, Bianchini, Hartley, & Adams, 1999; Yeniceri & Altan-Atalay, 2011). The present study provides partial evidence for this finding. Although T1stC was found to load onto concept formation factor in several studies (Heaton, 1981; Sing, Aich, Bhattarai, 2017; Yeniceri & Altan-Atalay, 2011), the present study made a contribution by showing that T1stC might be related with a process other than concept formation in this age group of children. Not being able to maintain the set might stem from a loss of focus on the task due to boredom, mind wandering, or an inability to maintain task relevant goals (Figueroa & Youmans, 2013). Hence, failure to maintain set may result in failures while completing categories. This argument is consistent with the research showing that the ability to maintain a set might be largely related with distractibility rather than cognitive flexibility (Barceló & Knight, 2002) and this ability reaches adult levels of performance around age of 13 (Crone, Ridderinkhof, Worm, Somsen & van der Molen, 2004).

The current findings revealed that the WCST and PCET are assessing various components of EF rather than being limited to one single domain. Thus, they can be considered valuable tests, enabling the researchers to gain insights into some executive cognitive processes. However, it is difficult to identify the specific cognitive process of the participant which leads to failure in these tasks. Thus, there is a need for more specific and less-complex tasks, which will provide researchers with more reliable data (Stuss, 2006).

4.2.2 The internal structures of the EF tests.

In the present study, similar factorial components were observed for two EF tests, the WCST and the PCET, in a sample of 5- to 8-year-old children. By comparing the internal structure of the PCET with internal structure of the WSCT, the present study indicates that the PCET is valid instrument in the assessment of EF of 6- to 8-year-old Turkish students but not for 5-year-olds. The present data showed that 5-year-olds had significantly different scores in concept formation of both the PCET and the WCST and regression analysis yielded significant findings only for the two concept formation scores. It is observed that concept formation scores of the PCET is significantly correlated with the concept formation scores of the WCST**.** In this regard, intelligence was found to be related to concept formation proficiency in earlier studies (e.g., Baggaley, 1955; Gridley, & Barnes, 1995). Some accepted the capacity for learning concept-formation habits as a component of intelligence (Denny, 1966; Kagan, 1966). Furthermore, concepts were accepted as essential while perceiving classroom conversations and teacher directions (Bracken, 1986), the administrative instructions of intelligence tests (Bracken, 1986) and academic achievement (Cummings & Nelson, 1980; Panter, 2000). Given that the present study did not include a measure of intelligence due to time constraints, it is not possible to draw a conclusion regarding the relationship between concept formation and intelligence. On the other hand, the present study claims that the concept formation factors of both tests are associated with each other. This argument is also consistent with studies underlying the role of abstraction in developing cognitive flexibility (Jacques and Zelazo, 2005; Rougier et al., 2005; Wallis et al., 2001; Vygotsky, 1962; Zelazo et al., 2003). However, it cannot be suggested that these factors are almost identical since correlations among those scores are at the moderate level (r=.40). In a study, Perrine (1993) suggested that similar tests utilized to measure concept formation might reflect different components of the construct such as rule learning or identification of stimulus attributes. Based on this evidence, such a difference in the meaning of factors for WCST and PCET may be due to the calculation and evaluation of the subscores. Considering the components of concept formation factor in the PCET, a principal component analysis with a direct oblimin rotation revealed three scores namely CAT, ACC2 and EFF. Accuracy score in the PCET is defined as the proportion of correct responses compared to total scores in each category (Gur et al., 2010), whereas efficiency score is to be able to give accurate responses as fast as possible. For example, if an individual had an accuracy score of 2.50 (very accurate) and a speed score of −2.50 (very slow), his/her efficiency score would be 0. High speed and accuracy mostly require identification of stimulus. However, the WCST does not include a speed variable in the calculation of concept formation.

Moreover, this moderate correlation might stem from the fact that stimulus attributions such as shape, size, number or line thickness require a certain level of conceptual reasoning. Conceptual reasoning has been accepted as part of executive functions in earlier studies. Because, executive functions in general are related with one’s ability to evaluate the accuracy of their own performance which requires metacognition (Roebers et al., 2012). Moreover, metacognitive skills are reported to be related with conceptual reasoning and thus may contribute to cognitive flexibility (Bilalic, McLeod, & Gobet, 2008). Confirming Bujoreanu and Willis (2008) who showed that although young children might complete some categories in card sorting tests, this might not be an indicator of their conceptual reasoning.

Because, Lezak (1983) stated that most of the tests such as the WCST and Object Classification Test measure conceptual function in relation with mental flexibility. Confirmingly, Greve et al. (2000) found that the development of concept recognition precedes sorting ability. The present study revealed that 5-year-old children have a significant difference not just in the concept formation of the WCST but also the PCET. Hence not just the number criteria in the WCST but also the line thickness, size or configurational differences in the PCET may confound the performance of younger children. In support with this argument, Grant and Curran (1952) concluded that abstraction of different concepts such as number, form and color does not have the same effect on the performance of children. Because, children's perception of color, depth, shape and spatial features are reported to exhibit different developmental patterns (Johnson & Hannon, 2015). Perception of dimensions is vital in the sense that conceptual structure is based on the perception (Smith & Heisse, 1992). In line with this argument, the tasks used in the present study includes different dimensions such as color, shape, number, thickness and size. Thus, it is meaningful that the findings of the present study has provided a moderate correlation only between the concept formation scores of the PCET and WCST. Regarding the development of the dimensions, research shows that terms such as color or size are acquired in different ways. Although size terms such as big and little are used starting from early childhood, children treat them as categorical terms rather than relative terms (Sandhofer & Smith, 2001). Thus, it might be hard for a child to think of an object as smaller compared to another one when it is labeled as big. Because, size words are fully comprehended around age of 5. And children's criteria that define size become fixed by age of 6 (Sandhofer & Smith, 2001). This applies to perception of shapes as well. Although children start to identify the shapes as circle, or triangle around age of 3, they have problems with categorizing these shapes based on the non-integral attributes of size, orientation, aspect ratio (i.e., the ratio of side lengths)

(Hannibal, 1999) and spatial segregation of different dimensions (Kloo & Perner, 2005; Zelazo et al., 2003). Thus, the present study made a crucial contribution by showing that the scores achieved on the WCST and the PCET might be affected by the conceptual deficits rather than solely cognitive inflexibility in this sample of children (Cinan, 2006).

In addition to moderate correlations between the two tests, group comparisons with factor scores also revealed different developmental trajectories for the Perseveration in the WCST and PCET. The PCET-Perseveration score is found to increase from 5- to 6-year-olds while starting to decrease from 6-to 7-year-old. However, it was the opposite for the WCST. Cognitive flexibility is a multidimensional concept and the way it is assessed by WCST and PCET may be completely different from each other and this can explain the lack of correlation between these two measures of perseveration. Besides, correlations among perseveration scores of the tests revealed that perseveration factors of the PCET and the WCST are not statistically related to each other although these tests have a perseveration component. The most prominent reason for this insignificant relation would be the different variables included in their perseveration factors. For instance, although WCST has perseverative errors and responses in the perseveration factor, the PCET includes one additional score that is number of incorrect responses, which is not included in the perseveration factor of the WCST.

Similarly, Cinan (2006) argued that there are two kinds of cognitive inflexibility named as “representational inflexibility”, and “switching inflexibility” (p. 378). Representational inflexibility stems from the improper forming of the rule or concept whereas switching inflexibility refers to a problem in flexible application of the rule due to the failure of inhibiting the prepotent response. For this specific sample, it might be the case that instruction given in the PCET (find the one that does not belong to the others) is hard to understand for younger children compared to the instruction given in the WCST (match with the similar one). Because, finding the similar card with another card and finding the different card among the whole cards might be related with different conceptual levels (Ravizza & Carter, 2008). Deak (2003) also noted that perseverating on a rule might be due not to general inflexibility but rather to poor comprehension of a cue or rule. Or the materials used in the educational settings in Turkey mostly include the similarity activities rather than the latter. However, this claim needs further investigation of the results in a larger sample of children attending several different schools.

In sum, younger children might have problems in comprehending the rule in the PCET whereas they have difficulties in inhibiting the previous response in the WCST. Hence, the perseveration scores in the two tests are not correlated with each other. Nevertheless, further investigation is necessary for a comprehensive understanding of similarities and differences of perseverative behaviors measured by these tests since the PCET is a newly adapted EF measure for children.

A crucial question regarding these EF tests would be whether or not these tests can be used as an alternative to the other. Regarding this question, the present study investigated the internal structure of both tests and the statistical correlations among their scores in a sample of 5- to 8-year-old Turkish children. Results suggest that although the PCET and the WCST provide assessment of similar components (i.e., concept formation and cognitive inflexibility), these capacities do not refer to identical constructs. More specifically, the concept formation scores of the PCET and the WCST are moderately related, whereas the perseveration factors are not significantly related to each other. In this regard, present study cannot claim that the PCET and the WCST can be used as an alternative to each other, but both tests have some advantages and disadvantages in comparison to the other.

Considering all, it is claimed that the PCET and the WCST are not used interchangeably, but they are valid screening instruments for measuring executive functioning for children older than 6-year-old for the present sample of children. Finally, given concerns of possible developmental discontinuities, it seems that the use of complex concepts as a sorting criteria in the sorting tasks requires further study at least for children younger than 6 year old. Considering all these findings, the differences in the factor loadings might be evaluated critically in order to understand the mechanisms of executive functions in this specific developmental period of time.

4.3 Development of Number Sense

Another focus of interest in the current study was to investigate the developmental process of number sense in this specific sample of children. The results of the present study showed that there was an overall improvement in children's performances between 5 and 6-year-olds in terms of numerical knowledge which may be indicative of a critical period for the development of this capacity. Secondly, the only significant difference between 6 and 7-year-olds were in using numerals and applying knowledge of number scores for the present study. This indicates that not just age but the effect of grade should not be disregarded since ENT items are mostly related with the skills that are learned in the first grade. The standardization study of the ENT with 6-year-old Turkish children revealed significant differences between all age groups (4-, 5-, 6-, and 7-years-old). In partial contrast with this finding, the present study could not find any significant differences between 6- and 7-year-olds. This difference might stem from the fact that Önkol (2012) used 6-year-old children who attend to pre-school in her study. However, in the sample of the present study, 6 years-olds were mostly compromised of children who attend to first grade. Thus, the difference may be due to schooling factors and changes in Turkish educational curriculum, resulting in an earlier ceiling in this sample of children. The impact of environmental factors and schooling on ENT scores likewise, had also been demonstrated by Önkol (2012), Şirin (2011) and Yalım (2009).

Considering all the questions together it was concluded that ill skills examined in the study there was a development by age. Increase in the ENT scores with age seemed to be the result of both cognitive development and the experiences gained with the attendance to primary school.

4.4 The Relationship between Executive Functions and Number Sense

Another purpose of the present study was to investigate the relationship between the EF and number sense. Concept formation and flexible use of sorting rules have a vital impact on the development of academic skills (Van der Sluis, de Jong, & Van der Leij, 2007). It was found that poor mathematical skills in early years of education is related with difficulties in tasks that require inhibition of inappropriate responses and flexible use of previously existing strategies (Bull & Scerif, 2001). In addition, Van der Sluis et al. (2007) emphasized the important role of EFs for numerical problems which require use of reasoning instead of memorization. Current results demonstrated that some sub-scores of ENT are correlated with the PCET and WCST at a moderate level. In addition, regression analysis results show that only comparison, classification, and estimation scores of the ENT significantly account for 21% of the variation in the concept formation scores of the PCET and 19% of the concept formation scores of the WCST but none of the predictors significantly predicted perseveration and set maintenance factors. Thus, the findings of the current study seem to be compatible with the view that executive function (PCET and WCST) and numerical knowledge (ENT) instruments measure somewhat related constructs (Van der Sluis et al., 2007). Yet, it is impossible to make a claim regarding the association between cognitive flexibility and number sense for the specific instruments without examining the possible confounders.

Taken the factorial structure of the WCST and PCET into consideration as mentioned above, it is clear that the WCST and PCET scores that were correlated with the ENT scores in fact reflect the concept formation factor of the WCST and PCET. In light of the findings mentioned above, the inter-correlations among the certain scores of the WCST, PCET and ENT in this study can be explained by the fact that all these tasks require conceptual thinking ability in common. Firstly, regarding the EF tasks, it is difficult to understand whether the performance is related with the conceptual knowledge or flexible thinking itself when different sorting criteria such as number, shape, size and density is included. A few studies (Frye, Zelazo, & Palfai, 1995; Zelazo et al., 2003) have explored size- and number-based rules. They found that prior difficulty of the rules is one of the factors affecting the performance of preschool children in EF tasks (Deák, 2003). Also called as subtask difficulty, it is stated to be a vital factor while comparing flexibility across tests. The present study also supported the finding that children's ability to comprehend and make use of the task rules affect their overall flexibility in a test. Likewise, numerical competence also requires the use of abstract thinking capacity, since the essence of mathematics is dependent on concepts and relationships as well as symbols (Jovanova-Mitkovska, 2014). Thus, from this point of view, it is not surprising that the most robust correlations of the ENT were found with the Concept Formation scores of the WCST and the PCET. Overall, the present study provided data on the relationship between children's EF performances and their numerical knowledge scores.

4.5 Limitations and Future Directions

The main limitation of this study is that the participants were selected through convenience sampling, resulting in a non-representative sample. Larger sample size would have allowed for examining factorial structure of the WCST and PCET for this age group, which will contribute to establish construct validity. Second, the test battery did not involve scales assessing WM and fluid intelligence due to the time constraints of administration. In this regard, further studies should include WM and fluid intelligence measures in order to obtain more comprehensive conclusions. Third, since the PCET is a new task, further investigations on the PCET are required with different clinical and non-clinical samples, with different EF measures, and for other age groups.

Finally, a recent study emphasized the importance of enhancement programs for pre-school children in order to improve their performance on two EF measures, DCCS and task orientation (Bierman et al., 2011). Nevertheless, further studies should employ different measures of multiple executive function components to see which executive function processes is influenced by school-related experiences. It would add considerably to our understanding of early executive development to know whether environmental effects account for individual differences in EF skills.

Chapter 5. Conclusion

The current study was the first study conducted with 5- to 8-year-old Turkish children, which examines the factor structure of not just the PCET but also the WCST. Additionally, a comparison of the WCST scores with the PCET revealed a common factor, concept formation, which might be affected by the difficulty level of the sorting dimensions for children 5 to 6-year-old. However, further research should be conducted with other computer based tasks for executive functioning skills, adequate sample size and participants that are seemingly heterogeneous.

References

Agrillo, C., Piffer, L., & Adriano, A. (2013). Individual differences in non-symbolic numerical abilities predict mathematical achievements but contradict ATOM. *Behavioral and Brain Functions*, *9*(1), 26. doi:10.1186/1744-9081-9-26

Anderson, P. (2002). Assessment and Development of Executive Function (EF) During Childhood. *Child Neuropsychology*, *8*(2), 71-82. doi:10.1076/chin.8.2.71.8724

Ardila, A., Rosselli, M., Matute, E., & Guajardo, S. (2005). The Influence of the Parents Educational Level on the Development of Executive Functions. *Developmental Neuropsychology*, *28*(1), 539-560. doi:10.1207/s15326942dn2801_5

Asato, M. R., Sweeney, J. A., & Luna, B. (2006). Cognitive processes in the development of TOL performance. *Neuropsychologia*, *44*(12), 2259-2269.

Baggaley, A. R. (1955). Concept formation and its relation to cognitive variables. *The Journal of General Psychology*, *52*(2), 297-306.

Barceló, F., & Knight, R. T. (2002). Both random and perseverative errors underlie WCST deficits in prefrontal patients. *Neuropsychologia*, *40*(3), 349-356.

Berch, D. B. (2005). Making Sense of Number Sense. *Journal of Learning Disabilities*, *38*(4), 333-339. doi:10.1177/00222194050380040901

Best, J. R., Miller, P. H., & Jones, L. L. (2009). Executive functions after age 5: Changes and correlates. *Developmental Review, 29*(3), 180-200. doi:10.1016/j.dr.2009.05.002

Best, J. R., & Miller, P. H. (2010). A Developmental Perspective on Executive Function. *Child Development, 81*(6), 1641-1660. doi:10.1111/j.1467-8624.2010.01499.x

Best, J. R., Miller, P. H., & Naglieri, J. A. (2011). Relations between executive function and academic achievement from ages 5 to 17 in a large, representative national sample. *Learning and Individual Differences, 21*(4), 327-336. doi:10.1016/j.lindif.2011.01.007

Bierman, K. L., Nix, R. L., Greenberg, M. T., Blair, C., & Domitrovich, C. E. (2008). Executive functions and school readiness intervention: Impact, moderation, and mediation in the Head Start REDI program. *Development and Psychopathology, 20*(03). doi:10.1017/s0954579408000394

Bilalić, M., McLeod, P., & Gobet, F. (2008). Why good thoughts block better ones: The mechanism of the pernicious Einstellung (set) effect. *Cognition*, *108*(3), 652-661.

Blair, C., & Razza, R. P. (2007). Relating effortful control, executive function, and false belief understanding to emerging math and literacy ability in kindergarten. *Child development*, *78*(2), 647-663.

Bracken, B. A. (1986). Incidence of basic concepts in the directions of five commonly used American tests of intelligence. *School Psychology International*, *7*(1), 1-10.

Brown, A. L., Campione, J. C., Bray, N. W., & Wilcox, B. L. (1973). Keeping track of changing variables: Effects of rehearsal training and rehearsal prevention in normal and retarded adolescents. *Journal of Experimental Psychology, 101*(1), 123-131. doi:10.1037/h0035798

Brydges, C. R., Fox, A. M., Reid, C. L., & Anderson, M. (2014). The differentiation of executive functions in middle and late childhood: A longitudinal latent-variable analysis. *Intelligence, 47*, 34-43. doi:10.1016/j.intell.2014.08.010

Bugden, S., & Ansari, D. (2015). Probing the nature of deficits in the 'Approximate Number System' in children with persistent Developmental Dyscalculia. *Developmental Science, 19*(5), 817-833. doi:10.1111/desc.12324

Bujoreanu, I. S., & Willis, W. G. (2008). Developmental and Neuropsychological Perspectives on the Wisconsin Card Sorting Test in Children. *Developmental Neuropsychology, 33*(5), 584-600. doi:10.1080/87565640802254364

Bull, R., & Scerif, G. (2001). Executive Functioning as a Predictor of Childrens Mathematics Ability: Inhibition, Switching, and Working Memory. *Developmental Neuropsychology, 19*(3), 273-293. doi:10.1207/s15326942dn1903_3

Bull, R., & Lee, K. (2014). Executive Functioning and Mathematics Achievement. *Child Development Perspectives, 8*(1), 36-41. doi:10.1111/cdep.12059

Cantlon, J. F. (2012). Math, monkeys, and the developing brain. *Proceedings of the National Academy of Sciences, 109*(Supplement_1), 10725-10732. doi:10.1073/pnas.1201893109

Cantlon, J. F., & Brannon, E. M. (2006). Shared System for Ordering Small and Large Numbers in Monkeys and Humans. *Psychological Science, 17*(5), 401-406. doi:10.1111/j.1467-9280.2006.01719.x

Cantlon, J. F., Platt, M. L., & Brannon, E. M. (2009). Beyond the number domain. *Trends in Cognitive Sciences, 13*(2), 83-91. doi:10.1016/j.tics.2008.11.007

Carlson, S. M. (2005). Developmentally Sensitive Measures of Executive Function in Preschool Children. *Developmental Neuropsychology, 28*(2), 595-616. doi:10.1207/s15326942dn2802_3

Cartwright, K. B. (2008). *Literacy Processes Cognitive Flexibility in Learning and Teaching*. New York: Guilford Publications.

Channon, S. (1996). Executive dysfunction in depression: The Wisconsin Card Sorting Test. *Journal of Affective Disorders, 39*(2), 107-114. doi:10.1016/0165-0327(96)00027-4

Chelune, G. J., & Baer, R. A. (1986). Developmental norms for the wisconsin card sorting test. *Journal of Clinical and Experimental Neuropsychology, 8*(3), 219-228. doi:10.1080/01688638608401314

Chen, Q., & Li, J. (2014). Association between individual differences in non-symbolic number acuity and math performance: A meta-analysis. *Acta Psychologica, 148*, 163-172. doi:10.1016/j.actpsy.2014.01.016

Chevalier, N., & Blaye, A. (2008). Cognitive flexibility in preschoolers: The role of representation activation and maintenance. *Developmental Science, 11*(3), 339-353. doi:10.1111/j.1467-7687.2008.00679.x

Cinan, S. (2006). Age-related changes in concept formation, rule switching, and perseverative behaviors: A study using WCST with 12 unidimensional target cards. *Cognitive Development,21*(3), 377-382. doi:10.1016/j.cogdev.2006.03.002

Clark, C. A., Pritchard, V. E., & Woodward, L. J. (2010). Preschool executive functioning abilities predict early mathematics achievement. *Developmental Psychology, 46*(5), 1176-1191. doi:10.1037/a0019672

Chu, F. W. (2015). K. vanMarle, DC Geary. *Early numerical foundations of young children's mathematical development, Journal of Experimental Child Psychology*, *132*, 205-212.

Clements, D. H., Sarama, J., & Germeroth, C. (2016). Learning executive function and early mathematics: Directions of causal relations. *Early Childhood Research Quarterly, 36*, 79-90. doi:10.1016/j.ecresq.2015.12.009

Cohen, L. B., & Marks, K. S. (2002). How infants process addition and subtraction events. *Developmental Science, 5*(2), 186-201. doi:10.1111/1467-7687.00220

Colombo, J. (2001). The development of visual attention in infancy. *Annual review of psychology, 52*(1), 337-367.

Conway, A., Waldfogel, J., & Wang, Y. (2018). Parent education and income gradients in children's executive functions at kindergarten entry. *Children and Youth Services Review*, *91*, 329-337.

Cordes, S., & Brannon, E. M. (2009). Crossing the divide: Infants discriminate small from large numerosities. *Developmental Psychology, 45*(6), 1583-1594. doi:10.1037/a0015666

Cragg, L., & Chevalier, N. (2012). The processes underlying flexibility in childhood. *Quarterly Journal of Experimental Psychology, 65*(2), 209-232. doi:10.1080/17470210903204618

Cragg, L., Keeble, S., Richardson, S., Roome, H. E., & Gilmore, C. (2017). Direct and indirect influences of executive functions on mathematics achievement. *Cognition, 162*, 12-26. doi:10.1016/j.cognition.2017.01.014

Crone, E. A., Richard Ridderinkhof, K., Worm, M., Somsen, R. J., & Van Der Molen, M. W. (2004). Switching between spatial stimulus–response mappings: a developmental study of cognitive flexibility. *Developmental science, 7*(4), 443-455.

Crone, E. A., Bunge, S. A., Van Der Molen, M. W., & Ridderinkhof, K. R. (2006). Switching between tasks and responses: A developmental study. *Developmental Science*, *9*(3), 278-287.

Cummings, J. A., & Nelson, R. B. (1980). Basic concepts in the oral directions of group achievement tests. *The Journal of Educational Research*, *73*(5), 259-261.

Dajani, D. R., & Uddin, L. Q. (2015). Demystifying cognitive flexibility: Implications for clinical and developmental neuroscience. *Trends in Neurosciences, 38*(9), 571-578. doi:10.1016/j.tins.2015.07.003

Davidson, M. C., Amso, D., Anderson, L. C., & Diamond, A. (2006). Development of cognitive control and executive functions from 4 to 13 years: Evidence from manipulations of memory, inhibition, and task switching. *Neuropsychologia, 44*(11), 2037-2078. doi:10.1016/j.neuropsychologia.2006.02.006

Dehaene, S., & Cohen, L. (1994). Dissociable mechanisms of subitizing and counting: Neuropsychological evidence from simultanagnosic patients. *Journal of Experimental Psychology: Human Perception and Performance*, *20*(5), 958-975. doi:10.1037/0096-1523.20.5.958

Dewind, N. K., & Brannon, E. M. (2012). Malleability of the approximate number system: Effects of feedback and training. *Frontiers in Human Neuroscience, 6*. doi:10.3389/fnhum.2012.00068

Deák, G. O. (2004). The Development of Cognitive Flexibility and Language Abilities. *Advances in Child Development and Behavior Advances in Child Development and Behavior Volume 31,* 271-327. doi:10.1016/s0065-2407(03)31007-9

Deák, G. O., & Narasimham, G. (2003). Is perseveration caused by inhibition failure? Evidence from preschool children's inferences about word meanings. *Journal of Experimental Child Psychology,86*(3), 194-222. doi:10.1016/j.jecp.2003.08.001

Denny, J. P. (1966). Effects of anxiety and intelligence on concept formation. *Journal of Experimental Psychology*, *72*(4), 596.

Diamond, A. (1988). Abilities and Neural Mechanisms Underlying AB Performance. *Child Development, 59*(2), 523. doi:10.2307/1130330

Diamond, A., Carlson, S. M., & Beck, D. M. (2005). Preschool Childrens Performance in Task Switching on the Dimensional Change Card Sort Task: Separating the Dimensions Aids the Ability to Switch. *Developmental Neuropsychology, 28*(2), 689-729. doi:10.1207/s15326942dn2802_7

Diamond, A. (2013). Executive Functions. *Annual Review of Psychology, 64*(1), 135-168. doi:10.1146/annurev-psych-113011-143750

Dias, N. M., & Seabra, A. G. (2015). Is it possible to promote executive functions in preschoolers? A case study in Brazil. *International Journal of Child Care and Education Policy, 9*(1). doi:10.1186/s40723-015-0010-2

Dillon, D. G., & Pizzagalli, D. A. (2007). Inhibition of action, thought, and emotion: a selective neurobiological review. *Applied and Preventive Psychology*, *12*(3), 99-114

Doebel, S., & Zelazo, P. D. (2015). A meta-analysis of the Dimensional Change Card Sort: Implications for developmental theories and the measurement of executive function in children. *Developmental Review, 38*, 241-268. doi:10.1016/j.dr.2015.09.001

Duncan, G. J., Dowsett, C. J., Claessens, A., Magnuson, K., Huston, A. C., Klebanov, P; & Sexton, H. (2007). School readiness and later achievement. *Developmental psychology*, *43*(6), 1428.

Espy, K. A., Mcdiarmid, M. M., Cwik, M. F., Stalets, M. M., Hamby, A., & Senn, T. E. (2004). The Contribution of Executive Functions to Emergent Mathematic Skills in Preschool Children. *Developmental Neuropsychology, 26*(1), 465-486. doi:10.1207/s15326942dn2601_6

Fazio, L. K., Bailey, D. H., Thompson, C. A., & Siegler, R. S. (2014). Relations of different types of numerical magnitude representations to each other and to mathematics achievement. *Journal of Experimental Child Psychology, 123*, 53-72. doi:10.1016/j.jecp.2014.01.013

Feigenson, L., Dehaene, S., & Spelke, E. (2004). Core systems of number. *Trends in Cognitive Sciences, 8*(7), 307-314. doi:10.1016/j.tics.2004.05.002

Feigenson, L., Libertus, M. E., & Halberda, J. (2013). Links Between the Intuitive Sense of Number and Formal Mathematics Ability. *Child Development Perspectives, 7*(2), 74-79. doi:10.1111/cdep.12019

Figueroa, I. J., & Youmans, R. J. (2013). Failure to maintain set: A measure of distractibility or cognitive flexibility?. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 57, No. 1, pp. 828-832). Sage CA: Los Angeles, CA: Sage Publications.

Fisher, N. J., Deluca, J. W., & Rourke, B. P. (1997). Wisconsin card sorting test and Halstead Category Test performances of children and adolescents who exhibit the syndrome of nonverbal learning disabilities. *Child Neuropsychology, 3*(1), 61-70. doi:10.1080/09297049708401368

Fletcher, J. M., & Taylor, H. G. (1984). Neuropsychological approaches to children: Towards a developmental neuropsychology. *Journal of Clinical Neuropsychology, 6*(1), 39-56.

Frye, D., Zelazo, P. D., & Palfai, T. (1995). Theory of mind and rule-based reasoning. *Cognitive Development*, *10*(4), 483-527. doi:10.1016/0885-2014(95)90024-1.

Garavan, H. (2002). Dissociable Executive Functions in the Dynamic Control of Behavior: Inhibition, Error Detection, and Correction. *NeuroImage, 17*(4), 1820-1829. doi:10.1006/nimg.2002.1326

Garon, N., Bryson, S. E., & Smith, I. M. (2008). Executive function in preschoolers: A review using an integrative framework. *Psychological Bulletin, 134*(1), 31-60. doi:10.1037/0033-2909.134.1.31

Geary, D. C., Hoard, M. K., Nugent, L., & Rouder, J. N. (2015). Individual differences in algebraic cognition: Relation to the approximate number and semantic memory systems. *Journal of Experimental Child Psychology, 140*, 211-227. doi:10.1016/j.jecp.2015.07.010

Gelman, R., & Gallistel, C. (1978). Young children's understanding of numbers. *Cambridge, MA.*

Genet, J. J., Malooly, A. M., & Siemer, M. (2013). Flexibility is not always adaptive: Affective flexibility and inflexibility predict rumination use in everyday life. *Cognition & Emotion, 27*(4), 685-695. doi:10.1080/02699931.2012.733351

Gersten, R., Jordan, N. C., & Flojo, J. R. (2005). Early Identification and Interventions for Students With Mathematics Difficulties. *Journal of Learning Disabilities, 38*(4), 293-304. doi:10.1177/00222194050380040301

Gilmore, C. K., Mccarthy, S. E., & Spelke, E. S. (2010). Non-symbolic arithmetic abilities and mathematics achievement in the first year of formal schooling. *Cognition, 115*(3), 394-406. doi:10.1016/j.cognition.2010.02.002

Gold, J. M. (1997). Auditory Working Memory and Wisconsin Card Sorting Test Performance in Schizophrenia. *Archives of General Psychiatry, 54*(2), 159. doi:10.1001/archpsyc.1997.01830140071013

Goschke, T. (2000). " IA Intentional Reconfiguration and J-TI Involuntary Persistence in Task Set Switching. *Control of cognitive processes: Attention and performance XVIII*, *18*, 331.

Göbel, S. M., Watson, S. E., Lervåg, A., & Hulme, C. (2014). Children's Arithmetic Development. *Psychological Science, 25*(3), 789-798. doi:10.1177/0956797613516471

Grant, D. A., & Curran, J. F. (1952). Relative difficulty of number, form, and color concepts of a Weigl-type problem using unsystematic number cards. *Journal of Experimental Psychology*, *43*(6), 408.

Greve, K. W., Bianchini, K. J., Hartley, S. M., & Adams, D. (1999). The Wisconsin Card Sorting Test in stroke rehabilitation: Factor structure and relationship to outcome. *Archives of Clinical Neuropsychology*, *14*(6), 497-509.

Greve, K. W., Love, J. M., Dickens Jr, T. J., & Williams, M. C. (2000). Developmental changes in california card sorting test performance. *Archives of clinical neuropsychology*, *15*(3), 243-249.

Greve, K. W., Stickle, T. R., Love, J. M., Bianchini, K. J., & Stanford, M. S. (2005). Latent structure of the Wisconsin Card Sorting Test: a confirmatory factor analytic study. *Archives of Clinical Neuropsychology*, *20*(3), 355-364.

Gur, R. C., Richard, J., Hughett, P., Calkins, M. E., Macy, L., Bilker, W. B., ... & Gur, R. E. (2010). A cognitive neuroscience-based computerized battery for efficient measurement of individual differences: standardization and initial construct validation. *Journal of neuroscience methods*, *187*(2), 254-262.

Halberda, J., & Feigenson, L. (2008). Developmental change in the acuity of the "Number Sense": The Approximate Number System in 3-, 4-, 5-, and 6-year-olds and adults. *Developmental psychology*, *44*(5), 1457.

Hanania, R., & Smith, L. B. (2009). Selective attention and attention switching: Towards a unified developmental approach. *Developmental Science, 13*(4), 622-635.

Hannibal, M. A. (1999). Young children's developing understanding of geometric shapes. *Teaching Children Mathematics, 5*(6), 353-358.

Hanson, S. L., & Tucker, D. M. (1992). *Neuropsychological assessment*. Philadelphia: Hanley & Belfus.

Happaney, K., Zelazo, P. D., & Stuss, D. T. (2004). Development of orbitofrontal function: Current themes and future directions. *Brain and Cognition, 55*(1), 1-10. doi:10.1016/j.bandc.2004.01.001

Heaton, R. K. (1981). *A manual for the Wisconsin card sorting test*. Western Psycological Services.

Heaton, R. K., Chelune, G. J., Talley, J. L., Kay, G. G., & Curtiss, G. (1993). *Wisconsin Card Sorting Test (WCST): Manual: Revised and Expanded*. Psychological Assessment Resources (PAR).

Hoof, J. V., Vamvakoussi, X., Dooren, W. V., & Verschaffel, L. (2017). The Transition from Natural to Rational Number Knowledge. *Acquisition of Complex Arithmetic Skills and Higher-Order Mathematics Concepts,* 101-123. doi:10.1016/b978-0-12-805086-6.00005-9

Hughes, C. (1998). Executive function in preschoolers: Links with theory of mind and verbal ability. *British Journal of Developmental Psychology, 16*(2), 233-253. doi:10.1111/j.2044-835x.1998.tb00921.x

Hughes, C., & Ensor, R. (2011). Individual differences in growth in executive function across the transition to school predict externalizing and internalizing behaviors and self-perceived academic success at 6 years of age. *Journal of experimental child psychology, 108*(3), 663-676.

Hund, A. M., & Foster, E. K. (2008). Understanding developmental changes in the stability and flexibility of spatial categories based on object relatedness. *Developmental Psychology, 44*(1), 218-232. doi:10.1037/0012-1649.44.1.218

Hyde, D. C., & Spelke, E. S. (2011). Neural signatures of number processing in human infants: Evidence for two core systems underlying numerical cognition. *Developmental Science, 14*(2), 360-371. doi:10.1111/j.1467-7687.2010.00987.x

Ionescu, T. (2012). Exploring the nature of cognitive flexibility. *New Ideas in Psychology, 30*(2), 190-200. doi:10.1016/j.newideapsych.2011.11.001

Isingrini, M., Angel, L., Fay, S., Taconnat, L., Lemaire, P., & Bouazzaoui, B. (2015). Age-Related Differences in the Reliance on Executive Control in Working Memory: Role of Task Demand. *Plos One, 10*(12). doi:10.1371/journal.pone.0145361

Isquith, P. K., Gioia, G. A., & Espy, K. A. (2004). Executive Function in Preschool Children: Examination Through Everyday Behavior. *Developmental Neuropsychology, 26*(1), 403-422. doi:10.1207/s15326942dn2601_3

Izard, V., Sann, C., Spelke, E. S., & Streri, A. (2009). Newborn infants perceive abstract numbers. *Proceedings of the National Academy of Sciences, 106*(25), 10382-10385. doi:10.1073/pnas.0812142106

Jacques, S., & Zelazo, P. D. (2001). The Flexible Item Selection Task (FIST): A Measure of Executive Function in Preschoolers. *Developmental Neuropsychology, 20*(3), 573-591.doi:10.1207/875656401753549807

Jacques, S., & Zelazo, P. D. (2005). Language and the development of cognitive flexibility: implications for theory of mind. In *Why Language Matters for Theory of Mind, Apr, 2002, University of Toronto, Toronto, ON, Canada; This chapter originated from the aforementioned conference.*. Oxford University Press.

Johnson, S. P., & Hannon, E. E. (2015). Perceptual development. *Handbook of Child Psychology and Developmental Science*, 1-50.

Johnson, M. H., Posner, M. I., & Rothbart, M. K. (1994). Facilitation of Saccades Toward a Covertly Attended Location in Early Infancy. *Psychological Science, 5*(2), 90-93. doi:10.1111/j.1467-9280.1994.tb00636.x

Jordan, N. C., Kaplan, D., Locuniak, M. N., & Ramineni, C. (2007). Predicting First-Grade Math Achievement from Developmental Number Sense Trajectories. *Learning Disabilities Research & Practice, 22*(1), 36-46. doi:10.1111/j.1540-5826.2007.00229.x

Jovanova-Mitkovska, S. (2014). How preschool children learn math?.

Kagan, J. (1966). Reflection-impulsivity: The generality and dynamics of conceptual tempo. *Journal of abnormal psychology*, *71*(1), 17.

Keller, L., & Libertus, M. (2015). Inhibitory control may not explain the link between approximation and math abilities in kindergarteners from middle class families. *Frontiers in Psychology, 6*. doi:10.3389/fpsyg.2015.00685

Kirkham, N. Z., Cruess, L., & Diamond, A. (2003). Helping children apply their knowledge to their behavior on a dimension-switching task. *Developmental Science, 6*(5), 449-467. doi:10.1111/1467-7687.00300

Klenberg, L., Korkman, M., & Lahti-Nuuttila, P. (2001). Differential Development of Attention and Executive Functions in 3- to 12-Year-Old Finnish Children. *Developmental Neuropsychology,20*(1), 407-428. doi:10.1207/s15326942dn2001_6

Kloo, D., & Perner, J. (2005). Disentangling dimensions in the dimensional change card-sorting task. *Developmental Science*, *8*(1), 44-56. doi:10.1111/j.1467-7687.2005.00392.x

Kolkman, M. E., Kroesbergen, E. H., & Leseman, P. P. (2013). Early numerical development and the role of non-symbolic and symbolic skills. *Learning and Instruction, 25*, 95-103. doi:10.1016/j.learninstruc.2012.12.001

Kroesbergen, E., Luit, J. V., Lieshout, E. V., Loosbroek, E. V., & Rijt, B. V. (2009). Individual Differences in Early Numeracy. *Journal of Psychoeducational Assessment, 27*(3), 226-236. doi:10.1177/0734282908330586

Kurtz, M. (2004). The Penn Conditional Exclusion Test: A new measure of executive-function with alternate forms for repeat administration. *Archives of Clinical Neuropsychology, 19*(2), 191-201. doi:10.1016/s0887-6177(03)00003-9

Landerl, K. (2013). Development of numerical processing in children with typical and dyscalculic arithmetic skills—a longitudinal study. *Frontiers in Psychology, 4*. doi:10.3389/fpsyg.2013.00459

Lee, M. D., & Sarnecka, B. W. (2009). A Model of Knower-Level Behavior in Number Concept Development. *Cognitive Science, 34*(1), 51-67. doi:10.1111/j.1551-6709.2009.01063.x

Lehto, J. E., Juujärvi, P., Kooistra, L., & Pulkkinen, L. (2003). Dimensions of executive functioning: Evidence from children. *British Journal of Developmental Psychology,21*(1), 59-80. doi:10.1348/026151003321164627

Lerner, M. D., & Lonigan, C. J. (2014). Executive Function Among Preschool Children: Unitary Versus Distinct Abilities. *Journal of Psychopathology and Behavioral Assessment, 36*(4), 626-639. doi:10.1007/s10862-014-9424-3

Lezak, M.D. (1983). *Neuropsychological assessment*. (2nd ed.). New York: Oxford University Press.

Libertus, M. E., & Brannon, E. M. (2010). Stable individual differences in number discrimination in infancy. *Developmental Science, 13*(6), 900-906. doi:10.1111/j.1467-7687.2009.00948.x

Libertus, M. E., Feigenson, L., & Halberda, J. (2011). Preschool acuity of the approximate number system correlates with school math ability. *Developmental Science, 14*(6), 1292-1300. doi:10.1111/j.1467-7687.2011.01080.x

Macario, J. F. (1991). Young childrens use of color in classification: Foods and canonically colored objects. *Cognitive Development, 6*(1), 17-46. doi:10.1016/0885-2014(91)90004-w

Maruish, M. E., & Moses, J. A. (2013). *Clinical neuropsychology: Theoretical foundations for practitioners*. Psychology Press.

Mazzocco, M. M., Feigenson, L., & Halberda, J. (2011). Preschoolers Precision of the Approximate Number System Predicts Later School Mathematics Performance. *PLoS ONE, 6*(9). doi:10.1371/journal.pone.0023749

Mcclelland, M. M., Acock, A. C., & Morrison, F. J. (2006). The impact of kindergarten learning-related skills on academic trajectories at the end of elementary school. *Early Childhood Research Quarterly, 21*(4), 471-490. doi:10.1016/j.ecresq.2006.09.003

Mcclelland, M. M., Cameron, C. E., Connor, C. M., Farris, C. L., Jewkes, A. M., & Morrison, F. J. (2007). Links between behavioral regulation and preschoolers literacy, vocabulary, and math skills. *Developmental Psychology, 43*(4), 947-959. doi:10.1037/0012-1649.43.4.947

Mccrink, K., & Wynn, K. (2004). Large-Number Addition and Subtraction by 9-Month-Old Infants. *Psychological Science, 15*(11), 776-781. doi:10.1111/j.0956-7976.2004.00755.x

Mccrink, K., & Wynn, K. (2007). Ratio Abstraction by 6-Month-Old Infants. *Psychological Science,18*(8), 740-745. doi:10.1111/j.1467-9280.2007.01969.x

Mcintosh, D. E., Wayland, S. J., Gridley, B., & Barnes, L. L. (1995). The relationship between the Bracken Basic Concept Scale and the Differential Ability Scales with a preschool sample. Journal of Psychoeducational Assessment, 13(1), 39-48.

Miller, E. K., & Cohen, J. D. (2001). An Integrative Theory of Prefrontal Cortex Function. *Annual Review of Neuroscience, 24*(1), 167-202. doi:10.1146/annurev.neuro.24.1.167

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The Unity and Diversity of Executive Functions and Their Contributions to Complex “Frontal Lobe” Tasks: A Latent Variable Analysis. *Cognitive Psychology, 41*(1), 49-100. doi:10.1006/cogp.1999.0734

Munakata, Y., Snyder, H. R., & Chatham, C. H. (2012). Developing Cognitive Control. *Current Directions in Psychological Science, 21*(2), 71-77. doi:10.1177/0963721412436807

Noble, K. G., Houston, S. M., Brito, N. H., Bartsch, H., Kan, E., Kuperman, J. M., ... & Schork, N. J. (2015). Family income, parental education and brain structure in children and adolescents. Nature neuroscience, 18(5), 773.

Negen, J., & Sarnecka, B. W. (2012). Number-Concept Acquisition and General Vocabulary Development. *Child Development, 83*(6), 2019-2027. doi:10.1111/j.1467-8624.2012.01815.x

Nielsen, M., & Dissanayake, C. (2004). Pretend play, mirror self-recognition and imitation: A longitudinal investigation through the second year. *Infant Behavior and Development, 27*(3), 342-365. doi:10.1016/j.infbeh.2003.12.006

Önkol, F. L. (2012). Erken sayı testi’nin uyarlanması ve erken sayı gelişim programı’nın altı yaş çocukların sayı gelişimlerine etkisinin incelenmesi. *Yayınlanmamış doktora tezi, Marmara Üniversitesi Eğitim Bilimleri Enstitüsü, İstanbul*.

Panter, J. E. (2000). Validity of the Bracken Basic Concept Scale-Revised for predicting performance on the metropolitan readiness test. *Journal of Psychoeducational Assessment*, *18*(2), 104-110.

Perrine, K. (1993). Differential aspects of conceptual processing in the Category Test and Wisconsin Card Sorting Test. *Journal of Clinical and Experimental Neuropsychology*, *15*(4), 461-473.

Pennington, B. F. (1997). Dimensions of executive functions in normal and abnormal development.

Piaget, J., & Cook, M. T. (1952). The origins of intelligence in children.

Piaget, J. (1953). How children form mathematical concepts. *Scientific American*, *189*(5), 74-79.

Piaget, J. (2013). Childs Conception of Number. doi:10.4324/9781315006222

Piazza, M., Pica, P., Izard, V., Spelke, E. S., & Dehaene, S. (2013). Education Enhances the Acuity of the Nonverbal Approximate Number System. *Psychological Science*, *24*(6), 1037-1043. doi:10.1177/0956797612464057

Pinheiro-Chagas, P., Wood, G., Knops, A., Krinzinger, H., Lonnemann, J., Starling-Alves, I., Haase, V. G. (2014). In How Many Ways is the Approximate Number System Associated with Exact Calculation? *PLoS ONE, 9*(11). doi:10.1371/journal.pone.0111155

Prevor, M. B., & Diamond, A. (2005). Color–object interference in young children: A Stroop effect in children 3½–6½ years old. *Cognitive Development, 20*(2), 256-278. doi:10.1016/j.cogdev.2005.04.001

Purpura, D. J., Schmitt, S. A., & Ganley, C. M. (2017). Foundations of mathematics and literacy: The role of executive functioning components. *Journal of Experimental Child Psychology, 153*, 15-34. doi:10.1016/j.jecp.2016.08.010

Ravizza, S. M., & Carter, C. S. (2008). Shifting set about task switching: Behavioral and neural evidence for distinct forms of cognitive flexibility. *Neuropsychologia, 46*(12), 2924-2935. doi:10.1016/j.neuropsychologia.2008.06.006

Rinsky, J. R., & Hinshaw, S. P. (2011). Linkages between childhood executive functioning and adolescent social functioning and psychopathology in girls with ADHD. *Child Neuropsychology,17*(4), 368-390. doi:10.1080/09297049.2010.544649

Roebers, C. M., Cimeli, P., Röthlisberger, M., & Neuenschwander, R. (2012). Executive functioning, metacognition, and self-perceived competence in elementary school children: an explorative study on their interrelations and their role for school achievement. *Metacognition and Learning*, *7*(3), 151-173.

Ropovik, I. (2014). Do executive functions predict the ability to learn problem-solving principles? *Intelligence, 44,* 64-74. doi:10.1016/j.intell.2014.03.002

Rosselli, M., & Ardila, A. (1993). Developmental norms for the wisconsin card sorting test in 5-to 12-year-old children. *Clinical Neuropsychologist, 7*(2), 145-154. doi:10.1080/13854049308401516

Rougier, N. P., Noelle, D. C., Braver, T. S., Cohen, J. D., & O'Reilly, R. C. (2005). Prefrontal cortex and flexible cognitive control: Rules without symbols. *Proceedings of the National Academy of Sciences*, *102*(20), 7338-7343.

Ruff, H. A., & Rothbart, M. K. (1996). *Attention in early development: Themes and variations*. Oxford: Oxford University Press.

Rybakowski, J. K., Borkowska, A., Skibinska, M., & Hauser, J. (2005). Illness-specific association of val66met BDNF polymorphism with performance on Wisconsin Card Sorting Test in bipolar mood disorder. *Molecular Psychiatry, 11*(2), 122-124. doi:10.1038/sj.mp.4001765

Sandhofer, C. M., & Smith, L. B. (2001). Why children learn color and size words so differently: Evidence from adults' learning of artificial terms. *Journal of experimental psychology: General*, *130*(4), 600.

Sarnecka, B. (2004). Six does not just mean a lot: Preschoolers see number words as specific. *Cognition*, *92*(3), 329-352. doi:10.1016/j.cognition.2003.10.001

Sarnecka, B. W., Goldman, M. C., & Slusser, E. B. (2014). How Counting Leads to Children's First Representations of Exact, Large Numbers. *Oxford Handbooks Online*. doi:10.1093/oxfordhb/9780199642342.013.011

Sasanguie, D., Göbel, S. M., Moll, K., Smets, K., & Reynvoet, B. (2013). Approximate number sense, symbolic number processing, or number–space mappings: What underlies mathematics achievement? *Journal of Experimental Child Psychology*, *114*(3), 418-431. doi:10.1016/j.jecp.2012.10.012

Sasanguie, D., Defever, E., & Reynvoet, B. (2013). The approximate number system is not predictive for symbolic number processing in kindergartners. *PsycEXTRA Dataset*. doi:10.1037/e636952013-045

Seidman, L. J., Biederman, J., Monuteaux, M. C., Valera, E., Doyle, A. E., & Faraone, S. V. (2005). Impact of gender and age on executive functioning: do girls and boys with and without attention deficit hyperactivity disorder differ neuropsychologically in preteen and teenage years?. *Developmental neuropsychology*, *27*(1), 79-105.

Senturk, N., Yeniceri, N., Alp, I. E., & Altan-Atalay, A. (2013). An Exploratory Study on the Junior Brixton Spatial Rule Attainment Test in 6- to 8-Year-Olds. *Journal of Psychoeducational Assessment, 32*(2), 123-132. doi:10.1177/0734282913490917

Singh, S., Aich, T. K., & Bhattarai, R. (2017). Wisconsin Card Sorting Test performance impairment in schizophrenia: An Indian study report. *Indian journal of psychiatry*, *59*(1), 88

Smith, L. B., & Heise, D. (1992). Perceptual similarity and conceptual structure. In *Advances in psychology* (Vol. 93, pp. 233-272). North-Holland.

Snyder, H. R., Miyake, A., & Hankin, B. L. (2015). Advancing understanding of executive function impairments and psychopathology: Bridging the gap between clinical and cognitive approaches. *Frontiers in Psychology, 6*. doi:10.3389/fpsyg.2015.00328

Sousa, D. A. (2014). *How the brain learns mathematics*. Corwin Press.

Stancher, G., Rugani, R., Regolin, L., & Vallortigara, G. (2014). Numerical discrimination by frogs (Bombina orientalis). *Animal Cognition, 18*(1), 219-229.

Starr, A., Libertus, M. E., & Brannon, E. M. (2013). Number sense in infancy predicts mathematical abilities in childhood. *Proceedings of the National Academy of Sciences, 110*(45), 18116-18120. doi:10.1073/pnas.1302751110

Strauss, E., Sherman, E. M., Spreen, O., & Spreen, O. (2006). *A compendium of neuropsychological tests: Administration, norms, and commentary*. Oxford: Oxford University Press.

Stuss, D. T. (2006). Frontal lobes and attention: processes and networks, fractionation and integration. *Journal of the International Neuropsychological Society*, *12*(2), 261-271.

Stuss, D. T., & Levine, B. (2002). Adult Clinical Neuropsychology: Lessons from Studies of the Frontal Lobes. *Annual Review of Psychology, 53*(1), 401-433. doi:10.1146/annurev.psych.53.100901.135220

Su, C. Y., Lin, Y. H., Kwan, A. L., & Guo, N. W. (2008). Construct validity of the Wisconsin Card Sorting Test-64 in patients with stroke. *The Clinical Neuropsychologist*, *22*(2), 273-287.

Sulik, M. J., Blair, C., Mills-Koonce, R., Berry, D., & Greenberg, M. (2015). Early Parenting and the Development of Externalizing Behavior Problems: Longitudinal Mediation Through Childrens Executive Function. *Child Development, 86*(5), 1588-1603. doi:10.1111/cdev.12386

Szkudlarek, E., & Brannon, E. M. (2017). Does the Approximate Number System Serve as a Foundation for Symbolic Mathematics? *Language Learning and Development, 13*(2), 171-190. doi:10.1080/15475441.2016.1263573

Şirin, S. (2011). Anaokuluna devam eden beş yaş grubu çocuklara sayı ve işlem kavramlarını kazandırmada oyun yönteminin etkisi. *Uludağ University, Bursa*.

Taatgen, N. A., Huss, D., Dickison, D., & Anderson, J. R. (2008). The acquisition of robust and flexible cognitive skills. *Journal of Experimental Psychology: General, 137*(3), 548-565. doi:10.1037/0096-3445.137.3.548

Taguchi, F. Y. (2014). Possible Protective Effect of Regulatory T cells on White Matter Microstructural Abnormalities in Stroke Patients. *Journal of Clinical & Cellular Immunology,05*(03). doi:10.4172/2155-9899.1000221

Tall, D., & Dehaene, S. (1998). The Number Sense: How the Mind Creates Mathematics. *The Mathematical Gazette, 82*(495), 528. doi:10.2307/3619925

van der Sluis, S., de Jong, P. F., & van der Leij, A. (2007). Executive functioning in children, and its relations with reasoning, reading, and arithmetic. *Intelligence*, *35*(5), 427-449.

Verdine, B. N., Irwin, C. M., Golinkoff, R. M., & Hirsh-Pasek, K. (2014). Contributions of executive function and spatial skills to preschool mathematics achievement. *Journal of Experimental Child Psychology, 126*, 37-51. doi:10.1016/j.jecp.2014.02.012

Vygotsky, L. S. (1964). Thought and language. *Annals of Dyslexia*, *14*(1), 97-98.

Wallis, J. D., Anderson, K. C., & Miller, E. K. (2001). Single neurons in prefrontal cortex encode abstract rules. *Nature*, *411*(6840), 953.

Wecker, N. S., Kramer, J. H., Hallam, B. J., & Delis, D. C. (2005). Mental Flexibility: Age Effects on Switching. *Neuropsychology, 19*(3), 345-352. doi:10.1037/0894-4105.19.3.345

Welsh, M. C., Pennington, B. F., & Groisser, D. B. (1991). A normative-developmental study of executive function: A window on prefrontal function in children. *Developmental Neuropsychology,7*(2), 131-149. doi:10.1080/87565649109540483

Wiebe, S. A., Sheffield, T., Nelson, J. M., Clark, C. A., Chevalier, N., & Espy, K. A. (2011). The structure of executive function in 3-year-olds. *Journal of Experimental Child Psychology*, *108*(3), 436-452. doi:10.1016/j.jecp.2010.08.008

Willcutt, E. G., Doyle, A. E., Nigg, J. T., Faraone, S. V., & Pennington, B. F. (2005). Validity of the Executive Function Theory of Attention-Deficit/Hyperactivity Disorder: A Meta-Analytic Review. *Biological Psychiatry*, *57*(11), 1336-1346. doi:10.1016/j.biopsych.2005.02.006

Wynn, K. (1992). Erratum: Addition and subtraction by human infants. *Nature*, *360*(6406), 768-768. doi:10.1038/360768b0

Yalçın, K., & Karakaş, S. (2007). Wisconsin kart eşleme testi performansında gelişimin niceliksel ve niteliksel etkileri. *Çocuk ve gençlik ruh sağlığı dergisi*, *14*(1), 24-32.

Yalım, N. (2009). *5-6 yaş çocuklarında matemetiksel şekil algısı ve sayı kavramının gelişiminde drama yönteminin etkisi* (Doctoral dissertation, Selçuk Üniversitesi Sosyal Bilimleri Enstitüsü).

Xu, F., & Spelke, E. S. (2000). Large number discrimination in 6-month-old infants. *Cognition*, *74*(1). doi:10.1016/s0010-0277(99)00066-9

Yeniceri, N., & Altan-Atalay, A. (2011). Age-Related Changes in the Wisconsin Card Sorting Test Performances of 8- to 11-Year-Old Turkish Children. *The Clinical Neuropsychologist, 25*(7), 1179-1192. doi:10.1080/13854046.2011.613855

Zelazo, P. D., & Müller, U. (2002). Executive function in typical and atypical development. *Blackwell handbook of childhood cognitive development*, 445-469

Zelazo, P. D., Frye, D., & Rapus, T. (1996). An age-related dissociation between knowing rules and using them. *Cognitive Development, 11*(1), 37-63. doi:10.1016/s0885-2014(96)90027-1

Zelazo, P. D., & Frye, D. (1998). Cognitive Complexity and Control. *Current Directions in Psychological Science*, *7*(4), 121-126. doi:10.1111/1467-8721.ep10774761

Zelazo, P. D., & Carlson, S. M. (2012). Hot and Cool Executive Function in Childhood and Adolescence: Development and Plasticity. *Child Development Perspectives*. doi:10.1111/j.1750-8606.2012.00246.x

Zelazo, P. D., Müller, U., Frye, D., & Marcovitch, S. (2003). The development of executive function in early childhood. Monographs of the Society for Research in Child Development, 68(3, Serial No. 274).

APPENDICES

APPENDIX A

Informed Consent Form

AYDINLATILMIŞ ONAM FORMU

Sayın Veli,

Koç Üniversitesi Psikoloji Bölümü öğretim üyesi Ayşe Altan Atalay ve tez öğrencisi Meryem Söğüt tarafından "sayı bilgisi ve yönetsel beceriler" konusunda yürütülen araştırmaya çocuğunuzun katılımı rica olunmaktadır. Bu çalışmada katılımınız tamamen gönüllülük esasına dayanır. Lütfen aşağıdaki bilgileri okuyunuz ve katılmaya karar vermeden önce anlamadığınız her hangi bir şey varsa çekinmeden sorunuz.

ÇALIŞMANIN ADI: Sayı Bilgisi ve Yönetsel Beceriler Arasındaki İlişkinin 5-8 Yaş Grubu Çocuklarında İncelenmesi

ÇALIŞMANIN AMACI

Bu çalışmanın amacı, okul öncesi ve okul çağındaki çocukların sayı bilgisi ve yönetsel becerileri arasındaki ilişkiyi araştırmaktır.

PROSEDÜRLER

Bu çalışmaya gönüllü katılmak istemeniz halinde yürütülecek çalışmalar şöyledir;

Söz konusu çalışma için zihinsel esneklik ve soyut düşünebilme testleri olan Wisconsin Kart Eşleme Testi ve Penn Durumsal Ret Testi kullanılacaktır. Bu testlere ilave olarak, sayı bilgisini ölçmek için Erken Sayı Testi uygulanacaktır. Okul müdürlüğünüzün uygun bulduğu saatler içerisinde yürütülecek olan çalışmada testler eğitilmiş araştırmacılar tarafından öğrencilere teker teker uygulanacaktır. Testlerin tümünün tamamlanması her çocukla yaklaşık 60 dakika sürmektedir.

OLASI RİSKLER VE RAHATSIZLIKLAR

Söz konusu ölçeklerin çocuklar üzerinde olumsuz bir etkisi yoktur.

TOPLUMA VE/VEYA DENEKLERE OLASI FAYDALARI

Bu çalışmanın amacı, çalışmaya katılan Türk çocuklarındaki sayı bilgisinin gelişimsel sürecinin ve bu sürecin yönetsel becerilere katkısının tanımlanmasıdır.

GİZLİLİK

Bu çalışmayla bağlantılı olarak elde edilen ve sizinle özdeşleşmiş her bilgi gizli kalacak, 3. kişilerle paylaşılmayacak ve yalnızca sizin izniniz ile ifşa edilecektir. Gizlilik tanımlanmış bir kodlama prosedürüyle sağlanacak ve kod çözümüne erişim yalnızca çalışmanın sorumlusu araştırmacıyla sınırlı kalacak ve diğer araştırmacılara açık olmayacaktır. Tüm veriler, sınırlı erişime sahip güvenli ve şifreli bir veritabanında tutulacaktır.

KATILIM VE AYRILMA

Bu çalışmanın içinde olmak isteyip istemediğinize tamamı ile bağımsız ve etki altında kalmadan karar verebilirsiniz. Araştırmaya yalnızca velisinin izni olan öğrencilerin alınacağını belirtir, çocuğunuzun katılımı için izninizi rica ederim. Bu çalışmaya gönüllü olarak katılmaya karar vermeniz halinde dahi, sahip olduğunuz her hangi bir hakkı kaybetmeden veya herhangi bir cezaya maruz kalmadan istediğiniz zaman çekilebilirsiniz. Çalışmadan çekilmek isterseniz bir cezası yoktur ve sahip olduğunuz faydaları kaybetmezsiniz.

ARAŞTIRMACILARIN KİMLİĞİ

Bu araştırma ile ilgili herhangi bir sorunuz veya endişeniz varsa, lütfen iletişime geçiniz:

Meryem Söğüt

Koç Üniversitesi

Psikoloji Bölümü

E: msogut16@ku.edu.tr

Yukarıda açıklanan prosedürleri anladım. Sorularım tatmin olacağım şekilde yanıtlandı ve dilediğim zaman ayrılma hakkım saklı kalmak koşulu ile bu çalışmaya katılmayı onaylıyorum. Bu formun bir kopyası da bana verildi.

____

Veli Kodu

____________________________________ ______________________

Veli İmzası Tarih

____________________________________ ______________________

Araştırmacının İmzası Tarih

APPENDIX B

Demographic Information Form

DEMOGRAFİK BİLGİ FORMU

ÇOCUĞUNUZUN İSMİ____

ÇOCUĞUNUZUN DOĞUM TARİHİ (gün/ay/yıl)________________________________

VELİNİN YAKINLIK DERECESİ (anne, baba, vs.) ______________________________

Annenin mesleğini yazınız:____

Annenin eğitim seviyesini işaretleyiniz:

a) Lisansüstü (yüksek lisans ve/veya doktora) b) Üniversite mezunu c) Lise mezunu

d) ilköğretim mezunu e) Okuryazar

Babanın mesleğini yazınız:____

Babanın eğitim düzeyini işaretleyiniz:

a) Lisansüstü (yüksek lisans ve/veya doktora) b) Üniversite mezunu c) Lise mezunu

d) ilköğretim mezunu e) Okuryazar

Çocuğun bakımını kim sağlamaktadır? (Bakıcı, anneanne, babaanne, vs.)_________________

Ailedeki çocuk sayısı kaçtır? _____________

Evinizde kimler yaşamaktadır? (çekirdek aile yahut dede, hala, vs.)_____________________

Evinizdeki ortamı nasıl değerlendirirsiniz? (sakin, yoğun, kalabalık vs.)

Çocuğunuzla evde oyun oynar mısınız?____

Cevabınız evetse, ne gibi oyunlar

oynarsınız?_______________________________________

Çocuğunuzun belirtmek istediğiniz bir sağlık sorunu var mı?

Çocuğunuzda renk körlüğü var mı?

APPENDIX C

Early Numeracy Test

Versiyon A için Yönerge Açıklamaları

Kavramların Karşılaştırılması

Materyal: Yok

YÖNERGE A1: Burada mantarlar görüyorsun. Hangi mantarın bu çiçekten daha uzun olduğunu gösterebilir misin?

YÖNERGE A2. Burada tahtalar var. Bu tahtan daha kısa olan tahtayı işaretle. (Sayfanın sol üstünde kare içerisindeki tahtayı gösteriniz.)

YÖNERGE A3: Burada adamlar görüyorsun. Hangi adam bu adamdan daha şişmandır? (gösterebilir misin?)

YÖNERGE A4: Burada Kızılderililer var (görüyorsun). Elinde yay ve ok olan Kızılderililin başındaki tüylerden daha az tüyü olan Kızılderili'yi gösterebilir misin?

YÖNERGE A5: Burada birbirine benzeyen kediler görüyorsun. Buradaki kedilerin içinde en az bıyığı olan kediyi gösterebilir misin?

Sınıflandırma

Materyal: Yok

YÖNERGE A6: Resimde bir balık, bir inek, bir yunus ve bir köpek balığı var (görüyorsun). Sence bunlardan kaç tanesi yüzebilir onları bana gösterir misin? (balık, yunus ve köpek balığı)

YÖNERGE A7: Buradaki adamlara bak. Sakalı olmayan adamları gösterir misin?

YÖNERGE A8.Buradaki resimlere bak. Resimlerden 5'li olmayanları bana gösterir misin? (3-7).

YÖNERGE A9: Bu resimde içinde 8 çiçek olan bir vazo görüyorsun. Resimlere bakıp bana içinde 8 tane çiçek olan diğer vazoları da göstere bilir misin? (f-g)

YÖNERGE A10: Bu resimde 10 noktası olan yeşil saplı bir şemsiye var (görüyorsun). Diğer şemsiyelerin içinden, bu resimdeki ile tamamen aynı olan şemsiyeleri bana göstermeni istiyorum. (b-d)

Eşleştirme

Materyal: Yönerge 11 ve 15 için bloklar, yönerge 13 ve 14 için iki çalışma sayfası ve bir kurşunkalem.

YÖNERGE A11: Çocuğa 10 blok verilir. Buraya bir zar atılmış ve “4” gelmiş. Elindeki blokların içinden aynı sayıda bloğu buraya koyabilir misin? (ayırabilir misin?).

YÖNERGE A12: Burada 3 tane otobüs görüyorsun. (Uygulayıcı sayfanın sol üstündeki kareyi gösterir.) Otobüslerin sayısı kadar noktası olan kutuyu işaretler misin?

YÖNERGE A13: Çocuğa bir çalışma sayfası ve bir kurşun kalem verilir. Burada mum ve mumluklar (şamdan) görüyorsun. Mumların mumlukların (şamdanların) içine koyulması gerekiyor. Hangi mum, hangi mumluğun içine koyulmalı, çizgilerle çizerek gösterebilir misin?

YÖNERGE A14: Çocuğa bir çalışma sayfası ve bir kurşun kalem verilir. Burada tavuklar ve yumurtalar görüyorsun. Her tavuğun altına bir yumurta gelen resmi bulup, çizgilerle çizebilir misin? (birleştirebilir misin?)

YÖNERGE A15: burada bir abaküs görüyorsun. (Elinizle resmi gösterin ve elinizi resmin üzerinde gezdirin). Sonra masaya 20 adet piyon koyun, ve abaküsteki kadar piyonu ayırmasını isteyin(piyonları nasıl koyduğu önemli değil. Abaküsteki sıra ile aynı olması gerekmiyor. 17 piyonu ayırması yeterli)

Serileme

Materyal: Yönerge 18 için bir çalışma sayfası ve bir kurşun kalem verilir.

YÖNERGE A16: Buradaki kutuların içinde elmalar görüyorsun. Hangi kutuda elmalar büyükten küçüğe doğru sıralanmış. Gösterebilir misin?

YÖNERGE A17: Burada sayılar görüyorsun. Bu sayıları 1'den başlayarak doğru bir şekilde sıralayabilir misin? (bunu bir kere de yapması gerekli).

YÖNERGE A18: Çocuğa bir çalışma sayfası ve bir kurşun kalem verilir. Burada ayakta duran insanlar ve ekmek dilimleri görüyorsun. En uzun boylu olan daha fazla dilimli ekmeği, en küçük olanda en az dilimli ekmeği yiyecek. Bu insanların yiyecekleri ekmekleri çizgiler çizerek gösterebilir misin?

YÖNERGE A19: Bu kutularda bazı eşyalar görüyorsun. Bu kutulardaki eşyalardan hangileri hafiften ağıra doğru sıralanmıştır.

YÖNERGE A20: Burada bir futbol topu görüyorsun. Bu top ile dört arkadaş futbol oynuyorlar ve gol atıyorlar. Oyunculardan Emre 2 gol attı, Hakan 3 gol attı, Arda 4 gol attı ve Ali 5 gol attı. Burada gördüğün sayılardan hangisi gol sırasını doğru göstermektedir?

Sayı Sayma

Materyal: Yok

YÖNERGE A 21: "20" ye kadar sayar mısın?

YÖNERGE A22: Çocuğa resim gösterilir ve 15. Yılanı göstermesi istenir.

YÖNERGE A23: "Birden başlayarak, 2'şer 2'şer 19'a kadar sayar mısın? Uygulayıcı 1-3-5 diyerek çocuğa ipucu verir.

YÖNERGE A 24: Bana buradaki "18." Laleyi gösterir misin?

YÖNERGE A 25: "14" ten geriye 2'şer 2'şer sayar mısın? Çocuğa kolaylık olması açısından uygulayıcı "ondört ", "oniki", "on", "sekiz", "altı" diye saymayı başlatabilir.

YÖNERGE A25: Şimdi sana bir resim göstereceğim. Bu resme kısa bir süre dikkatle bakmanı istiyorum.(resim 2 saniye gösterilir ve kaldırılır) Zarın üzerinde kaç (tane) nokta vardı?

Yapısal Sayma (Eşzamanlı sayma ve kısaltılmış sayma)

Materyal: 27. ve 30. Yönergeler için bloklar

YÖNERGE A26: Şimdi sana bir resim göstereceğim. Bu resme kısa bir süre dikkatle bakmanı istiyorum.(resim 2 saniye gösterilir ve kaldırılır) Zarın üzerinde kaç (tane) nokta vardı?

YÖNERGE A 27: Aralarında az mesafeler olan "8" blok masa üzerinde bir daire içine konulur. Bu blokları sayar mısın? (çocukların sayarken blokları ayırmasına veya göstererek saymasına izin verilir.)

YÖNERGE A28: Başparmaklar saklanarak 8 parmak masa üzerine konulur. Çocuktan ellerimize dikkatlice bakması istenir ve 2 saniye süre sonra eller masadan kaldırılır. Çocuğa kaç parmak sayabildin? diye sorulur.

YÖNERGE A29: Burada 6 adet 2'li zar grubu görüyorsun. bu zar gruplarından hangisinde "10 nokta" vardır? (e)

YÖNERGE A30: Aralarında az mesafeler olan "20" blok dizilerek masaya konulur. Burada kaç blok olduğunu söyleyebilir misin? (Çocukların göstererek saymasına izin verilir).

Sonuçsal Sayma

Materyal: 31- 33- 34- 35. yönergeler için bloklar kullanılır.

YÖNERGE A31: Masaya 3 adet blok konulur ve Burada "3" blok var denir. Bu blokları elimin altına itiyorum diyerek üzeri elimiz ile kapatılır. (sonra "3" bloğu elinin altına doğru iter ve bunu yaparken çocuklara gösterir). Elimin altına "2" blok daha ekledim. Elimin altında kaç tane blok var? (oldu) (5)

YÖNERGE A32: Burada 1'den 10'a kadar dizilmiş kartlara bakmanı istiyorum.(Çocuktan kartlara aşağıdan yukarıya doğru, sıra ile bakması istenir ve sonra kartlar kaldırılır.) bu kartlardan biri eksikti, eksik olan kartı fark edebildin mi? (4)

YÖNERGE A33: çocuğa "15" adet blok verilir ve çocuktan bu piyonlardan "11" tanesini sıralaması istenir.(nasıl sıralandığının önemi yok).

YÖNERGE A34: Aralarında küçük mesafeler olan "9" blok masa üzerinde bir daire içine konulur. Bu blokları sayar mısın? (çocukların göstererek saymasına izin verilmez)

YÖNERGE A35: Aralarında az mesafe olacak şekilde masaya "14" blok konulur. Bu bloklardan 5 tanesini alsam (çıkarsam) geriye kaç blok kalır?

<u>Genel Sayı Bilgisi</u>

Materyal: Yok

YÖNERGE A36: Burada "2" kutu görüyorsun. Siyah kutunun içinde "onsekiz" şeker var. Beyaz kutunun içinde "onaltı" şeker var. Hangi kutunun içindeki şeker daha az? (B)

YÖNERGE A37: Burada "13 " ve "15" rakamlarını görüyorsun. Bu rakamların arasına aşağıda gördüğün rakamlardan hangisi girmelidir?

YÖNERGE A38: Resimdeki zar gösterilerek, "Bu bir zar, sen bu zarları atıyorsun" denir ve iki zar gösterilir. Şimdi bak attığın zarların üzerinde kaç tane nokta var ve sen piyonunu nereye koymalısın?

YÖNERGE A39: Dokuzlu ve yedi noktalı resim gösterilir. Yedi ve dokuz arasında kaç tane nokta olmalıdır? Doğru noktaları olan kutuyu bana gösterir misin?

YÖNERGE A40: burada 12 kek var (görüyorsun). Bu keklerin "7" tanesi yesem geriye kaç kek kalır?ı Buradaki kek resimlerinden hangisi kalan kekleri gösterir söyler misin?

<u>Tahmin Etme</u> Sol üst köşedeki rakam gösterilerek " bu sayıyı görüyor musun? Bana kaç olduğunu söyleyebilir misin? – eğer çocuk doğru cevabı verirse – peki şimdi, bu sayı gördüğün çubuk üzerinde hangi tarafa yakın olmalı ve sence sayı bu çubuk üzerinde nerde durmalı?

(Yönerge tüm sorular için aynı. Çocuk sol üstteki sayıyı doğru bilemezse diğer soruya geçilir.)

YÖNERGE A41:

YÖNERGE A42:

YÖNERGE A43:

YÖNERGE A44:

YÖNERGE A45: