INVESTIGATING THE RELATIONSHIP BETWEEN EXECUTIVE FUNCTIONS AND PATTERNING KNOWLEDGE IN CHILDREN AGED 4 TO 7 YEARS

BURCU ŞANLI KARMAZ

BOĞAZİÇİ UNIVERSITY

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Burcu Şanlı Karmaz

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DECLARATION OF ORIGINALITY

I, Burcu Şanlı Karmaz, certify that

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ABSTRACT

Investigating the Relationship between Executive Functions and Patterning Knowledge in Children Aged 4 to 7 Years

This study aimed to investigate to what extent executive functions (cognitive flexibility, working memory, and inhibitory control) predict patterning knowledge in children aged 4 to 7 years, with and without considering their ages. The sample comprised 50 children and their parents who volunteered from different provinces of Turkey. The participants, involving 30 girls and 20 boys, ranged in age from 47 to 83 months, with an average age of 66.36 months. Four measures were used in the study, including an online Early Patterning Assessment scale, the Dimensional Change Card Sort (DCCS) test, the Childhood Executive Functioning Inventory (CHEXI) parent form, and a post-study survey. A hierarchical multiple regression analysis was conducted with age, cognitive flexibility, and working memory variables, which were significantly associated with patterning knowledge. The age of children was the variable that most strongly predicted patterning knowledge. In addition, cognitive flexibility had a higher role in patterning when considered with age, whereas it had a much less role regardless of age. However, working memory did not predict patterning knowledge. This study provided valuable insights by investigating the role of executive functions in patterning knowledge and suggesting that a significant proportion of the contribution of executive functions to patterning knowledge is age dependent.

ÖZET

4-7 Yaş Arası Çocuklarda Yürütücü İşlevler ve Örüntü Oluşturma Bilgisi Arasındaki İlişkinin İncelenmesi

Bu çalışmanın amacı 4-7 yaş arası çocukların yürütücü işlevlerinin (bilişsel esneklik, çalışma belleği ve engelleyici kontrol), yaş kontrol edildiğinde ve edilmediğinde, örüntü oluşturma bilgisi üzerindeki rolünü araştırmaktır. Örneklem, Türkiye'nin farklı illerinden gönüllü olan 50 çocuk ve ebeveynlerinden oluşmaktadır. Yaşları 47 ile 83 ay arasında değişen katılımcıların 30'u kız, 20'si erkektir ve yaş ortalaması 66,36 aydır. Çalışmada, çevrimiçi Erken Çocuklukta Örüntü Değerlendirme ölçeği, Boyut Değiştirerek Kart Eşleme (BDKE) testi, Çocukluk Dönemi Yönetici İşlev Envanteri (CHEXI) ebeveyn formu ve çalışma sonrası anket olmak üzere dört adet ölçme aracı kullanılmıştır. Örüntü oluşturma bilgisi ile anlamlı şekilde ilişkili bulunan yaş, bilişsel esneklik ve çalışma belleği değişkenleri ile hiyerarşik çoklu regresyon analizi yapılmıştır. Çocukların yaşı, örüntü oluşturma bilgisini en güçlü şekilde yordayan değişken olmuştur. Buna ek olarak, bilişsel esnekliğin örüntü oluşturma bilgisi üzerindeki rolü, yaşla birlikte değerlendirildiğinde yüksek iken yaştan bağımsız olarak değerlendirildiğinde daha düşüktü. Bununla birlikte, çalışma belleği, örüntü oluşturma bilgisini anlamlı şekilde yordamamıştır. Bu çalışma, yürütücü işlevlerin örüntü oluşturma bilgisi üzerindeki rolünü araştırarak ve yürütücü işlevlerin örüntü oluşturma bilgisi üzerindeki rolünün önemli bir kısmının yaşa bağlı olduğunu öne sürerek değerli katkılar sağlamıştır.

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CHAPTER 1

INTRODUCTION

The word *pattern*, which derives from the word *patron*, meaning the perfect model to be imitated, is used in many different disciplines, such as art, literature, and music, as well as in daily life (McGarvey, 2012, p. 311). The pattern, defined as "replicable regularity" by Papic et al. (2011, p. 238), allows generalization to be made by helping to bring sequence, unity, and predictability to seemingly chaotic situations (ClementS & Sarama, 2009). Since children have an innate sense of rhythm in their behaviors, motions, and visual cues, a thorough understanding of patterns increasingly emerges during infancy (Clements & Sarama, 2009). The first patterns that children recognize are basic repeating patterns that are linear and consist of repetitive objects or pictures in one dimension, such as red-red-yellow-red-red-yellow or triangular-round-triangle-round (Rittle-Johnson et al., 2013). The unit is frequently made up of a few components (such as AB, ABB) that vary on a single dimension, such as color (such as green-pink-pink-green-pink-pink), shape (such as ellipse-square-ellipse-square), or measure (such as narrow-wide-narrow-wide) (Fyfe et al., 2017).

Patterning, an everyday free-play activity of preschool children, is the ability to identify and manipulate patterns (Schmerold, 2015). Many researchers consider understanding patterns and their structure as the foundation of mathematics as it contributes to developing relational thinking, generalization, abstraction, and reasoning (Clements & Sarama, 2009; Papic et al., 2011; Steen, 1988). Therefore, supporting children's patterning knowledge from an early age is essential for their pre-algebraic development. It is necessary to investigate which cognitive skills children need to recognize patterns and which executive function components affect patterning knowledge.

Mental processes that regulate, guide, or organize other mental processes are called executive functions (EF; Lee et al., 2011). Executive functions begin to form between the ages of 3-5 (Carlson et al., 2016). They develop and separate from each other throughout early and middle childhood, even though they may start to appear as a unified concept in preschool (Bock et al., 2018). Although the areas of EF for young children continue to be a subject of theoretical contention, three distinct EF processes are consistently acknowledged: Cognitive flexibility, working memory, and inhibitory control (Diamond et al., 2005; Marcovitch & Zelazo, 2009).

Firstly, working memory is the ability to remember and use information to solve problems (Diamond, 2006; 2013). Secondly, the capacity to shift views on an issue and adapt quickly to changing requirements, guidelines, or priorities, such as moving between activities, is known as cognitive flexibility (Diamond, 2013). Children may, for instance, need to rotate the pieces or attempt other placements when completing a puzzle (Harvey & Miller, 2017). Finally, inhibitory control is a crucial attention regulator and is described as the capacity to restrain a dominating or instinctive response to consider other or better methods or ideas (Barkley, 1997). Ultimately, while working memory and inhibitory control enable fast and flexible adaptation to altered conditions and the ability to meet new, unexpected challenges, cognitive flexibility is defined as the capacity to transfer viewpoints and focus on concentration easily (Diamond, 2013).

These three EF mechanisms alter specifically with age in young children (Zelazo et al., 2008). The age range of 3 and 5 years, when the prefrontal cortex develops quickly, is critical for EF development and coordination of simple skills

(Garon et al., 2008). 3 to 7 years old, specifically up to 5 years old, inhibition control and cognitive flexibility, particularly the capacity to switch perspectives, show significant gains (Diamond, 2006). Best and Miller (2010) also noted in their screening research on children and adolescents that most studies had a clear developmental focus on the preschool years. Developmentally, it is assumed that first, the working memory that gives rise to the response develops, then the inhibitory control and the working memory coordinate, and finally, cognitive flexibility, which is generally claimed to consist of the combination of the first two components (Garon et al., 2008). Additionally, the inhibition capacity shows notable improvements in early childhood compared to the following years (Best & Miller, 2010). On the other hand, working memory and cognitive flexibility develop gradually and in a straight line. According to Miyake et al. (2000), the preschool years are crucial for the growth of executive functions; each executive function develops independently but concurrently with one another, and it does so despite individual differences in the development of executive functions.

Despite general agreement that repeating pattern knowledge impacts relative thinking, early math, and reading, more study and evidence about what cognitive skills patterning requires. In particular, the effect of executive functions, which are the basis of children's cognitive development, on the patterning has yet to be discovered. When the literature is examined, it is seen that there are few studies that focus on executive functions and patterning relationships, and the results of these studies are not consistent (Bock et al., 2018; Kidd et al., 2019; Miller et al., 2015; Rittle-Johnson et al., 2013; Schmerold, 2015). The reasons for this situation are which pattern types the patterning assessment tools cover, how many dimensions they contain, or the characteristics of these dimensions (number, shape, or letter)

(Schmerold, 2015). In addition, the fact that the assessments used to measure executive functions were not determined based on the age group prevented the research results from being consistent (Kidd et al., 2019; Strauss et al., 2020). Researchers have thus urged more thorough investigations that employ suitable assessment techniques (Bock et al., 2018; Kidd et al., 2013; Miller et al., 2015).

1.1 Purpose of the study

Repeating patterns are the cornerstone of pre-algebraic development in preschool children and the most exposed patterns in daily life and preschool classes (Rittle-Johnson et al., 2013; Miller et al., 2015). More information on the relationship between executive functions and patterning allows for understanding what executive function skills young children may need to recognize patterns and contribute to their pre-algebraic thinking and early academic success by making assumptions that will improve patterning knowledge. Thus, this study aimed to examine the contribution of executive functions (cognitive flexibility, working memory, and inhibitory control) to patterning knowledge. Children from 4 to 7 years old, critical for developing executive functions (Diamond, 2006; Garon et al., 2008), were chosen. In addition, the contribution of executive functions to patterning needs to be examined while considering children's ages, given that the development of executive functions in early childhood is strongly associated with age. Therefore, this study aimed to explain to what extent executive functions (cognitive flexibility, working memory, and inhibitory control) predict patterning knowledge in children aged 4 to 7 years, with and without considering their ages.

1.2 Research questions and hypotheses

- To what extent patterning knowledge is associated with child age and executive functions (cognitive flexibility, working memory, and inhibitory control)?

It has been argued that children need executive functions to complete some patterning tasks. Since there were three different patterning tasks in this study, patterning performance was expected to correlate with children's executive functions positively. Additionally, as children's cognitive development and the patterning exercises they experience are directly proportional to their age, patterning knowledge was expected to be positively correlated with age.

- To what extent do children's age and executive functions (cognitive flexibility, working memory, and inhibitory control) predict the patterning knowledge of children aged 4 to 7?

Although previous research results have been inconsistent, in this study, age and executive functions (cognitive flexibility, working memory, and inhibitory control) were expected to predict patterning knowledge.

- To what extent do children's executive functions (cognitive flexibility, working memory, and inhibitory control) predict the patterning knowledge of children aged 4 to 7 years independent of their age?

Although researchers have thought that executive functions predict patterning knowledge, how much of this prediction depends on the age of the children has not yet been elucidated. Some executive function components were expected to predict patterning knowledge regardless of age.

CHAPTER 2

LITERATURE REVIEW

2.1 Patterning in early childhood

In preschool and at the beginning of primary school, simple patterns can be copied, expanded upon, and developed by children (Clements & Sarama, 2009). The patterns experienced by children in this period can be generally classified as repeating patterns, growing patterns, and spatial patterns (Mulligan & Mitchelmore, 2009). ABABAB, ABCABCABC, and other patterns that have a fixed unit of a repeat are examples of repeating patterns, growing patterns increase or decrease gradually over time (e.g., ABABBABBBABBBB, 2-4-6), and spatial patterns explain the arrangement of discrete components that exist in two or three dimensions (Papic & Mulligan, 2007). There is growing evidence that understanding the underlying structure or repeating unit of repeating patterns has a significant role in mathematics education (Economopoulos, 1998; Papic et al., 2011). Indeed, Economopoulos (1998) suggested that "To generalize and predict, children must move from looking at a pattern as a sequence of 'what comes next' to analyzing the structure of the pattern, that is, seeing that it is made of repeating units" (p. 230). In other words, the foundations of children's skills, such as generalization and abstraction, which are essential in mathematical thinking, are laid by understanding patterns.

2.1.1 Patterning in early childhood curriculum

Preschool teachers think patterning, a foundational part of most preschool programs, is essential to learning. (Economopoulos, 1998; Schmerold, 2017). Research has shown that the most frequent mathematical exercise seen during playtime of 4- and

5-year-olds was patterning in early childhood education in the United States (Ginsburg et al., 2003). Researchers have attributed this situation to several different reasons. One is that patterning activities that children perform spontaneously in free play are accessible and suitable in early childhood classrooms (Fox, 2005). Another reason is that patterning activities are the basis of preschool children's mathematics education (Papic et al., 2011). According to Fox (2005), knowledge of arithmetic, geometry, metrics, and statistics is tightly related to patterns. As a final reason, the National Council of Teachers of Mathematics (2000), arguing that patterns are the central algebraic topic, expected prekindergarten children to identify and copy simple repeating patterns. Kindergarten children also were expected to recognize, copy and continue repeating and growing patterns.

In the United States, it was recommended that children understand the patterns to prepare them for mathematical reasoning by the National Council of Teachers of Mathematics (2006). On the other hand, when the commonness and recommendation of patterning teaching in the United States of America were discussed at the Mathematics Advisory Panel (2008), it was recommended to streamline mathematics teaching in the first years of primary schools to highlight the more essential issues rather than patterns. This recommendation might be due to insufficient evidence for patterning knowledge at that time (Rittle-Johnson et al., 2015). However, recently there has been strong evidence that patterns should be retained in mathematical content standards. Early mathematics curriculum strongly emphasizes the significance of patterns as a mechanism for children to relate to their surroundings and as the basis for algebraic reasoning (Kidd et al., 2013).

Similarly, patterning knowledge was included in the outcomes of the 2013 Preschool Education Program of the Ministry of National Education implemented in

Turkey (MoNE, 2013). The definition of pattern and examples were given in the section on outcomes related to cognitive development. Children were supposed to extend the provided pattern and create their patterns, which were called mathematical activities. The rule of a pattern, the gap in a pattern, and the creation of a unique pattern using objects were different expectations. These activities were designed to help children recognize patterns in their surroundings, create and test hypotheses, solve problems, reason, and interact with others using mathematical principles. Suggestions for activities that can be applied to children were presented by giving examples from daily life. Besides, the studies on patterns in Turkey are generally within the scope of mathematics teaching in primary and secondary education, while there are fewer studies in early childhood education (Gök Çolak, 2020). The fact that patterning knowledge is an increasingly widespread research topic due to the increasing understanding of its importance suggests that this topic, which is very important for early childhood education, will be the subject of more studies in Turkey.

2.1.2 Assessment of patterning in early childhood

According to Collins and Laski (2015), the structure of patterns can differ depending on whether they contain repeating units, recurring rules, or growing relationships. Additionally, they can differ in the pattern's content, such as whether it contains numbers, forms, or colors, and in its complexity, ranging from basic regularities to more sophisticated ones (Collins & Laski, 2015). Repeating patterns -linear, emphasizing one repeating unit, and usually one-dimensional- are thought to be the first kinds of patterns that preschoolers learn (Rittle-Johnson et al., 2015). The repeating patterns children experience become more complex as they grow.

Repeating patterns with more than one dimension, such as a square green-red round-square green-red round, or patterns with a long repeating unit, such as ABBAABBA can be given as examples.

Clements and Sarama (2009) have developed a patterning trajectory suitable for the developmental processes of young children, which they call *learning trajectory for patterns and structure*. In this case, patterning instructions suitable for 2-year-olds include not being able to distinguish patterns exactly but using them through songs, poems, and dances. It is stated that in the age group of 3, patterns can be distinguished, and in the age group of 4, an incomplete pattern can be completed, and a pattern can be duplicated and extended. In line with developmental progress, it is stated that 5-year-olds can form patterns, and 6-year-olds can distinguish repeating pattern units (Clements & Sarama, 2009). Based on this structure, Rittle-Johnson et al. (2013) have created a "construct map" consisting of 4 levels for knowledge of repeating patterns. The levels are intended to aid in visualizing the understanding of progress, which is probabilistic and ongoing. Children can copy patterns at level 1, continue them at level 2, then abstract the pattern at level 3 so they can create it using different materials. Lastly, it is presumable that at level 4, they can quickly identify the unit of a repeating pattern (Rittle-Johnson et al., 2013).

The degree to which mental manipulation and representation of the repeating unit are necessary varies among patterning tasks (Collins & Laski, 2015). The simplest tasks to demonstrate whether children understand repeating patterns are duplicating (copying) and extending the patterns (Collins & Laski, 2015; Miller et al., 2015). Duplicating patterns, meaning reproducing a model pattern, is the patterning knowledge that children first experience (Rittle-Johnson et al., 2013). Extending patterns is more challenging because it requires continuing a provided pattern (Rittle-Johnson et al., 2013). For instance, when the child is asked to continue the pattern of red-white-red-white, she/he extends the pattern in the form of red-white-red-white-red-white. Research has revealed that the vast majority of children between the ages of 3 and 5 can accomplish activities requiring pattern duplication, whereas around half of them can complete tasks requiring pattern extension (Bock et al., 2018). However, extending and duplicating patterns can be accomplished by object-matching (one-to-one matching) techniques, and they might not resist arithmetical regards (Threlfall, 1999). Children can, for instance, copy a pattern by pairing the dimensions of each object in it (Collins & Laski, 2015). Therefore, the accuracy of these tasks may not indicate that the child understands the pattern.

Two advanced patterning knowledge more suggestive of an essential comprehension of the repeating patterns' structures are abstraction and pattern unit recognition (Miller et al., 2015). Abstracting a pattern which entails recreating a model pattern with different elements is a more challenging patterning knowledge that visual matching cannot be applied (Rittle-Johnson et al., 2013). Children might be demonstrated a pink-white-pink-white-pink-white pattern, for instance, and instructed to make a similar pattern out of squares and circles. Less than a third of preschool-aged children have completed this test which calls for children to focus on the form of the pattern rather than its surface aspects and to be able to abstract the underlying unit (Rittle-Johnson et al., 2015). Further, Warren (2005) has suggested that the purpose of comprehending mathematics is the abstraction of patterns, which is the foundation of structural understanding. Finally, the structure of the patterns should be better understood in order to complete the task of identifying repeating patterns' units (Miller et al., 2015). Only a tiny percentage of 4-year-old children were proficient at recognizing explicit pattern units (Rittle-Johnson et al., 2015).

According to Collins and Laski (2015), this process shows that the best way to support preschoolers' developing pattern knowledge may be to analyze the cognitive requirements of various tasks of patterning and the strategies children can employ.

Age is also an essential factor determining the accuracy of the measured patterning performance, as are the different patterning tasks (Bennett & Müller, 2010; Fyfe et al., 2017; Rittle-Johnson et al., 2013). Studies have shown that patterning performance is directly proportional to age. Moreover, in the study by Bennett and Müller (2010) with 3-5 years old children, performance on some difficult patterning tasks was revealed to be more related to age than scores on other patterning tasks. Similarly, in a study conducted by Fyfe et al. (2017) with a sample divided into two according to age groups (5-8 years old as young children and 9-13 years old as older children), the age-related relationship of the resolution of difficult pattern items was found to be stronger in older than in youngers. Furthermore, Collins and Laski (2015) found that children's age and executive functions predicted their patterning knowledge in their study examining how preschoolers completed visual repeating patterning tasks. Harvey and Miller (2017) who reached another similar result found that the age of the children predicted their patterning knowledge in their study, which examined the executive functions capacities and early mathematical knowledge of 92 children at the age of 3 and 4 attending Head Start centers. These results may indicate that children can understand more complex patterns with more difficult types or more dimensions because of improvements in their cognitive skills as they develop and mature.

2.2 Relations between cognitive skills and patterning knowledge in children

2.2.1 The relationship between pre-algebraic thinking and patterning

According to Piaget (1965), young children have limited mathematical knowledge. However, studies conducted in later years have shown that preschool children may have high levels of mathematics knowledge with the skills of abstraction and generalization (Papic et al., 2011; Rittle-Johnson et al., 2013). After many numbers-based mathematical studies that were carried out decades ago, Steen (1988) has argued that mathematics results from patterns, saying, "Mathematics is the science of patterns" (p. 616). Similarly, Warren (2005) has suggested that the strength of mathematics consists in linkages and transformations which give birth to patterns. Because patterning is early, age-appropriate instruction involving rules and relations, it also helps with pre-algebra (Threlfall, 2004).

Moreover, Clements and Sarama (2007c) have stated that the first step in mathematics is to look for patterns. Finding patterns enables one to detect links and draw generalizations while bringing regularity, unity, and predictability to chaotic events. Increasing evidence shows that early exposure to mathematical patterns, connections, and structure helps children develop algebraic thinking and reasoning in mathematics and geometry (Kidd et al., 2013).

Learning mathematics requires an intuitive understanding of patterning principles and structural relationships (Papic et al., 2011). The idea that one object represents another is the foundation of what is typically considered a required ability for higher study in algebra (Lee et al., 2012; Clements & Sarama, 2009). Therefore, the development of pre-algebraic thinking is supported by the abstract representation of patterns like ABBABB (alphabetically) in early childhood patterning activities (Clements & Sarama, 2009). According to Papic et al. (2011), thanks to algebra, someone can describe connections and generalizations frequently tied to numbers and use those relationships and generalizations to handle issues. Because of this, patterning exercises in early childhood support the children's pre-algebraic thinking (Papic et al., 2011). By identifying similarities, defining norms and relationships, and eventually symbolizing those links, patterning helps children strengthen their capacity to communicate generalizations (McGarvey, 2012). Likewise, Mulligan and Mitchelmore (2009) have claimed that children's capacity for pattern recognition shows signs of pre-algebraic thinking.

Children pay particular attention to how easily the pattern's pieces may be predicted (Kidd et al., 2014). This concentration might extend to the predictability of relationships between numbers because mathematical reasoning revolves around recognizing, extending, and explaining predictable sequences in things or numbers (Rittle-Johnson et al., 2015). According to Economopoulos (1998), since children believe that repeating units make patterns predictable, they must generalize to identify a unit in a repeating pattern and make educated guesses about unidentified structures. From this viewpoint, patterning involves induction which entails generalizing pattern structure, and deduction requiring recognition of the repeating unit (Strauss et al., 2020). As the child completes increasingly more patterning tasks, their inductive and deductive thinking gets progressively stronger (Strauss et al., 2020). McGarvey (2012), in her study, asked students and their teachers questions about recognizing patterns. According to the answers, she realized that there were two points that students and teachers focused on most when recognizing patterns: generalization and predictability. Because in order to recognize a pattern, it is required first to determine the repeating unit, then generalize it and finally question its predictability. Early exposure to patterns is crucial for later algebraic reasoning as it offers possibilities for relational thinking, including considering how different components of a given issue connect (Collins & Laski, 2015).

2.2.2 The relationship between relational thinking and patterning

Although there is a consensus that repeating patterns in early childhood education contribute to relational thinking of children, rule inference, and mathematical thinking skills, there is little research and knowledge on which cognitive skills are required for patterning (Bock et al., 2018; Collin & Laski, 2015; Miller et al., 2015). Young children can solve simple repeating patterns in two ways: relational thinking or one-to-one appearance (object-matching) (Bock et al., 2018).

Children must consider relations between the objects to abstract repeating patterns instead of only focusing on the perceptual characteristics of each object (Rittle-Johnson et al., 2013). Therefore, relational knowledge is an essential cognitive skill for patterning knowledge in children (Threlfall, 1999). For example, children must determine the relationships between various parts of a pattern to recognize a pattern's repeat unit (Rittle-Johnson et al., 2015). In some studies, on pattern recognition strategies, attention has been drawn to analogical reasoning, a type of relational thinking (Bock et al., 2018; Collins & Laski, 2015). It has been suggested that analogical reasoning is positively associated with recognizing patterns and their structures because it needs to make comparisons between objects on a relational basis (Bock et al., 2018; Rittle-Johnson et al., 2015).

Patterning is a general cognitive knowledge that necessitates generalization and abstraction abilities (Clements & Sarama, 2007b). Finding similarities between items, essential for generalization, may be done with the help of abstraction skills (Bennet & Müller, 2010), supported by patterning skills that develop in preschool and early primary school (Bennett & Müller, 2010; Kidd et al., 2017). Thanks to the pattern abstraction experiences, children get the ability to focus on a pattern's general structure rather than its surface characteristics (Rittle-Johnson et al., 2015), which is the basis of algebraic thinking (National Council of Teachers of Mathematics, 2006; Papic et al., 2011).

According to Miller et al. (2015), relational knowledge, which makes comparisons between objects and experiences based on underlying similarities, is a central component of children's knowledge of patterns and explains by the three main theories: relational complexity, relational primacy, and relational shift.

Relational complexity theory emphasizes the importance of working memory, which argues that the capacity of working memory to process relational similarities must play a role in the development of repeating pattern knowledge (Miller et al., 2015). Multiple dimensions can be used simultaneously in repeating patterns. For example, the child should realize that in a pattern of red round-green square-blue triangle-red round-green square-blue triangle, the pattern rule is broken when only the shape of any object changes. According to the relational complexity theory, the stronger the child's working memory, the more likely it is to recognize a similar two or more-dimensional pattern (Halford, 1993). In addition, preschoolers' performance on repeating patterns may also benefit from keeping and manipulating information, quickly shifting attention between pattern components, and inhibiting unnecessary pattern characteristics (Miller et al., 2015).

According to relational primacy and relational shift theories, children's age and their experience of logical similarity effectively improve their understanding of relationships (Miller et al., 2015). These theories suggest that children's experiences with repeating patterns from an early age will contribute to developing their relational primacy and relational shift skills. While relational knowledge is a natural ability developed with experiences about relationships according to the relational primacy theory, the relational shift theory argues that young children pay attention to superficial resemblances until they accumulate relational knowledge (Miller et al., 2015). Therefore, young children are more inclined to match the superficial features of objects in patterns (Collins & Laski, 2015). According to Rittle-Johnson et al. (2015), the tasks of duplicating and extending patterns in which young children are most successful can be handled with an object-matching strategy.

Some mathematicians and educators have examined if high performance in patterning tasks requires actual patterning knowledge. It is thought that children must analyze the pattern's structure and examine what units it consists of instead of preoccupying with the question of "What comes next" so that they can generalize and predict through patterning (Economopoulos, 1998, p. 230). For instance, spontaneous patterning in children demonstrated in the study of Papic and her colleagues (2011), defined as "local rather than structural" (p. 261). In other words, their techniques were centered on the relationships between nearby pieces. Functional thinkers can forecast the element that will fill each gap in a pattern because they can perceive the underlying structure of the pattern (Wijns et al., 2019). On the other hand, recursive thinkers can only understand the relationship between the final consecutive components in a pattern.

Although young learners can identify patterns, this early identification may not support the relational reasoning necessary for algebra (McGarvey, 2012). Because they tend to pay attention to sequential items, which provides them to extend a pattern or predict the next item in a repeating pattern (McGarvey, 2012). Further, studies on children's relational thinking have argued that children can benefit from object-matching techniques while completing patterning tasks (Collins & Laski, 2015). Children's recognition of a repeating unit without the propensity to benefit from this recursive reasoning is crucial for establishing the relationship between patterning and generalization (Threlfall, 1999).

To conclude, according to the relational primacy and relational shift theories, it is anticipated that children's patterning knowledge would be connected to relational knowledge and develop due to exposure to repeating patterns (Miller et al., 2015). Additionally, the relational complexity theory predicts that toddlers' awareness of repeating patterns would positively correlate with individual variations in executive functions, age, exposure to patterning activities, and relational knowledge (Miller et al., 2015).

2.2.3 Research on relations between executive functions and patterning

Executive functions, developing rapidly and critically in preschool children, are the subject of many academic studies and attract educators' attention (Best & Miller, 2010). Recently, the relationship between executive functions and patterning knowledge in children has been investigated. Although there is an agreement that some cognitive processes underlie patterning knowledge, there is still little evidence on how each executive function predicts patterning skills (Schmerold, 2015). Understanding the necessary executive functions is meaningful and valuable for best teaching children about patterning and helping children with difficulties (Bock et al., 2018). Because patterning knowledge not only needs children's executive functions but also supports them. Therefore, further studies are needed to examine the relationship between executive functions and patterning knowledge.

2.2.3.1 Cognitive flexibility and patterning

Many children can recognize similarities and differences in standard dimensions like color, shape, and height before they start school. They can also recognize simple temporal sequences where one thing comes before or after another. These children can comprehend a basic set of two or three objects. It is more challenging to connect two dimensions, such as size and shape or shape and color, in a way that makes sense since it takes adequate executive control to quickly switch concentration from more to less preferred dimensions as necessary (Kidd et al., 2013).

According to the relational shift theory, while young children notice the superficial similarities between elements, in the following years, they start to focus on relational similarities (Miller et al., 2015). Considering this theory, Jacques and Zelazo (2001) created an assessment called the Flexible Item Selection Task (FIST), which children perform with some cards depicting items that can change in four dimensions to estimate their cognitive flexibility capacity. Children are expected to choose cards according to one of these four dimensions. After completing this task, the children are asked to choose cards according to another dimension; however, 4-year-olds are generally unsuccessful (Jacques & Zelazo, 2001). While the success rate in the first selection represented the abstraction skill in children, the failure in the second selection indicated that the cognitive flexibility capacity was not fully developed in 4-year-old children (Bennett & Müller, 2010).

Similarly, many researchers have thought young children benefit from object-matching or cognitive-based strategies in patterning tasks (Bennett & Müller, 2010; Bock et al., 2018; Collins & Laski, 2015). Controlling for age, Bennett and Müller (2010) found that difficult items in the patterning scale were still significantly associated with cognitive flexibility. Therefore, they argued that as the patterning task becomes complex, the matching strategy does not work, and children begin to rely on their skills for cognitive flexibility (Bennett & Müller, 2010). Studies have shown that the general cognitive ability to be flexible or change thoughts begins to develop after age 4 (Bennett & Müller, 2010; Schmerold, 2015). For instance, according to Bennett and Müller (2010), in line with the relational shift theory, older children are better at solving challenging items in recognizing patterns tasks. Although a limited number of studies examine the relationship between cognitive flexibility and recognizing repeating patterns, cognitive flexibility has been shown to be associated with patterning (Bennett & Müller, 2010; Schmerold, 2015).

Schmerold (2015) conducted a study with 7-year-old first-year students and found that the results of the patterning test, which includes complex and various patterns, were most related to the cognitive flexibility assessments rather than the other two executive functions. Cognitive flexibility was associated with a medium effect with patterning results, while working memory results were associated with a small effect size. In addition, only cognitive flexibility significantly predicted patterning scores in the regression analysis (Schmerold, 2015). Furthermore, after this study, Schmerold et al. (2017) found that cognitive flexibility is connected to academic performance, but that association was thought to be contingent on its correlation with patterning and cognitive flexibility. Likewise, with first graders, in order to determine if these associations vary depending on the type of pattern, Bock et al. (2018) examined the relationships between executive functions, patterning, and reading. They found that whereas performance in pictorial patterns was associated with cognitive flexibility, performance in spatial patterns was associated with working memory. In the study using a multiple-choice patterning task, the patterns also placed a minimal burden on working memory because the children were given a choice between four choices. At the same time, the pattern was still visible in order to finish it. However, moving between growing, decreasing, and symmetrical patterns in the study required flexibility in thought, which may explain the correlation between cognitive flexibility and patterning (Strauss et al., 2020). Also, according to Strauss et al. (2020), the executive functions were mostly independent for five-year-old children; thus, cognitive flexibility was not highly correlated with any other measure in the study of Bock and her colleagues (2018).

Considering the relationship between executive functions and age, the results of studies with younger children should also be evaluated. In the study of Kidd et al. (2019) with kindergarten children, four groups were taught early literacy, mathematics, social studies, or one of six pattern instruction types. At the end of the year, tests for early literacy, mathematics, executive functions, and patterning knowledge were administered. In this study, patterning was strongly related to working memory and inhibitory control but weakly related to cognitive flexibility. Indeed, this research contributed to the hypothesis that cognitive flexibility develops after four years of age (Bennett & Müller, 2010; Schmerold, 2015).

Similarly, the study conducted by Harvey and Miller in 2017 with children aged 3-4 revealed that working memory and inhibitory control contributed to patterning skill regardless of age. The researchers interpreted it as follows: a child may need to prevent sticking with one set too long before switching to another, and according to Diamond's (2006) hypothesis that cognitive flexibility may be a dependent predictor, in an assessment involving working memory and inhibitory control, any dual relationship may be absent (Harvey & Miller, 2017). For another support of this hypothesis, the study by Bock et al. (2018) with first graders demonstrated that cognitive flexibility had significant correlations with both working memory and inhibitory control. However, there was no significant correlation between working memory and inhibitory control. The researchers have suggested that cognitive flexibility may come from the interaction of these two often unrelated factors (Bock et al., 2018; Garon et al., 2008). Besides, the fact that patterning and cognitive flexibility were found to be unrelated while working memory and inhibitory control were found in these studies may provide some evidence for some studies that there is strong association between cognitive flexibility and updating capacity (Miyake et al., 2000). In the study of Bennett and Müller (2010), in which only the relationship of cognitive flexibility with patterning was examined, cognitive flexibility was associated with patterning regardless of age also supports this hypothesis.

In the study of Miller et al. (2015), patterning skills, relational knowledge, and executive function capacities of 4 and 5-year-old children were measured before and after a brief patterning intervention. Relational shifting results were unrelated to patterning skills in the posttest but related in the pretest, indicating that young children may begin to rely less on their cognitive flexibility, thanks to repeating pattern exercises performed over time (Miller et al., 2015). The findings of this study demonstrated that the children's innate capacity for pattern recognition entirely served as a mediator between the influence of cognitive flexibility on posttest scores (Schmerold et al., 2017).

As a result, in the patterning scales used in these studies, the varying degree of difficulty for each age, the characteristics of the samples, whether they have been applied before, and the determination of tests suitable for executive function skills are still controversial issues. In order to determine the relationship between cognitive flexibility and patterning in preschool children, it may be helpful to make an assessment independent of other executive functions and age, using scales appropriate for the age group of the sample.

2.2.3.2 Working memory and patterning

According to Rittle-Johnson et al. (2013), working memory, which influences success on various cognitive tasks, including math achievement, is partially related to patterning knowledge. Considering and using more than one piece of information when creating a pattern and matching new objects with existing objects in the sample pattern when duplicating and extending patterns are required (Rittle-Johnson et al., 2013). Additionally, in abstracting patterns, working memory is involved in translating the pattern into a related one utilizing various objects because it is necessary to actively transform by keeping the information in mind (Collins & Laski, 2015). Ultimately, children's working memory capacity may limit their understanding of relationships in a pattern. Because in agreement with the relational complexity theory, processing and learning about the patterns' elements may be made more accessible by working memory capacity, which makes repeating patterns more apparent and easier to comprehend in terms of relational similarities (Miller et al., 2015). According to Okamoto and Case (1996), it is thanks to the increase in working memory capacity that children can focus not only on one dimension but also on two or more dimensions. For instance, children who recognize one-dimensional patterns such as red-yellow-yellow-red-yellow-yellow begin to recognize two-dimensional patterns more conveniently, such as red A-white B-white B-red A-white-B-white B, as their working memory capacity develops.

Besides, in the study of Collins and Laski (2015), working memory capacity, an indicator of the use of relational similarity strategy in pattern recognition, was positively associated with performance only in transferring (abstracting) pattern tasks. In this case, children were thought to engage in mental processes beyond one-to-one matching in abstracting pattern tasks. They attributed the duplicating and extending pattern tasks, in which children generally benefit from an object matching strategy, are unrelated to working memory. Since object matching does not involve any cognitive processing, it is not affected by individual differences in working memory (Collins & Laski, 2015).

The study by Lee et al. (2012) with 163 6-year-old children enrolled in primary school found that working memory was the only executive function that predicted patterning skills. Although patterning was found to be slightly related to cognitive flexibility and inhibitory control according to the correlation analysis, when the relationships between working memory and these executive functions were controlled, the relationship between patterning and working memory and inhibitory control disappeared. This result showed that the correlations between patterning and cognitive flexibility or inhibitory control may have resulted from the relationship between these executive functions and working memory.

Based on the National Mathematics Advisory Panel's (2008) recommendation to review resources devoted to teaching and assessment of patterns, Lee and her colleagues (2011) examined the relationship between 10-year-old children's abilities in pattern recognition, calculation and working memory tasks and their growing skill in solving algebraic word problems. This study pointed out that *updating* was used instead of working memory. Although both terms have the same meaning in the literature, working memory refers to a broader process and structure. The study results presented that updating predicted patterning and computational capabilities; however, it correlated with algebraic problems only through patterning and computation. Lee et al. (2011) interpreted the results as follows: The updating could be a source for various components children carried out while solving algebraic problems. In addition, they predicted that algebraic reasoning would develop less in children if the updating capacity or calculation skills were weak or the ability to identify and generalize patterns' rules was lacking. (Lee et al., 2011).

In another study with similar results, Fyfe et al. (2017) gave three different extending patterning tasks and three mathematics tasks measuring calculation and mathematical concept knowledge to 36 children aged between 5 and 13 years. The study's results revealed that although pattern extension knowledge was associated with mathematical performance, this might not be valid for all types of mathematical knowledge. A critical result was that verbal working memory, independent of age, predicted patterning scores. It is surprising and needs further investigation, as the study's sample was in the broader age range. On the other hand, Collins and Laski (2015), who found working memory as a predictor, realized that it was not significant when they controlled the age variable in the regression analysis.

Moreover, Fyfe et al. (2017) found that the patterning skill was related to computational skills independently of age and verbal working memory but not concept knowledge. This result supported some of the suggestions in Kidd et al.'s (2013) study. They argued that thanks to patterning practices, it becomes easier for children who develop their abstract thinking skills to comprehend mathematics rather than directly recognize some mathematical concepts. Indeed, patterning teaching should be continued with short sessions throughout the year to realize the benefits of patterning teaching on mathematics achievement (Kidd et al., 2013).

Despite these studies deducing that arithmetic skill is directly related to patterning, Lee et al. (2012) argued that the relationship between arithmetic skills and patterning in children is a working memory artifact. In their study, Lee et al. (2012) showed that the relationships between arithmetic skills and patterning tasks did not become significant when the updating contribution was entered. This result indicated that the updating may be responsible for significant variance in arithmetic skills. The opposite results of Lee and her colleagues' (2011) previous study were thought to be due to the older age of the children (Lee et al., 2012), which may mean that as children grow, it becomes more difficult to distinguish the effect of working memory. Older children are more likely to use computational skills in patterning tasks, while younger children who have not mastered computational skills may have to rely on their working memory to complete them (Orton & Orton, 1999). All these studies show that understanding the relationship between working memory and patterning is essential for patterning development and gaining mathematical skills.

Another study that can provide evidence for the relationship between recognizing repeating patterns and working memory capacity is the study of Rittle-Johnson and her colleagues (2013) to understand patterning in 4-year-old children. In this study, working memory capacity was associated with increased patterning skills. Similarly, in a study measuring relational knowledge, executive functions, and repeating pattern skills of 124 children aged 4 to 5 years before and after a patterning intervention, relational knowledge and executive functions uniquely predicted the pretest initial patterning knowledge of preschoolers (Miller et al., 2015). However, the remarkable point is that in the posttest, only working memory among executive functions independently predicted preschool children's patterning performance (Miller et al., 2015). This finding aligned with studies claiming that patterning knowledge contributes to understanding mathematics through working memory (Lee et al., 2012) because it can be concluded that working memory and patterning are influential factors on each other and in relational learning processes.

Like mathematical performance that requires relational knowledge, patterning knowledge development is related to working memory development. Schmerold (2015) found in their regression analysis that patterning predicted all achievement tests while working memory predicted all achievement tests except one test, which assesses a student's capacity for mathematical analysis and problem-solving. Since the test established a significant correlation with working memory, she thought that this correlation was due to the patterning and working memory relationship. Moreover, in 2017, Schmerold and her colleagues' continuation study suggested that working memory has both patterning-directed and independent effects on achievement.

All these analyses conclude that the relationship between working memory and patterning significantly impacts learning processes and mathematical achievement. However, studies examining the relationship between working memory and patterning have been limited and have had inconsistent results. For this reason, this relationship needs to be revealed in more detailed studies including the interactions of age and other executive functions.

2.2.3.3 Inhibitory control and patterning

According to the study of Rittle-Johnson et al. (2013), repeating pattern knowledge and an increase in age were associated independently of working memory capacity. These results can be attributed to the age-related development of other executive functions, such as cognitive flexibility and inhibitory control, which is effective in pattern recognition. It has been assumed that inhibitory control, similar to cognitive flexibility, begins developing at 4 (Dempster, 1992). Inhibitory control can prevent children from focusing on common out-of-pattern behaviors, such as playing with materials or focusing on the perceptual features of the pattern, enabling them to notice the unit of repeats of the patterns and focus on the structure of the pattern (Miller et al., 2015; Rittle-Johnson et al., 2013). Moreover, inhibitory control prevents children from producing more familiar patterns instead of desired complex patterns in abstracting pattern tasks, such as a tendency to create an AB-AB pattern instead of the AAB-AAB pattern. It also helps them disregard a smaller, conspicuous unit of a pattern to recognize a more complicated unit, such as focusing on the repeating AB unit in the pattern of the AAB repeating unit (Collins & Laski, 2015).

According to Collins and Laski (2015), children with higher inhibition control capacity can use relational similarity strategy better in patterning tasks because inhibitory control is thought to be related to analogical reasoning. In their study, inhibitory control was unrelated to duplicating and extending pattern tasks in which children were observed to apply the object-matching strategy. However, relational strategy errors in abstraction patterns were found to be associated with inhibitory control (Collins & Laski, 2015). Additionally, Kidd et al. (2019) found that both inhibition measures (the Day-Night test and the Head-Toes-Knees-Shoulders [HTKS]) they used in their study were shown to be related to patterning in kindergarten children.

On the other hand, in the study of Miller et al. (2015), although it was predicted that the recognition of repeating patterns and inhibitory control capacities of children aged 4-5 years was predicted to be significantly positively correlated, no significant relationship was found. Researchers thought this result might result from Luria's Hand Game used as an inhibitory control scale (Miller et al., 2015). While

Collins and Laski (2015) determined the inhibition control capacities of preschool children with the HTKS scale, Schmerold et al. (2017) and Bock et al. (2018) used the Day-Night scale for first-grade students. As a result of the research, only Collins and Laski (2015) found inhibitory control predicted patterning performances. Moreover, they found that inhibitory control was negatively associated with patterning errors in their analysis by controlling the age of the children (Collins & Laski, 2015). This result indicated that inhibitory control's effect on patterning depends not only on age. Varied degrees of inhibitory capacity in samples from various populations and diverse measurement requirements appear to induce specific variations in the relationships between inhibition and patterning (Kidd et al., 2019). Besides, according to Strauss et al. (2020), this is because the Day-Night test is relatively simple to measure, especially for first-year students' inhibitory controls, and younger children have difficulties in the HTKS assessment.

Although inhibitory control is thought to be effective in recognizing and manipulating patterns, the relationship between inhibitory control and patterning is not yet clear. Examining this relationship in detail with various age groups, samples, and variables is necessary.

CHAPTER 3

METHODOLOGY

3.1 Sample

Within the scope of the "Boğaziçi Öğrenme Laboratuvarı" study, data were collected from 112 children and their parents, but 21 of them were excluded because there were parent interventions while children were completing the tasks in 6, practitioner error in 2, participant error in 4, technical problems in 3, participant reluctance to continue in 5, and there were scales that the parent did not complete in. Therefore, in this research, there were 91 participants who consisted of preschool and first-year students aged 4, 5, and 6 and their parents. The collected data were divided into the experimental group which was given the unit of repeating pattern clue and the control group which was not given. However, only the control group data were evaluated in this study since the focus was the relationship between executive functions and patterning knowledge and that tasks needed to be equal for all the participants. Therefore, 41 children in the experimental group were excluded, and the final data used for the analyses included 50 children and parents consisting of 30 girls and 20 boys. The youngest of the participants was 47 months old, and the oldest was 83 months old, while the average was 66,36 *(SD=9.699).*

The convenience sampling method was used to select participants in this study. Since the data were collected online, participants who live in different provinces of Turkey could be included. Parents who were aware of the study due to online posts, social media, and fliers that were distributed in a range of platforms and wanted to participate voluntarily filled out the application form, and parents whose children were in the appropriate age group were invited to be included in the study.

Although the convenience sampling allowed the participants to be reached relatively quickly, the data collection period took 13 months as each child is interviewed individually. Since the parents voluntarily participated in the study, the convenience sampling method made it difficult to make generalizations about the target population from the sample (Etikan et al., 2016). However, it is expected that parental involvement and interest in children's academic achievement to be somewhat consistent among the participating children and their families as it is evident that parent involvement in children's schooling influences child performance (Ma et al., 2016; Sy et al., 2013). The students at the schools whose principals could be reached and the children of the parents who looked at the relevant content on social media could be aware of this study. It was thought that the socio-economic levels of the participants were from medium to high because the parents voluntarily participated in the study, and for the study to take place, a computer (the platform on which the scales were applied did not work on tablets and phones), a stable internet connection, and a quiet environment were required. Parents' education levels were also relatively high, as detailed in the Result section.

Thirty-five of the children participating in the study attended preschool, 14 attended the first grade, and 1 did not attend any school. Among the schools attended were both private and public schools. In addition to obtaining online informed consent forms from the parents who wanted to participate in the study, verbal consent was requested from the parents in order to receive video recordings during the study carried out via Zoom. During each study, verbal consent was obtained from the child before starting each scale.

While cognitive flexibility and patterning knowledge data were collected from the children, parents were informants for children's working memory and inhibitory control. Moreover, demographic information about parents and children was obtained from parents. Descriptive statistics about the gender, age, and educational status of the children and the educational status of the parents were stated in the Result section in detail.

3.2 Instruments

3.2.1 Early Patterning Assessment

Zippert and Rittle-Johnson (2019) developed a patterning assessment to measure the repeating and growing patterning knowledge of 4- and 6-year-old children. The assessment, administered to 47 children during their first term of kindergarten, consisted of 2 subscales as growing and repeating patterning. In the repeating pattern subscale of this scale, 20 items which consisted of 5 different pattern types (identifying, completion, extension, abstraction of repeating patterns, and identifying pattern unit), were used. In addition, good reliability values of repeating and growing subscales (Cronbach's $\alpha = .81$, $\alpha = .76$, and .74, respectively) were obtained (Rittle-Johnson et al., 2020).

Due to the pandemic, Kaufman and his colleagues (2021) recreated this scale in the online environment. Due to the difficulty of the online application, the identifying unit pattern task in the first version was removed, and the repeating subscale of the assessment was applied as 16 items containing four pattern types. In a study conducted with 96 children aged 4-6 years, the reliability value of the growing subscale was measured as $\alpha = .48$. However, the total reliability value of the scale was $\alpha = .74$, and the reliability value of the repeating subscale was $\alpha =.73$. When the results were examined, it was predicted that the online Early Patterning Assessment would be suitable for measuring preschool and first-grade school children's overall and repeating patterning knowledge.

In order to measure the repeating patterning knowledge of preschool and first-grade school children in Turkey, "Boğaziçi Öğrenme Laboratuvarı" adapted the repeating pattern subscale of the online Early Patterning Assessment into Turkish. Every task on this scale required pattern recognition or manipulation involving repeating elements. Children's patterning knowledge were assessed using three tasks (see Figure 1 for sample items): pattern identification (pattern ID), pattern extension, and pattern abstraction. By completing the pattern identification task, children needed to decide whether a group of elements provided to them was a repeating pattern. In the pattern extension task, children were asked to continue the pattern shown by choosing one of three possible pattern units. Finally, children needed to determine which of the three patterns had the same rule as the pattern displayed but were created with different items for the pattern abstraction test.

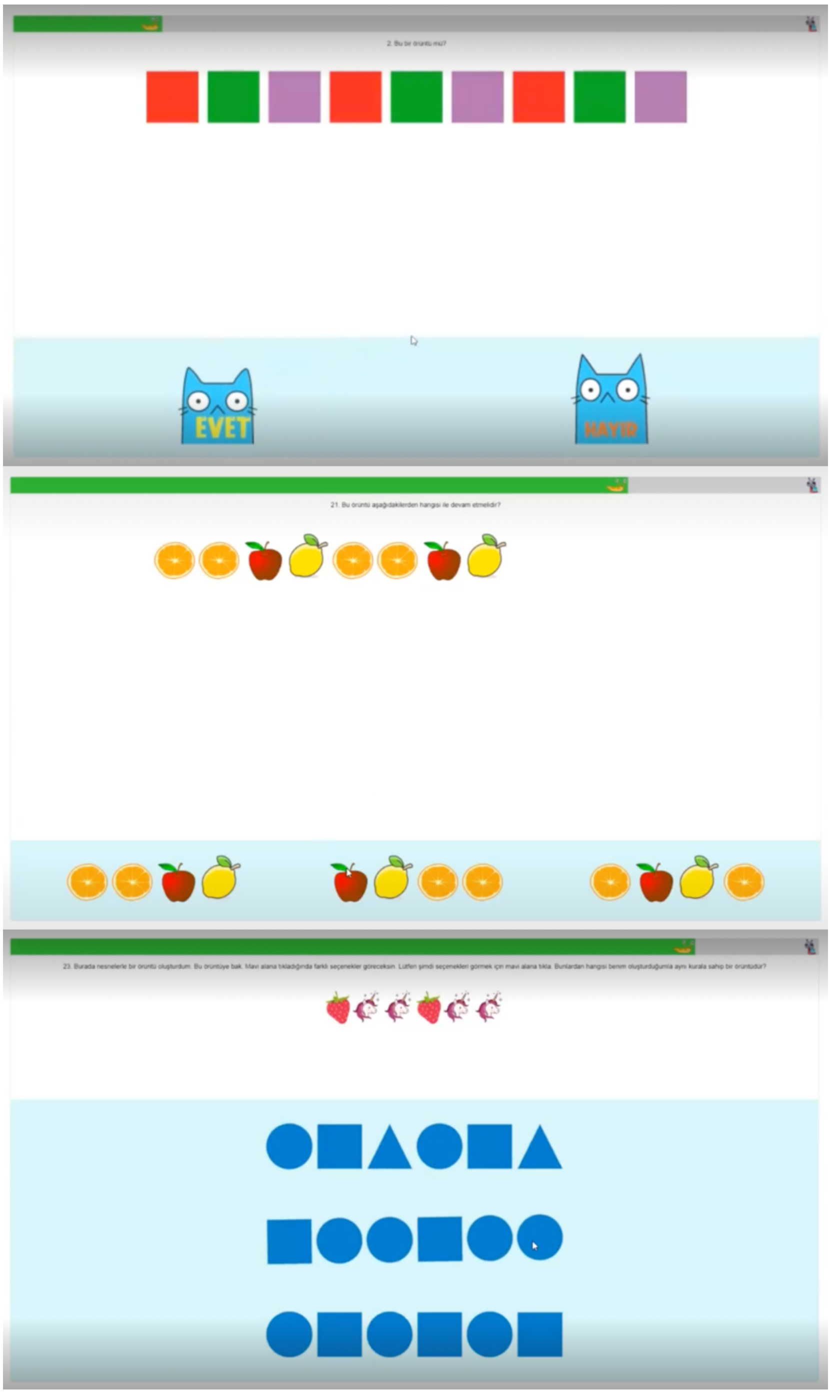

Figure 1. Sample items for each patterning task (ID, extension, and abstraction, respectively)

There were 23 items in total in this assessment. Table 1 presents the distribution of items based on categories and item types. The first three questions were a baseline with pattern ID, extension, and abstraction tasks. The following twelve questions constituted stage 1, which included all three patterning types. The repeating unit of the patterns in the stage 1 questions in the experimental group flashed for a few seconds, giving the student a clue. In the control group, such a situation was not applied. This clue was used in neither the control nor the experimental groups in stage 2, which constituted the following eight questions and included all three patterning types. Since only the control group was evaluated within the scope of this study, there was no difference between stage 1 and stage 2. Thus, these 20 questions were evaluated together. When the reliability value of the scale was calculated, the Cronbach alpha value was found to be .820.

Table 1. Sample Items for Each Task

Repeating items	Pattern ID	Extend	Abstract	Total by individual item type
AB			1	1
AAB		2	1	3
ABB	1	1	1	3
ABC	2	1		3
ABCC			1	1
AABC		1	1	2
AABB	1	2		3
ABCD	1	1	1	3
Not a pattern	4			4
Total	9	8	6	23

3.2.2 The Dimensional Change Card Sort (DCCS)

In the standard version of the Dimensional Change Card Sort (DCCS) scale developed by Frye et al. (1995) to determine children's levels of cognitive flexibility, children are instructed to match the cards based on one dimension (for e.g., color). They are directed to match the same test cards based on another dimension (for e.g., form). In the border version as a more challenging version of the DCCS, added by Zelazo in 2006, children are asked to play a color game if the given picture has a border and a shape game if it has no border. When these two versions are used together (see Figure 2), it is stated that it is appropriate for children aged 2,5-7 (Zelazo, 2006).

Both versions of the DCCS scale were transferred to the online environment by adhering to the instructions in this study. Instructions of both versions of the test was presented in the Appendix A, and the Turkish versions of the scale was illustrated in Appendix B. First, children were told the rule of the color game by playing the exercise game twice. Then, the children played the color game six times without interfering with their answers. Then the shape game started, and the shape game's rule was explained to the child. In this part, the practice game was not played. Children played the shape game six times. Children who got at least five correct points in each game were automatically directed to the border version (This game was not played with children who made more mistakes in previous games). Children starting the border version repeated the game 12 times after playing the trial game twice. In all three parts (color-shape-border version), the researcher repeated the rule of the game every time the children tried.

For scoring, it is recommended to give 0 points if the first phase is unsuccessful; 1 point if the pre-switch phase is passed; 2 points if both the pre-and post-transition phases are passed, but the border version is unsuccessful; 3 points if both the border version and standard version phases are passed. This scale was scored differently in this study, where it was applied online because the standard version, considered the most straightforward possible transition task (Rogers & Monsell, 1995), can be passed by the majority of 4 and 5 years old (Zelazo, 2006).

Those who failed in the standard version of the scale and were successful but failed in the border version were assigned 0 points, and those who were successful in both standard and border versions were assigned 1 point. This study also determined this scale's internal consistency (KR-20) coefficient as .918.

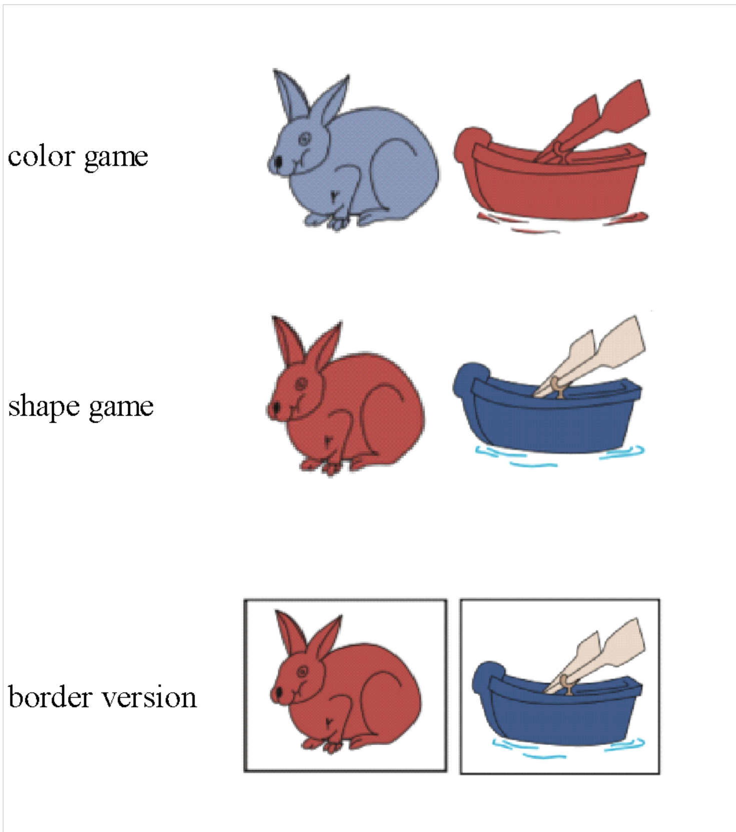

Figure 2. Sample items of the DCCS scale

3.2.3 The Childhood Executive Functioning Inventory (CHEXI)

A scale called "The Childhood Executive Functioning Inventory" (CHEXI), created by Thorell and Nyberg in 2008, assesses the executive functioning of children between the ages of 4 and 12 in terms of working memory and inhibitory control. Test-retest reliability was determined as .86 for the inhibition subscale and .75 for the working memory subscale. The scale was adapted to Turkish by Kayhan (2010) and applied to teachers and parents of first and second-grade students. Arslan-Çiftçi et. al. (2020) removed two items from the test and applied the teacher form to 48–72-month-old children. When this 24-item scale was applied to the parents of 48-72 months old children by Hamamcı and her colleagues (2021), the working memory subscale's internal reliability (Cronbach's alpha) value was determined to be .90, while the inhibitory control subscale's value was .78. In this study, participating parents filled out this scale online. The scale was demonstrated in Appendix C, and Turkish version of the test was presented in Appendix D. The Cronbach's alpha reliability coefficient obtained for inhibitory control was .813, and the Cronbach's alpha reliability coefficient obtained for working memory was .870.

3.2.4 Post study survey

This questionnaire was prepared to receive feedback from parents about the study and to obtain demographic information about the participants. Appendix E presented this survey, and Appendix F illustrated Turkish version of the survey. In this scale, the gender of the children participating in the study, the city they lived in, which school they attended, the number of siblings, their birth order, and their parents' education and employment status were learned.

3.3 Procedure

Before the start of the current study, the necessary permission was obtained from Boğaziçi University Social and Human Sciences Master's and Doctoral Thesis Ethics Review Committee in Appendix G. Participants were determined by the convenience sampling method. First, the research's purpose, how it will be done, and the data collection process were shared by communicating with preschool and school principals. When consent was obtained, an email containing information about the study was sent to the parents/guardians of the children in the age range suitable for the study. In addition, information about this study was provided on the website where "Boğaziçi Öğrenme Laboratuvarı" studies are displayed. Finally, the study was announced on social media accounts (Instagram and Twitter). Parents who wanted to participate in the study filled out the online consent form through Redcap, a secure virtual data collection platform created by Vanderbilt University. The consent form was presented in Appendix H, and Turkish version of this form was demonstrated in Appendix I. After the consent form was filled, Redcap automatically directed the participant candidates to the Calendly page, an online communication platform. Participant candidates chose a date and time that they found convenient for participating in the study on the calendar on this page.

On the specified date, each participant was interviewed via Zoom, a communications platform allowing users to connect via video. In addition to the previously filled online consent form, parents' consent was requested for video recording before starting the study. Besides, verbal consent was requested from the child to start the study. After approval, the website for the online Early Patterning Assessment was provided. Parents stood by the children to help set up the screen and initiate the assessment. Children were asked to answer all questions without any help from their parents. However, parents were allowed to use the mouse if the child did not feel comfortable using the mouse to select responses. This assessment took approximately 20 minutes to complete. For the Dimensional Change Card Sort, verbal consent was obtained from the child for a new game after administering the Early Patterning Assessment. The application was terminated in cases where the children did not want it. (Only five children wanted to stop the study.) The

Dimensional Change Card Sort test started when verbal approval was received. The application time of the test was between 5-10 minutes.

After the children finished the Dimensional Change Card Sort, their accompanying parents were asked to complete the Childhood Executing Functioning Inventory form. It took about 5 minutes to fill out this form. They were then asked to complete the post study survey. The parents filled out this form in approximately 2-3 minutes.

The data collection process completed in interviews lasting approximately 45 minutes with each participant took 13 months. The first participant was interviewed in November 2021, and the last in December 2022. Participants did not be paid or given any other incentives. However, individuals participating in the virtual data collection received a patterning tips document highlighting ways to help their child. In addition, the children received a certificate of participation as a token of appreciation.

During the interviews, the participants completed the scales with the Open Lab platform, where online experiments were conducted. At the end of each study, data from Open Lab was retrieved and securely saved with the code provided to the participant. In addition, the Zoom video recording of the study was also recorded with the same participant code. Moreover, the practitioner reported whether there was a problem that would prevent the use of the data. Before analyzing the data, all the video recordings were watched, and the data in which problems such as parental intervention or practitioner error were detected were extracted. Detailed information about the extracted data is available in the Sample section.

3.4 Research design and data analysis

The SPSS 27.0 (Statistical Package for the Social Sciences) computer program was used to analyze the data of this study using correlational research design. For statistical tests, the significance level was determined at .05. The relationships between the independent and dependent variables were examined in order to test the research questions.

Firstly, demographic characteristics of the participants, including age, gender, school status, and parents' educational status, were reported using frequency, percentage, standard deviation, mean, and maximum and minimum values. After the demographic information was presented, the descriptive data of the variables were shown including frequency, percentage, mean score, standard deviation, and maximum and minimum scores. Before the hierarchical multiple regression analysis, Pearson Product Moment correlation analysis was performed using all the variables in the study.

Moreover, the assumptions required for the regression have been tested. Sample size, normality, linearity, autocorrelation, multicollinearity, and homoscedasticity were analyzed. Finally, a multiple hierarchical regression analysis was performed by taking age (monthly), cognitive flexibility, and working memory predictors, which were associated with patterning in the Pearson Product Moment correlation analysis. Age was entered into the regression model in the first step, cognitive flexibility in the second step, and working memory in the third step.

CHAPTER 4

RESULT

Fifty children from different cities in Turkey participated in this study. Children participating in the study performed patterning and cognitive flexibility assessments, respectively. Parents filled out the Childhood Executive Functioning Inventory which includes working memory and inhibitory control subscales about their child, and the post study survey containing demographic questions about themselves and their children.

4.1 Descriptive findings on demographic information of participants

The age of the children (monthly) varied from 47 to 83 months. The average age of the participating children was 66.36 *(SD = 9.699)* in months and 5.06 *(SD = .108)* in years. There were 30 female children, 60.0% of the participants, and 20 male children, 40.0% of participants. The mean age of the girls was 65.17 months (SD = 9.599), and the boys was 68.15 months (SD = 9.816). The gender distribution by age group and percentage were given in Table 2.

Table 2. Age and Gender Distribution of Participants

		Gender of children			
		Male	Female	Total	Percentage
Age	4	3	10	13	26
	5	8	13	21	42
	6	9	7	16	32
Total		20	30	50	100

The participants included both private and public-school children. While 70% (N=35) of the children were attending preschool, 28% (N=14) were attending first grade, and 2% (N=1) were not attending any school. Moreover, the results of parental educational backgrounds showed that the highest percentage (58%) of the fathers of children participating in the study graduated from university, and no fathers graduated from secondary school or lower levels of education. Likewise, a high percentage of mothers (70%) were university graduates, and at least (2%) were secondary education graduates as shown in Table 3.

Table 3. Distribution of Educational Status of Parents

	Father's Educational Status		Mother's Educational Status	
	Frequency	Percent	Frequency	Percent
Secondary Education	0	0	1	2.0
High School Education	8	16.0	3	6.0
University Education	29	58.0	35	70.0
Master's Degree	11	22.0	6	12.0
Doctoral Degree	2	4.0	5	10.0
Total	50	100.0	50	100.0

4.2 Descriptive analysis of the study variables

Table 4 shows the means, standard deviations, and minimum and maximum scores of the Early Patterning Assessment, The Dimensional Change Card Sort (DCCS), and The Childhood Executive Functioning Inventory (CHEXI) involving their subscales. Patterning scores were obtained from the Early Patterning Assessment scale, cognitive flexibility was obtained from DCCS, and working memory and inhibitory control scores were obtained from the subscales of CHEXI.

Table 4. Descriptive Statistics of the Research Variables

	N	Minimum	Maximum	Mean	Std. Deviation
Patterning	50	5	20	14.44	4.234
Cognitive flexibility	50	0	1	.44	.501
Inhibitory control	50	1.82	4.45	3.39	.643
Working memory	50	2.46	5.00	4.06	.522

In addition, in order to confirm if each variable in the regression model has a normal distribution, skewness and kurtosis were determined in the descriptive statistics. Data is normal, skewness is between -2 and +2, and kurtosis is between -7 and +7 (Bryne, 2010; Curran et al., 1996; Hair et al., 2010). As seen in Table 6, all variables were within the acceptable range.

Table 5. Skewness and Kurtosis for the Study Variables

	N	Skewness		Kurtosis	
	Statistic	Statistic	Std. Error	Statistic	Std. Error
Age (monthly)	50	-.133	.337	-.857	.662
Gender	50	-.421	.337	-1.900	.662
Education level of father	50	.436	.337	.364	.662
Education level of mother	50	.616	.337	1.749	.662
Patterning	50	-.357	.337	-1.067	.662
Cognitive flexibility	50	.249	.337	-2.020	.662
Working memory	50	-.339	.337	.828	.662
Inhibitory control	50	-.814	.337	.327	.662
Valid N (listwise)	50				

4.3 Preliminary analysis for the research variables

Using Pearson Product Moment correlation, bivariate correlations between the research variables were calculated (see Table 5). In this case, grade children were in at the school attended by the children participating in the study was not included in the correlation since it was directly related to age. The results revealed that the age of the children was significantly and positively related to the patterning scores r =.510, *p* =.000 suggesting that older children scored higher than younger children. The age of children was also significantly associated with all executive function components. The correlation of children's age with executive functions was r =.353, *p* =.012 for cognitive flexibility, r =.355, *p* =.011 for working memory, and r =.409, *p* =.003 for inhibitory control.

Mothers' education levels were positively related to fathers' education levels r =.442, *p* =.001. Additionally, the mother's educational status was significantly related to the cognitive flexibility scores of children r =.317, *p* =.025.

When the relationship between patterning scores and other variables was examined, it was found that the variable with the highest significant correlation was age r =.510, *p* =.000. Besides, patterning was positively associated with cognitive flexibility r =.416, *p* =.003, and working memory r =.299, *p* =.035, but no significant correlation was found with inhibitory control. When the significant relationships between executive functions were examined, the highest positive correlation was between working memory and inhibitory control scores r =.578, *p* =.000. Another significant relationship was the positive relationship between cognitive flexibility and working memory r =.465, *p* =.001.

Table 6. Bivariate Correlations for the Research Variables

Variable	1	2	3	4	5	6	7	8
1. Monthly age	1							
2. Gender	-.152	1						
3. Educational status of father	-.074	.045	1					
4. Educational status of mother	-.013	-.084	.442**	1				
5. Patterning	.510**	-.051	.152	.202	1			
6. Cognitive flexibility	.353*	.148	.107	.317*	.416**	1		
7. Working memory	.355*	-.050	-.144	-.062	.299*	.465**	1	
8. Inhibitory control	.409**	-.076	-.084	-.092	.127	.227	.578**	1

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

4.4 Assumptions requiring for hierarchical multiple regression analysis

This study aimed to determine whether executive functions (cognitive flexibility, working memory, and inhibitory control) predict patterning knowledge and, if so, how much. However, the regression did not include the inhibitory control, as the patterning according to the binary correlations shown in Table 5 was unrelated to the inhibitory control. Age, cognitive flexibility, and working memory variables associated with patterning were determined as predictors.

In order to assess the regression assumptions, sample size, linearity, autocorrelation, multicollinearity and homoscedasticity were tested in SPSS software (Pallant, 2016). Below are the results reported in detail.

4.4.1 Sample size

For a reliable equation in a social science study, approximately 15 participants are required for each predictor (Stevens, 1996). In the regression model in this study, the total number of participants had to be at least 45 since it would be examined whether three predictors (age, cognitive flexibility, and working memory) predicted patterning. As a result, the power of the study was obtained with the data collected from 50 participants.

4.4.2 Linearity

To confirm the linearity assumption, the SPSS software was used to conduct the linear regression analysis. In the normal p-p plot of regression standardized residual, the points formed a diagonal path predominantly straight, as seen in Figure 3.

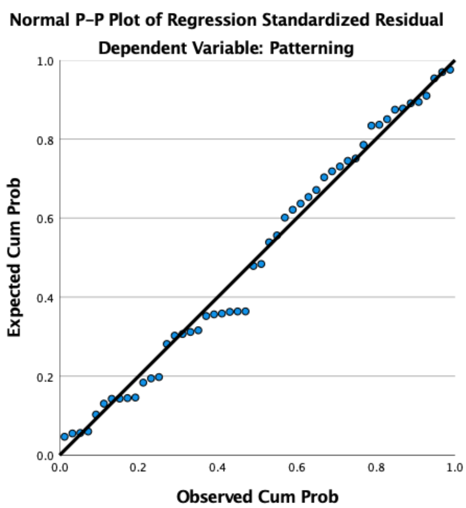

Figure 3. Normal p-p plot of regression standardized residual

4.4.3 Autocorrelation

Durbin-Watson test in the SPSS program was used to test whether there was autocorrelation in the regression model. If the Durbin-Watson test results are between 1.5 and 2.5, it is considered that there is no autocorrelation (Draper & Smith, 1981). In this case, it was assumed that there was no autocorrelation since the results of the Durbin-Watson result was 2.370.

4.4.4 Multicollinearity

To determine how much of each independent variable's variability was not explained by the other independent variables in the model, the multicollinearity test was used. To assert that the variables in the regression model do not exhibit multicollinearity, variance inflation factor (VIF) values are expected to be below 10 and tolerance values above 0.1 (Myers, 1990). Since the VIF and tolerance values obtained from the independent variables in this model were in the acceptable range, the model did not have a multicollinearity problem (see Table 7).

Table 7. Multicollinearity Statistics

	Collinearity Statistics	
	Tolerance	VIF
Age (monthly)	.829	1.206
Cognitive flexibility	.744	1.345
Working memory	.742	1.347

a. Dependent Variable: Patterning

4.4.5 Homoscedasticity

Figure 4 illustrates the application of a scatterplot for regression standardized residuals for patterning. The homoscedasticity assumption is satisfied because the scatterplot displays a random pattern.

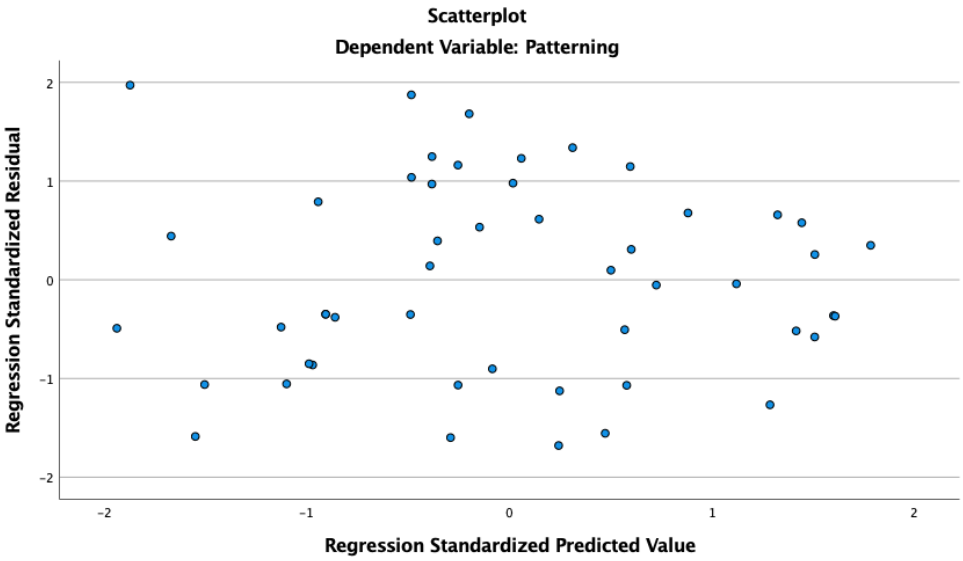

Figure 4. Scatterplot for regression standardized residuals

4.5 Results of hierarchical multiple regression analysis

A three-stage hierarchical multiple regression was conducted with patterning as the dependent variable, as seen in Table 8. Age (monthly) was entered at stage one of the regression to control for children's ages. Cognitive flexibility, which had a stronger correlation with patterning, was entered into stage two, and working memory was entered into stage three. The hierarchical multiple regression revealed that at stage one, age (monthly) contributed significantly to the regression model, $F\ (1,48) = 16.87$, $p < .001$ and accounted for 26% of the variation in patterning. Subsequently, introducing the variable of cognitive flexibility explained an additional 6.4% of the variation in patterning. This change in R^2 was significant, $F\ (1,47) = 4.44$, $p < .05$

with b = .415, SE = .056, *p* <.05 for age and b = .270, SE = 1.082, *p* <.05 for cognitive flexibility (see Table 9). Finally, adding working memory to the regression model explained no significant change in R^2. When all three independent variables were included in stage three of the regression model, neither cognitive flexibility nor working memory was a significant predictor of patterning. In this case, a significant regression equation was found (F [3, 46] = 7.379, *p* <.001) with R^2 =.325. This means that stage three of the regression model explained 33% of the variance in the patterning scores. Further, the only significant variable that predicted patterning was age (monthly) b = .407, SE = .058, *p* <.05. Table 9 shows that cognitive flexibility b = .256, SE = 1.186, *p* >.05 and working memory b = .036, SE = 1.140, *p* >.05 were not significant predictors.

Table 8. First Model Summary of Multiple Hierarchical Regression

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.510[a]	.260	.245	3.680	.260	16.869	1	48	.000
2	.569[b]	.324	.295	3.554	.064	4.442	1	47	.040
3	.570[c]	.325	.281	3.590	.001	.065	1	46	.800

a. Predictors: (Constant), Age (monthly)
b. Predictors: (Constant), Age (monthly), CF
c. Predictors: (Constant), Age (monthly), CF, WM
d. Dependent Variable: Patterning

Table 9. Coefficients of the First Multiple Hierarchical Regression Model

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.332	3.634		-.091	.928
	Age (monthly)	.223	.054	.510	4.107	.000
2	(Constant)	1.426	3.608		.395	.695
	Age (monthly)	.181	.056	.415	3.235	.002
	Cognitive flexibility	2.281	1.082	.270	2.108	.040
3	(Constant)	.523	5.082		.103	.919
	Age (monthly)	.178	.058	.407	3.058	.004
	Cognitive flexibility	2.164	1.186	.256	1.824	.075
	Working memory	.291	1.140	.036	.255	.800

CHAPTER 5

DISCUSSION

5.1 General discussion of the study

Most preschool and kindergarten programs include patterning as a fundamental component, and preschool instructors agree that patterning knowledge is crucial for early childhood education (Economopoulos, 1998; Schmerold et al., 2017). The ability to form patterns has been recognized as an essential cognitive process that forms the basis of pre-algebraic thinking (Papic & Mulligan, 2005). For this reason, research on patterning knowledge has been increasing in recent years. However, while many studies have shown that patterning helps young children learn mathematical skills, only a few studies have focused on the cognitive aspects of patterning knowledge (Schmerold, 2015).

In the literature, the relationships between patterning and mathematics, reading, or relational knowledge in children have been investigated generally. However, few studies have examined the relationship between executive functions and patterning knowledge. Moreover, the findings of these studies have been inconsistent (Bock et al., 2018; Kidd et al., 2019; Miller et al., 2015; Rittle-Johnson et al., 2013; Schmerold, 2015). Researchers have based this situation on the types of patterning tasks used in the studies (Schmerold, 2015) and the relevance of executive function scales (Kidd et al., 2019; Strauss et al., 2020). Therefore, more thorough studies using proper assessment techniques have been suggested (Bock et al., 2018; Kidd et al., 2013; Miller et al., 2015). From this point of view, this study examined the role of executive functions (cognitive flexibility, working memory, and inhibitory control) on patterning knowledge in children aged 4 to 7 years.

The online Early Patterning Assessment translated into Turkish by the "Boğaziçi Öğrenme Laboratuvarı" was applied to Turkish children for the first time with this study. In the online interviews, parents and their children who voluntarily participated in the study were interviewed via Zoom. In the interviews that lasted approximately 45 minutes with each child and her/him parent, patterning and cognitive flexibility scores were obtained from the child, and the child's working memory and inhibitory control scores were obtained from the parents. Data from 50 children and their parents were analyzed, and the results were discussed in detail below.

5.1.1 Assessment of patterning knowledge

Some features of the patterning knowledge assessment in this study that may have an impact on the results of the study are discussed below. These are patterning types, Item difficulties and observational assessments.

According to Bock et al. (2018), studies investigating the relationship between patterning and executive function have revealed varying results, which can be explained by the fact that the scales of patterning knowledge utilize diverse stimuli, including numbers, colors, and letters. The online patterning scale used in this study contained no numbers or letters. This situation can be counted as one of the study's strengths, as only a small proportion of the children participating in the study started primary school.

Item difficulty analysis of the current study demonstrated that the pattern ID questions which were expected to be easier were indeed found to be easier than the others, and extension and abstraction pattern items were more difficult. However, the abstraction items, expected to be the most difficult for children, could not be completely differentiated from the other patterning tasks. There may be several reasons for not enough apparent differences in difficulty between the patterning types in the assessment.

Firstly, children may have experienced learning the task introduced to them (experiment-wise error) during the patterning assessment. According to the observational evaluation, while the students had more difficulty with the first questions of the scale, they answered the questions more quickly as the test progressed. In particular, some students who encountered the concept of pattern for the first time understood this concept better and started to give more correct answers as time progressed while making more mistakes at first. In the meantime, the parents of some students said that their children did not fully understand the concept of "pattern" and asked for permission to explain themselves. However, only the practitioner explained the pattern concept to each student through the practice questions. No additional explanation was given to the children who needed to learn the pattern to treat every child equally. As a result, due to learning, in the pattern identification items, which make up the first questions of the scale and were expected to be easier, a similar number of wrong answers to the extension and abstraction questions may have been obtained.

Secondly, observational evaluations suggested that some children solved the patterning questions using object matching. Some children matched the elements in two different patterns with their fingers in abstraction patterning items. In contrast, others verbally expressed which element in one pattern matched which element in the other pattern. However, in the abstraction questions, the expectation was for the children to recognize the unit and rule of the given pattern and to select the pattern with the same rule from the given choices on the screen. Children who did one-to-one matching could answer these questions without needing cognitive skills (Collins & Laski, 2015). Therefore, this situation may have led to more correct answers in the abstraction items.

Finally, it was observed that some children gave incorrect answers to the two pattern extension questions in stage 1, not from lack of patterning knowledge but from inattention. Although the repeating pattern unit is blue-yellow-red in item 10 in stage 1, which appears in Figure 5, some children hastily chose the first option when they saw that the first element of the first choice was blue. Similarly, although the repeating pattern unit was red-yellow-green-purple in item 11 in stage 1, some students saw that the first choice started with red and hurried to mark the first choice.

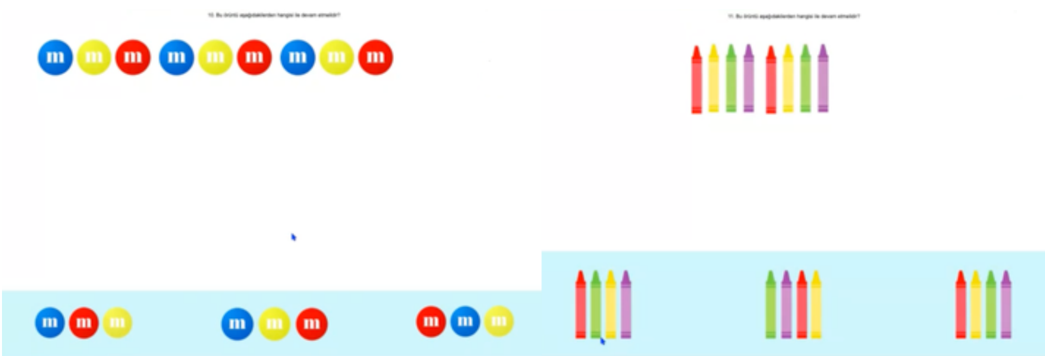

Figure 5. Extension of patterns items

One of the things that attracted attention during the online patterning assessment of the children was that some students hummed and repeated the pattern elements. One student even counted the different colored elements in the pattern as 2-1-2-1. As previously mentioned in some studies, these children tended to comprehend patterns by focusing on sequential objects (Economopoulos, 1998; McGarvey, 2012; Papic et al., 2011). When the mother of a child who did not understand the question "Which pattern has the same rule?" said the following sentence, the child could answer correctly: "Which one proceeds in the same way?". Likewise, when the mother of another child instructed the child to "Count the colors", the child began to answer the questions correctly. According to Threlfall (1999), for determining the connection between patterning and generalization, children's sense of a unit of repeat in a pattern without the propensity to use this recursive thinking to patterns is essential. During this study, some children chose the wrong option because they only paid attention to the first element of the pattern units in the choices.

5.1.2 The role of age

The present study results obtained using the Pearson Product Moment correlation test showed that patterning was significantly associated with age, cognitive flexibility, and working memory. As detailed in the Result section, the patterning had the highest correlation with age. Indeed, hierarchical multiple regression results showed that a substantial proportion of executive functions' contribution to patterning knowledge is age dependent. Many studies evaluating patterning in children also support these results.

Bennett and Müller (2010) examined the patterning and cognitive flexibility skills of children aged 3-5. They found that performance on difficult items in the patterning scale was significantly associated with age. Bennett and Müller (2010) suggested no significant difference in the easy items in the patterning scale because older children might have obtained incorrect results by using more complex strategies. Likewise, in a study with children aged 5 to 13, Fyfe et al. (2017) found that older children had higher scores on difficult items in the patterning assessment. They even found that children's ages predicted their patterning scores. Similar results were obtained in studies with a narrower age range. For instance, Collins and Laski (2015), in their research with children aged 4 and 5, showed that children's ages predicted patterning performance and even that they were the most effective predictors in duplication repeating pattern tasks. Harvey and Miller (2017) also revealed that their ages had an impact on patterning in children aged 3 to 4.

As can be seen, age significantly affects patterning knowledge, especially in preschool children. Since executive functions develop rapidly in the preschool period (Diamond, 2006; Garon et al., 2008), a large part of this effect can be attributed to the development of executive functions. In this study, in order to obtain a more precise result, hierarchical multiple regression analysis was applied to find out the role of cognitive flexibility and working memory in patterning regardless of age. There was no significant correlation between inhibitory control and patterning to run a regression analysis.

5.1.2.1 The role of cognitive flexibility

According to the preliminary analysis, cognitive flexibility was the executive function with the strongest correlation with children's patterning knowledge. Moreover, in the regression model, it was the only executive function that predicted patterning before age was introduced. Only when age, cognitive flexibility, and working memory were added to the regression model, it did not significantly predict patterning. This result was most likely since the executive function development of preschool children is closely related to age (Diamond, 2006; Garon et al., 2008). The other results were expected because although only a few studies have been conducted on this subject, studies have shown that preschool children's cognitive flexibility capacities and patterning performances are related (Bennett & Müller, 2010; Bock et al., 2018; Schmerold, 2015). As a study that overlaps with the results of this study, in Schmerold's (2015) study with first graders, cognitive flexibility was found to be the only executive function that predicts children's patterning knowledge.

The hierarchical multiple regression results in the present study showed that cognitive flexibility was a predictor in children's patterning knowledge, with and without considering their ages. However, cognitive flexibility had a higher role in patterning when considered with age, whereas it had a much less role regardless of age. One reason might be that as children grow, they have more opportunities to practice patterns at school and in their daily lives (Miller et al., 2015). Thus, children might become less in need to use their cognitive flexibility capacities. For example, in Miller et al.'s (2015) study, while children's cognitive flexibility scores were related to patterning before the patterning intervention, they were unrelated after the intervention, possibly due to a similar reason.

In conclusion, within the scope of this study, cognitive flexibility was found to be the only executive function that predicts the patterning knowledge of children aged 4, 5, and 6 years, in line with the literature. When evaluated independently of age, the reasons for the decrease in its effect may be that the development of cognitive flexibility is closely related to age, that patterning experiences increase in direct proportion to age, and other reasons that have not been investigated yet.

5.1.2.2 The role of working memory

Correlation analysis in the current study revealed that patterning knowledge in children aged 4 to 7 years was significantly associated with working memory, although less than with cognitive flexibility. This was an expected result because researchers have suggested that the duplication, extension, and abstraction of repeating patterns need the working memory capacities of children. In order to do these tasks, children need to consider and use more than one piece of information, match new items with existing items in the sample pattern, order them correctly, and actively transform them (Collins & Laski, 2015; Rittle-Johnson et al., 2013). Rittle-Johnson et al. (2013) showed that 4-year-old children's working memory capacities were significantly related to their patterning performances. In addition, Kidd et al. (2019) found a positive correlation between them in preschoolers. Moreover, Miller et al. (2015) found that 4- and 5-year-olds' patterning knowledge was predicted only by working memory before and after the intervention, suggesting that working memory had an essential role in learning through patterning.

In this study, although a significant and positive correlation was detected between working memory and patterning, it was found that working memory did not predict patterning in the hierarchical multiple regression analysis conducted after correlation analyses. The result in correlation analysis may have resulted from the relationship between working memory and cognitive flexibility. Similarly, in the study of Schmerold (2015) with first graders, working memory was slightly related to children's patterning knowledge but did not predict it.

Additionally, Bock et al. (2018) found that working memory predicted spatial patterns but did not reach a significant result for pictorial patterns. They attributed this to the fact that children do not need much working memory capacity in multiple-choice pictorial pattern questions. In this study, multiple-choice pictorial patterns were used, and both questions and choices continued appearing on the screen until the children solved the question. Hence, children may have completed the patterning scale without much need for working memory, which explains why it did not predict patterning.

Finally, another possible reason working memory was not a significant predictor of patterning is that the abstraction items in this study were not appropriate enough. Children need working memory to solve abstract pattern items because they cannot comprehend these patterns only with the one-to-one matching strategy (Collins & Laski, 2015). According to observational assessments, children generally used the object-matching strategy during the patterning assessment. Besides, the results of the difficulty analyses of the patterning scale items also supported this hypothesis.

The literature shows that there is still a lack of consistent studies on the role of working memory in patterning. The relationship between working memory and patterning may be affected by age, other executive functions, object-matching strategy, and other variables that are not yet known. More detailed studies are needed to elucidate these variables. The result of this study is an essential contribution to the literature on this subject that working memory was found to be significantly associated with patterning but not significantly predicting it. In further studies, it is still vital to elucidate the relationship between working memory and patterning.

5.1.2.3 The role of inhibitory control

Based on the preliminary analysis within the scope of this study, inhibitory control scores obtained from 50 participating children aged 4, 5, and 6 did not significantly correlate with their patterning knowledge. Despite the inconsistent results of previous studies on this subject, it is thought that children with high inhibition control capacity can better use the relational similarity strategy in pattern-making tasks (Collins & Laski, 2015). Inhibitory control can help children focus on the pattern's structure and create complex patterns instead of getting distracted by simple ones (Miller et al., 2015; Rittle-Johnson et al., 2013). It also helps them identify repeating units in a pattern and focus on larger and more complex units (Collins & Laski, 2015).

Although inhibitory control is thought to be effective in recognizing and manipulating patterns, the relationship between inhibitory control and patterning is not fully elucidated yet. Kidd et al. (2019) found that children's patterning performance was associated with inhibitory control, while Collins and Laski (2015) found that only abstraction pattern items were associated with inhibitory control scores. On the other hand, no significant relationship was found in the study of Miller et al. (2015). Additionally, Schmerold (2017) and Bock et al. (2018) did not find a significant relationship using another inhibitory control scale for first graders. These inconsistent study results have been attributed to variations in different populations' inhibitory capacity and measurement requirements (Kidd et al., 2019). Strauss et al. (2020) argued that age-appropriate assessments for inhibitory control should be chosen in research.

In this study, no significant correlation was found between patterning and inhibitory control, although there was no problem with the appropriateness of the scales for children's ages. The inappropriateness of abstraction items and the fact that children generally use the object-matching method may have caused them not to need inhibitory capacities because children often need inhibitory control skills in abstraction patterning items (Collins & Laski, 2015). The relationship between inhibitory control and patterning knowledge in children needs to be examined with patterning assessments that do not allow object-matching techniques in the future.

5.2 Limitations of the study

This study has some limitations. The first is the issues arising from the study being conducted online. Since it was an online study, children generally participated in it in their home environment and were accompanied by at least one parent. Because some children exhibit behaviors dependent on their parents, it was difficult to expect them to participate in the study without the influence of their parents. In addition, some parents were overly intrusive despite being warned at the beginning of the study. These studies were excluded from the dataset. Also, although some parents did not verbally interfere with the children's responses, they provided feedback on their responses with gestures and facial expressions. These data were also removed because they would be affected by the parents.

The second limitation is the lack of knowledge of children's previous patterning knowledge and experience. All but one of the children participating in the study attended preschool or first-grade education. Since there is no information about the frequency or quality of the patterning practices they experience in schools, this situation may have affected the patterning performance of the children in different ways. In order to minimize the limitation of not knowing the pattern concept, the concept of the pattern was introduced to each child, the study was started, and then three practice questions were applied.

The third limitation is that children frequently used the object-matching strategy during the patterning assessment. Contrary to expectations, the difficulty levels of all patterning types were close to each other. Some children made one-to-one matching by murmuring, while some also answered the questions by matching objects in different patterns with their fingers. While developing the scale, the size of the elements of the patterns in the answer options was designed to be smaller than the size of the elements of the pattern in the question to prevent this. However, it was understood that object-matching could not be avoided entirely. In future studies, some changes can be made to the scale to prevent children from object-matching. For example, in abstraction patterns questions, instead of multiple choice, it can be ensured that children select the elements of the pattern one by one by drag-and-drop on the screen and bring them together.

The fourth limitation is that the order of application of the scales is the same for each participant. Each child completed the patterning scale first and then the DCCS scale. After the patterning scale lasts for about 20 minutes, children may get bored and distracted, so cognitive flexibility performances evaluated by this scale may be affected. In future studies, the scales may be counterbalanced and reapplied.

5.3 Educational recommendations

It is thought that patterning teaching given in early childhood education and the first years of primary school contributes positively to children's relational knowledge, pre-algebraic thinking, mathematical problem-solving skills, and even their future mathematics achievements (Bock et al., 2018.; Collin & Laski, 2015; Miller et al., 2015; Pasnak, 2017). Understanding the role of executive functions, which have common features and begin to become independent in early childhood, in patterning is one of the prerequisites for making the appropriate interventions for children in this period when cognitive development is most critical. This study provides valuable information about the role of executive functions in patterning knowledge. It also emphasizes the significance of using age-appropriate assessment techniques to examine the connection between children's cognitive and mathematical skills.

Broad pattern teaching raised the exam results of first graders needing help understanding general mathematical concepts and patterns (Kidd et al., 2013; 2014). According to Kidd et al. (2013), it was suggested that children who develop their abstract thinking skills thanks to patterning practices understand mathematics as a whole rather than directly recognizing mathematical concepts. For this reason, they claimed that pattern teaching must be continued with short sessions throughout the year to realize the benefits of pattern teaching on mathematics achievement. Moreover, Lee et al. (2012) assumed that it has been with different long-term experiences that recognizing patterns support computational skills in children. In early mathematics teaching, recognizing patterns may be crucial in defining or expressing the linkages due to first defining and then calculating (Post et al., 1988).

As the results of this study supported, cognitive flexibility predicts children's patterning performance, which can guide educators and researchers to pattern teaching or scale development processes. The lower-than-expected contribution of executive functions to patterning in children, regardless of age, may be a good starting point for future research. Factors other than executive functions that underlie the strong influence of age on patterning can be explored. In addition, the findings on working memory and inhibitory control also showed that object-matching prevents children from experiencing these cognitive skills. In pattern activities implemented in early childhood education, strategies can be developed to prevent children from using object matching. Thus, children's development of relational knowledge is supported.

To conclude, pattern education must be included in the early childhood and primary education curriculum suitable for each age group, considering that it is not only about teaching specific sequences but also related to children's cognitive and mathematical skills. In this regard, various patterning activities and practices that preschool and primary school teachers and parents can apply with children in school or daily life can be beneficial. Based on this, teacher training and parent training programs for theory and practice can be developed, and support materials can be designed.

APPENDIX A

THE DIMENSIONAL CHANGE CARD SORT

(ENGLISH)

Part 1

The researcher shows the target pictures and says, "Now we will play a game with you using these pictures". Then he/she introduces them by saying "Here is a blue rabbit and here is a red boat". Then he/she says, "Now we will play a color game with you". The practice starts by explaining the color game: "In the color game, blue colors go under the blue rabbit." and shows the target picture with the blue rabbit. "Red colors go under the red colored boat." and the target picture with the red boat is shown.

Then "Look! The blue picture will go under the blue rabbit. To do this, just click on the blue rabbit once." The target picture with the blue rabbit is clicked and the picture is placed under the blue rabbit. The rules of the color game are reminded again: "Blues go under the blue rabbit and reds go under the red colored boat."

Then another test picture (the red rabbit because the blue boat was taken on the first try) is shown and the children are asked, "Look! The red picture, where does it have to go? Click once on the picture that needs to go" and so on.

If the child places the picture correctly, the child is praised by saying "Well done!". If the child places the picture incorrectly, the child is corrected by saying "No, it is red and in the color game, reds go under the red boat." Make sure that the child clicks on the picture once. Without waiting, the color game is started with the child.

"Now it is your turn! Please remember, if it is blue, it will go under the blue rabbit, if it is red, it will go under the red boat. It is enough to click once on the picture that needs to go" and the rule is reminded.

The child is shown 6 pictures in turn and the rule is repeated before each picture: "If it is blue, it will go under the blue rabbit, if it is red, it will go under the red boat. It is enough to click on the picture once."

No feedback is given whether the child is right or wrong. When 6 cards are finished, the shape game is started.

"Now we will play a new game with you. We will not play color game anymore. Now we will play shape game with you. In the shape game, the rabbits go under the rabbit picture. It is enough to click once on the picture that needs to go" and the target picture with the blue rabbit is shown. Then, "The boats go under the picture of the boat. Just click once on the picture that needs to go" and the target picture with the red sandal is shown.

The rule of the figure game is repeated.

"Please remember, if it is a rabbit, it goes under the rabbit picture, if it is a sandal, it goes under the sandal picture. It is enough to click once on the picture it should go to."

There is no trial phase before the shape game. A picture is selected, and the child is asked where to go. The child is shown 6 pictures in turn and the rule is repeated before each card:

"If it is a rabbit, it goes under the rabbit picture, if it is a boat, it goes under the boat picture. It is enough to click once on the picture that needs to go."

No feedback is given whether the child is right or wrong.

Points to be considered by the researcher:

During the applications, the child should not be given the same picture more than 2 times in a row. In order for the children to move on to the shape game, they must place at least 5 pictures correctly in the color game. If children place less than 5 pictures correctly in the color game, they get 0 points. If they place 5 or more pictures correctly in the color game but less than 5 pictures correctly in the shape game, they get 1 point. If they place 5 or more pictures correctly in both the color game and the shape game, they get 2 points.

Part 2 (Framed Version)

Children who score 2 points in part 1 of the DCCS task (at least 5 correct answers in part 1 and at least 5 correct answers in part 2) can immediately move on to part 2, which uses the same framed pictures as part 1.

"OK, you played the game really well. Now I have a more difficult game for you. In this game, sometimes you will see pictures with a black frame around it, like this one [show a red rabbit with a frame]. When you see the picture with the black frame, you must play the color game. In the color game, the red ones go under the red boat and the blue ones go under the blue rabbit [pointing to appropriate pictures]. This picture is red, so I will click once on the red-colored rabbit. But if there is no black frame like this on the cards [show a picture of a red rabbit without a frame], you must play the shape game. In the shape game, if it is a rabbit, we click once on the rabbit to make it go under the rabbit picture, and if it is a boat, we click once on the boat to make it go under the boat picture [point to the appropriate pictures]. This is a rabbit, so I'm going to match it with the rabbit picture, so I'm going to click once on the rabbit picture, OK? Now it's your turn."

Part 2, the framed version, consists of 12 trials. Repeat the rules for each trial ("If the picture has a frame, play the color game. If there is no frame in the picture, play the shape game."). After the child has made each match, say, "Let's do another one". For example, "Remember, if there is a black frame, you have to play the color game. But if there is no black frame, you must play the shape game. Here is a picture with a black frame. Where should it go? Just click once on the picture where it should go. [Let's make another one". As in part 1, respond to the children in a neutral, evaluative, and non-corrective way.

Performance in the framed version is scored out of 12. Children are considered to have successfully completed this task if they correctly match 9 or more cards out of 12 attempts.

APPENDIX B

THE DIMENSIONAL CHANGE CARD SORT

(TURKISH)

Bölüm 1

Araştırmacı hedef resimleri gösterir ve "Şimdi bu resimleri kullanarak seninle bir oyun oynayacağız" der. Ardından, "Burada mavi tavşan ve burada da kırmızı sandal var" diyerek tanıtır. Daha sonra "Şimdi seninle renk oyunu oynayacağız" der. Uygulamaya renk oyunu anlatılarak başlanır: "Renk oyununda mavi renkler, mavi renkli tavşanın altına gider" diyerek mavi tavşanın olduğu hedef resim gösterilir. "Kırmızı renkler, kırmızı renkli sandalın altına gider" diyerek kırmızı sandalın olduğu hedef resim gösterilir.

Daha sonra "Bak! Mavi resim, mavi renkli tavşanın altına gidecek. Bunun için mavi tavşanın üzerine bir kere tıklaman yeterli" diyerek mavi tavşanın olduğu hedef resme tıklanır ve resim mavi tavşanın altına gelecek şekilde yerleştirilir. Renk oyunun kuralları tekrar hatırlatılır: "Maviler mavi tavşanın altına, kırmızılar ise kırmızı renkli sandalın altına gider."

Daha sonra bir test resmi daha (ilk denemede mavi sandal alındığı için kırmızı tavşan) gösterilerek, "Bak! Kırmızı resim, nereye gitmesi gerekiyor? Gitmesi gereken resmin üzerine bir kez tıkla" denir.

Çocuk resmi doğru yerleştirirse "Aferin! " diyerek çocuk övülür. Çocuk resmi yanlış yerleştirirse "Hayır, bu kırmızı renkli ve renk oyununda kırmızılar kırmızı sandalın altına gider" diyerek düzeltilir. Çocuğun resmin üzerine bir kez tıklamasına dikkat edilir. Hiç beklenmeden çocuk ile renk oyununa başlanır.

"Şimdi sıra sende! Lütfen unutma, eğer maviyse mavi tavşanın altına, kırmızıysa kırmızı sandalın altına gidecek. Gitmesi gereken resmin üzerine bir kere tıklaman yeterli" diyerek kural hatırlatılır.

Sırayla 6 adet resim çocuğa gösterilir ve her resimden önce kural tekrar edilir: "Eğer maviyse mavi tavşanın altına, kırmızıysa kırmızı sandalın altına gidecek. Gitmesi gereken resmin üzerine bir kere tıklaman yeterli. "

Çocuk doğru da yapsa yanlış da yapsa geri dönüt verilmez. 6 adet kart bittiği zaman şekil oyununa geçilir.

"Şimdi seninle yeni bir oyun oynayacağız. Artık renk oyunu oynamayacağız. Şimdi seninle şekil oyunu oynayacağız. Şekil oyununda tavşanlar, tavşan resminin altına gider. Gitmesi gereken resmin üzerine bir kere tıklaman yeterli" diyerek mavi tavşanın olduğu hedef resim gösterilir. Ardından "Sandallar, sandal resminin altına gider. Gitmesi gereken resmin üzerine bir kere tıklaman yeterli" diyerek kırmızı sandalın olduğu hedef resim gösterilir.

Şekil oyunun kuralı tekrar edilir.

"Lütfen unutma, eğer tavşansa tavşan resminin altına, sandalsa sandal resminin altına gider. Gitmesi gereken resmin üzerine bir kere tıklaman yeterli. "

Şekil oyunundan önce herhangi bir deneme aşaması yoktur. Bir resim seçilir ve çocuğa nereye gideceği sorulur. Sırayla 6 adet resim çocuğa gösterilir ve her karttan önce kural tekrar edilir:

"Eğer tavşansa tavşan resminin altına, sandalsa sandal resminin altına gider. Gitmesi gereken resmin üzerine bir kere tıklaman yeterli. "

Çocuk doğru da yapsa yanlış da yapsa geri dönüt verilmez.

Araştırmacını Dikkat Etmesi Gereken Noktalar:

Uygulamalar sırasında çocuğa aynı resimden 2 defadan fazla art arda verilmemelidir. Çocukların şekil oyununa geçebilmeleri için renk oyununda en az 5 adet resmi doğru yerleştirmeleri gerekmektedir. Çocuklar renk oyununda 5 adetten az resmi doğru yerleştirirlerse 0 puan alırlar. Renk oyununda 5 adet ve daha fazla resmi doğru yerleştirirler fakat şekil oyununda 5 adetten az resmi doğru yerleştirirlerse 1 puan alırlar. Hem renk oyununda hem de şekil oyununda 5 adet ve daha fazla resmi doğru yerleştirirlerse 2 puan alırlar.

Bölüm 2 (Çerçeveli Versiyon)

Boyut Değiştirerek Kart Eşleme görevinin 1. bölümünden 2 puan alan çocuklar (1. kısımdan en az 5 adet doğru ve 2 kısımdan en az 5 adet doğru yanıt veren çocuklar), 1. bölüm ile aynı resimleri çerçeveli bir şekilde kullanan 2. bölüme hemen geçebilirler.

"Tamam, gerçekten oyunu iyi oynadın. Şimdi senin için oynaması daha zor bir oyunum var. Bu oyunda, bazen bunun [çerçeveli kırmızı bir tavşan gösterin] gibi çevresinde siyah bir çerçevesi olan resimler göreceksin. Siyah çerçeveli resmi gördüğünde, renk oyunu oynamalısın. Renk oyununda kırmızı olanlar kırmızı sandalın altına, mavi olanlar mavi tavşanın altına gidiyor [uygun resimleri göstererek]. Bu resim kırmızı, bu yüzden kırmızı renkli tavşanın üzerine bir kez tıklayacağım. Ama kartlarda bunun gibi siyah bir çerçeve yoksa [çerçevesiz kırmızı bir tavşan resmini gösterin], şekil oyununu oynamalısın. Şekil oyununda tavşansa, tavşan resminin altına gelmesi için tavşanın üzerine bir kez tıklarız, sandalsa, sandal resminin altına gelmesi için sandalın üzerine bir kez tıklarız [uygun resimleri göstererek]. Bu bir tavşan, bu yüzden onu tavşan resmi ile eşleştireceğim, bunun için de tavşan resminin üzerine bir kez tıklayacağım. Tamam mı? Şimdi sıra sende."

Çerçeveli versiyon olan 2. bölüm, 12 denemeden oluşmaktadır. Her denemede kuralları tekrarlayın ("Resimde çerçeve varsa renk oyununu oyna. Resimde çerçeve yoksa şekil oyununu oyna."). Çocuk her eşleştirmeyi yaptıktan sonra, "Hadi bir tane daha yapalım" deyin. Örneğin, "Unutma, siyah bir çerçeve varsa renk oyununu oynaman gerekir. Ancak siyah çerçeve yoksa şekil oyununu oynamalısın. İşte siyah çerçeveli bir resim. Nereye gitmeli? Gitmesi gereken resmin üzerine bir kere tıklaman yeterli. [Çocuk yaptıktan sonra] Haydi bir tane daha yapalım". 1. bölümde olduğu gibi, çocuklara tarafsız, değerlendirici ve düzeltici olmayan bir şekilde yanıt verin.

Çerçeveli versiyondaki performans 12 üzerinden puanlanır. Çocuklar, 12 denemesinden 9 veya daha fazla kartı doğru eşleştirirse bu görevi başarıyla tamamlamış sayılırlar.

APPENDIX C

THE CHILDHOOD EXECUTIVE FUNCTIONING INVENTORY (CHEXI) – PARENT FORM (ENGLISH)

Below, you will find a number of statements. Please read each statement carefully and thereafter indicate how well that statement is true for the child. You indicate your response by circling one of the numbers (from 1 to 5) after each statement.

Definitely not true	**Not true**	**Partially true**	**True**	**Definitely true**
1	2	3	4	5

	1	2	3	4	5
1. Has difficulty remembering lengthy instructions					
2. Seldom seems to be able to motivate him/herself to do something that he/she doesn't want to do					
3. Has difficulty remembering what he/she is doing, in the middle of an activity					
4. Has difficulty following through on less appealing tasks unless he/she is promised some type of reward for doing so					
5. Has a tendency to do things without first thinking about what could happen					
6. When asked to do several things, he/she only remembers the first or last					
7. Has difficulty coming up with a different way of solving a problem when he/she gets stuck					
8. When something needs to be done, he/she is often distracted by something more appealing					
9. Easily forgets what he/she is asked to fetch					
10. Gets overly excited when something special is going to happen (e.g., going on a field trip, going to a party)					
11. Has clear difficulties doing things he/she finds boring					
12. Has difficulty planning for an activity (e.g., remembering to bring everything necessary for a field trip or things needed for school)					

13. Has difficulty holding back his/her activity despite being told to do so					
14. Has difficulty carrying out activities that require several steps (e.g., for younger children, getting completely dressed without reminders; for older children, doing all homework independently)					
15. In order to be able to concentrate, he/she must find the task appealing					
16. Has difficulty refraining from smiling or laughing in situations where it is inappropriate					
17. Has difficulty telling a story about something that has happened so that others may easily understand					
18. Has difficulty stopping an activity immediately upon being told to do so. For example, he/she needs to jump a couple of extra times or play on the computer a little bit longer after being asked to stop					
19. Has difficulty understanding verbal instructions unless he/she is also shown how to do something					
20. Has difficulty with tasks or activities that involve several steps					
21. Has difficulty thinking ahead or learning from experience					
22. Acts in a wilder way compared to other children in a group (e.g., at a birthday party or during a group activity)					
23. Has difficulty doing things that require mental effort, such as counting backwards					
24. Has difficulty keeping things in mind while he/she is doing something else					

APPENDIX D

THE CHILDHOOD EXECUTIVE FUNCTIONING INVENTORY (CHEXI) –

PARENT FORM (TURKISH)

Aşağıda, bir dizi ifadeler bulacaksınız. Lütfen, her ifadeyi dikkatlice okuyunuz ve sonra o ifadenin için doldurduğunuz çocuk **ne kadar doğru** olduğunu belirtiniz. Cevabınızı, her ifadeden sonra yer alan sayılardan (1'den 5'e kadar) **birini** daire içine alarak gösteriniz. Lütfen **her soruya** yanıt verdiğinizden emin olunuz. Katılımınız için teşekkür ederiz.

Kesinlikle doğru değil	**Doğru değil**	**Kısmen doğru**	**Doğru**	**Kesinlikle doğru**
1	2	3	4	5

	1	2	3	4	5
Uzun talimatları hatırlamakta zorluk yaşar.					
Yapmak istemediği bir şeyi yapmak konusunda kendini nadiren motive edebilir.					
Bir etkinliğin ortasındayken, ne yapıyor olduğunu hatırlamada zorluk yaşar.					
Yapması için bir ödül vaat edilmezse, daha az ilgisini çeken görevleri tamamlamakta zorluk yaşar.					
İlk olarak ne olabileceği hakkında düşünmeden bir şeyleri yapma eğilimi vardır.					
Birkaç işi yapması istenildiğinde sadece ilk veya sonuncu olarak yapılması isteneni hatırlar.					
Takıldığı zamanlarda, bir sorunu farklı yollarla çözmekte zorluk yaşar.					
Bir işin yapılması gerektiğinde, sıklıkla, daha ilgi çekici bir şeyden dolayı dikkati dağılır.					
Gidip alması istenen şeyi kolayca unutur.					

Özel bir durum (örn; okul gezisine gitmek, bir eğlenceye gitmek vb.) olacağı zaman aşırı derecede heyecanlanır.					
Sıkıcı bulduğu işleri yapmada belirgin zorluk yaşar.					
Bir etkinliği planlamada zorluk yaşar (Örn; okul gezisi veya okul için gerekli olan malzemeleri getirmeyi hatırlamak gibi).					
Söylenilmesine rağmen, kendini tutmakta veya zapt etmekte zorluk yaşar.					
Birçok adımdan oluşan etkinlikleri devam ettirmekte zorluk yaşar (Örn; küçük çocuklar için, hatırlatılmadan tüm kıyafetlerini giyebilmek; büyük çocuklar için, tüm ev ödevlerini kendi başına yapabilmek).					
Konsantre olabilmesi (dikkatini verebilmesi) için verilen görevi ilgi çekici bulması gerekir.					
Uygun olmayan durumlarda, gülümsememek veya gülmemek için kendini tutmakta zorlanır.					
Başkalarının kolayca anlayacağı şekilde, olmuş bir olay hakkında hikâye anlatmakta zorlanır.					
Durdurulması söylendikten **hemen sonra** bir etkinliği durdurmakta zorlanır. Örneğin, durdurması istendikten sonra birkaç kez daha zıplar veya bilgisayarda bir süre daha oynar.					
Nasıl yapıldığı ayrıca **gösterilmediği** sürece sözlü talimatları anlamakta zorlanır.					
Birkaç adımı içeren işlerde ya da etkinliklerde zorluk yaşar.					
İleriyi düşünme veya deneyimlerinden ders çıkarmada zorluk yaşar.					
Bir grup içinde, diğer çocuklar ile karşılaştırıldığında daha haşarı şekilde davranır (Örn; Bir doğum günü partisinde veya grup etkinliği sırasında).					
Geriye doğru sayma gibi zihinsel çaba gerektiren görevleri yapmakta zorlanır.					
Bir işle uğraşırken başka şeyleri aklında tutmakta zorlanır.					

Her soruyu cevapladığınızdan emin olunuz. Katılımınız için teşekkür ederiz.

Alt boyutlar:

Çalışan Bellek	**Ketleyici Kontrol**
Madde 19	Madde 2
Madde 3	Madde 8
Madde 20	Madde 13
Madde 6	Madde 4
Madde 23	Madde 15
Madde 1	Madde 18
Madde 9	Madde 11
Madde 24	Madde 5
Madde 21	Madde 10
Madde 7	Madde 22
Madde 14	Madde 16
Madde 17	
Madde 12	

*Tüm maddeler ters puanlanır.

APPENDIX E

POST STUDY SURVEY

(ENGLISH)

1. Do you have any questions about the study?

2.

	Very bad	Bad	Average	Good	Very good
How was the video quality?					
How was the sound quality?					
How interesting was the activity for your child?					

3. How did you hear about our study?
   - Email/phone call from the Çocuk Öğrenme Lab
   - From my child's school
   - From a friend
   - Internet/social media
   - Other
4. Which city are you participating in the study?
5. Does your child go to school/nursery school?
   - Yes
   - No
6. If yes, how would you describe your child's class?
   - A class with a mix of different ages
   - Nursery

- Kindergarten
- Other

7. What is the sex of your child?
    - Girl
    - Boy
8. How many siblings (if any) does your child have?
9. What is the birth order of your child?
10. What is the mother's education level?
    - Primary school
    - Middle School
    - High School
    - University
    - Master's Degree
    - PhD
    - None
11. What is the education level of the father?
    - Primary school
    - Middle School
    - High School
    - University
    - Master's Degree
    - PhD
    - None
12. What is the mother's occupation (if working)?

(If not working, you can write NOT WORKING).

13. What is your father's occupation (if working)?

(If not working, you can write NOT WORKING).

14. If you still allow us to keep the record we have received, please select one of the following options. You can also choose to have the records deleted. What is your preference?
    - Level 1: Research team only (only the study team will see it).
    - Level 2: For academic/educational purposes (can be shown as an example in lectures or conferences)
    - Level 3: General access (e.g., sharing of findings, can be shared in definitions to be used to reach more people).
    - I want the record deleted.

APPENDIX F

POST STUDY SURVEY

(TURKISH)

1. Çalışma hakkında bir sorunuz var mı?

2.

	Çok kötü	Kötü	Orta	İyi	Çok iyi
Görüntü kalitesi nasıldı?					
Ses kalitesi nasıldı?					
Etkinlik çocuğunuz için ne kadar ilgi çekiciydi?					

3. Çalışmamızı nereden duydunuz?
    - o Çocuk Öğrenme Lab'ından e-posta/telefon
    - o Çocuğumun okulundan
    - o Arkadaşımdan
    - o İnternet/Sosyal medya
    - o Diğer
4. Hangi şehirden çalışmaya katılıyorsunuz?
5. Çocuğunuz okula/kreşe gidiyor mu?
    - o Evet
    - o Hayır
6. Cevabınız evet ise, çocuğunuzun sınıfını nasıl tanımlarsınız?
    - o Farklı yaşların bir arada olduğu sınıf
    - o Kreş

- Anaokulu
- Diğer

7. Çocuğunuzun cinsiyeti nedir?
    - Kız
    - Erkek
8. Çocuğunuzun (varsa) kaç kardeşi var?
9. Çocuğunuzun doğum sırası nedir?
10. Annenin eğitim seviyesi nedir?
    - İlkokul
    - Ortokul
    - Lise
    - Üniversite
    - Yüksek Lisans
    - Doktora
    - Hiçbiri
11. Babanın eğitim seviyesi nedir?
    - İlkokul
    - Ortaokul
    - Lise
    - Üniversite
    - Yüksek lisans
    - Doktora
    - Hiçbiri
12. Annenin (çalışıyorsa) mesleği nedir?

(Çalışmıyorsa ÇALIŞMIYOR yazabilirsiniz.)

13. Babanın (çalışıyorsa) mesleği nedir?

(Çalışmıyorsa ÇALIŞMIYOR yazabilirsiniz.

14. Eğer aldığımız kaydı hala saklamamıza izin veriyorsanız, lütfen aşağıdaki seçeneklerden birisini seçin. Kayıtların silinmesini de seçebilirsiniz. Tercihiniz nedir?

    - Seviye 1: Sadece araştırma ekibi (sadece çalışma ekibi görecek).
    - Seviye 2: Akademik/ Eğitim amaçlı (Derslerde veya konferanslarda örnek olarak gösterilebilir)
    - Seviye 3: Genel erişim (örneğin, bulguların paylaşılması, daha fazla kişiye ulaşmak için kullanılacak tanımlarda paylaşılabilir.)
    - Kaydın silinmesini istiyorum.

APPENDIX G

ETHICS COMMITTEE APPROVAL

Evrak Tarih ve Sayısı: 01.12.2022-100172

T.C.
BOĞAZİÇİ ÜNİVERSİTESİ
SOSYAL VE BEŞERİ BİLİMLER YÜKSEK LİSANS VE DOKTORA TEZLERİ ETİK İNCELEME KOMİSYONU
TOPLANTI KARAR TUTANAĞI

Toplantı Sayısı	:	37
Toplantı Tarihi	:	30.11.2022
Toplantı Saati	:	16:00
Toplantı Yeri	:	Zoom Sanal Toplantı
Bulunanlar	:	Prof. Dr. Feyza Çorapçı, Doç. Dr. Arhan S. Ertan, Dr. Öğr. Üyesi Yasemin Sohtorik İlkmen, Dr. Öğr. Üyesi Ayşegül Metindoğan
Bulunmayanlar	:	Doç. Dr. Senem Yıldız, Dr. Öğr. Üyesi Harun Muratoğulları

Burcu Şanlı Karmaz
Temel Eğitim

Sayın Araştırmacı,

"The relationship between patterning and executive function skills in 4- to 7-year-old children" başlıklı projeniz ile ilgili olarak yaptığınız SBB-EAK 2022/86 sayılı başvuru komisyonumuz tarafından 30 Kasım 2022 tarihli toplantıda incelenmiş ve uygun bulunmuştur.

Bu karar üyelerin toplantıya çevrimiçi olarak katılımı ve oy birliği ile alınmıştır. Onay mektubu üye ve raportör olarak Yasemin Sohtorik İlkmen tarafından toplantıya katılan bütün üyeler adına e-imzalanmıştır.

Saygılarımızla, bilgilerinizi rica ederiz.

Dr. Öğr. Üyesi Yasemin
SOHTORİK İLKMEN
ÜYE

e-imzalıdır
Dr. Öğr. ÜyesiYasemin Sohtorik
İlkmen
Öğretim Üyesi
Raportör

SOBETİK 37 30.11.2022

Bu belge, güvenli elektronik imza ile imzalanmıştır.

APPENDIX H

INFORMED CONSENT FORM FOR PARENTS

(ENGLISH)

T.C.

BOĞAZİÇİ UNIVERSITY

SOCIAL SCIENCES AND HUMANITIES HUMAN RESEARCH ETHICS COMMITTEE

Participant Information and Consent Form

Institution supporting the research: Institute of Education Sciences (IES)

Name of the study: Development of a Patterning Knowledge Online Scale for 4- and 7-Year-Old Children and Measurement of Executive Function Skills

Name of the Researcher: Burcu Şanlı Karmaz

Thesis Supervisor: Aysegül Metindoğan

Project Coordinator: Serkan Özel

Dear parent,

Assoc. Prof. Serkan Özel, a faculty member at Boğaziçi University, Department of Mathematics and Science, is conducting a scientific research project titled "Development of a Patterning Knowledge Online Scale for 4 and 7 Year Old Children". The aim of this study is to develop an online measurement tool that will enable the measurement of patterning knowledge, which is an important variable in predicting mathematical skills at an early age, and to evaluate the relationship between patterning knowledge and executive function skills. We invite you to participate with your child in this research that examines early mathematics skills between the ages of 4-7. The mathematical knowledge that children have when they start kindergarten is associated with their success in later school years. Therefore, it is important to identify which skills are needed to develop mathematical knowledge in preschool. Before you make your decision, we would like to inform you about the research.

If you agree to participate in this research, we will organize a video conference call with you via Zoom platform on a jointly determined date. Two games, a pattern game, and a picture matching game, will be played with children aged 4-7 years. The parents of the participating children are expected to fill out a form related to their children's general executive functioning skills. In addition, a post-study questionnaire will be applied to the parents in order to learn their opinions about the study and to obtain demographic information. The completion of the evaluation is expected to take 30-60 minutes. The evaluation data will be collected through a code number and the personal information of the participants will be protected. If you give your consent, screen recording and camera video recording will be taken during the study. These records will be kept on secure university servers.

Participating children will receive a participation certificate certifying their participation in this study. You will receive a brochure on patterning knowledge. Apart from these, there will be no remuneration or other rewards.

Participation in this study is completely voluntary. If you participate, you have the right to withdraw your consent at any stage of the study without giving any reason. If you would like additional information about the research project, please contact Assoc. Prof. Serkan Özel, Lecturer, Department of Mathematics and Science Education, Boğaziçi University. You can consult the Social Sciences and Humanities Human Research Ethics Committee about your research rights.

Me, (name of the parent of the participant child) ...., have read the above text and fully understood the scope and purpose of the study in which I was asked to participate and my responsibilities as a volunteer. I had the opportunity to ask questions about the study. I understood that I can leave this study at any time and without having to give any reason and that I will not face any adverse attitude if I leave.

Under these conditions, I agree to participate in this study voluntarily and without any pressure or coercion.

I give my consent for screenshots and voice recordings to be made. ☐ I do not give my consent to screen and voice recording. ☐

Name-Surname of the Parent of the Participant Child:………………………………..

Signature:...

Address (Telephone No, Fax No if available):………………………………………...

………………………………………………………………………………………

Date (day/month/year):...../......./...........

Name-Surname of the researcher:..

Signature:...

Date (day/month/year):...../......./.............

APPENDIX I

INFORMED CONSENT FORM FOR PARENTS

(TURKISH)

T.C.

BOĞAZİÇİ ÜNİVERSİTESİ

SOSYAL VE BEŞERİ BİLİMLER İNSAN ARAŞTIRMALARI ETİK KURULU

Katılımcı Bilgi ve Onam Formu

Araştırmayı destekleyen kurum: Institute of Education Sciences (IES)

Araştırmanın adı: 4-7 Yaşındaki Çocuklar için Örüntüleme Becerisi Çevrimiçi Ölçeği Geliştirilmesi ve Yürütücü İşlev Becerileri Ölçme

Araştırmacının Adı: Burcu Şanlı Karmaz

Tez Danışmanı: Ayşegül Metindoğan

Proje Yürütücüsü: Serkan Özel

Sayın veli,

Boğaziçi Üniversitesi Matematik ve Fen Bilimleri Bölümü öğretim üyesi Dr. Serkan Özel "4 ve 7 Yaşındaki Çocuklar için Örüntüleme Becerisi Çevrimiçi Ölçeği Geliştirilmesi" adı altında bilimsel bir araştırma projesi yürütmektedir. Bu çalışmanın amacı ileri yaşlardaki matematik becerisinin tahmin edilmesinde önemli bir değişken olan örüntüleme becerisinin erken yaşta ölçülebilmesini sağlayacak bir çevrimiçi ölçme aracı geliştirmek ve örüntüleme becerisinin yürütücü işlev becerileri ile ilişkisini değerlendirmektir. 4-7 yaş arası erken matematik becerilerini inceleyen bu araştırmaya çocuğunuzla birlikte katılmak üzere sizi davet ediyoruz. Çocukların anaokuluna başladıklarında sahip oldukları matematik bilgisi, onların ilerleyen okul yıllarındaki başarıları ile ilişkilidir. Bu nedenle, okul öncesi dönemde matematik bilgisini geliştirmek için hangi becerilerin gerekli olduğunun belirlenmesi önemlidir. Kararınızdan önce araştırma hakkında sizi bilgilendirmek istiyoruz.

Bu araştırmaya katılmayı kabul ettiğiniz takdirde sizinle ortak belirlediğimiz bir tarihte Zoom platformu üzerinden bir video konferans görüşmesi gerçekleştireceğiz. 4-7 yaş arası çocuklarla örüntü oyunu ve resim eşleştirme oyunu olmak üzere iki oyun oynanacaktır. Katılımcı çocukların velilerinden ise çocuklarının genel yürütücü işlev becerileriyle alakalı bir form doldurmaları beklenmektedir. Ayrıca çalışma hakkındaki görüşlerini öğrenmek ve demografik bilgi edinmek amacıyla velilere çalışma sonrası anketi uygulanacaktır. Değerlendirmenin tamamlanmasının 30-60 dakika olması beklenmektedir. Değerlendirme verileri bir kod numarası aracılığı ile toplanarak katılımcıların kişisel bilgileri koruma altına alınacaktır. Onay vermeniz halinde çalışma esnasında ekran kaydı ve kamera görüntüsü kaydı alınacaktır. Bu kayıtlar güvenli üniversite sunucularında tutulacaktır.

Katılımcı çocuklara bu çalışmaya katıldıklarını belgeleyen bir katılım belgesi verilecektir. Size ise örüntüleme becerileri ile ilgili bir broşür verilecektir. Bunların dışında herhangi bir ücret veya başka bir ödül verilmeyecektir.

Bu araştırmaya katılmak tamamen isteğe bağlıdır. Katıldığınız takdirde çalışmanın herhangi bir aşamasında herhangi bir sebep göstermeden onayınızı çekmek hakkına da sahipsiniz. Araştırma projesi hakkında ek bilgi almak istediğiniz takdirde lütfen Boğaziçi Üniversitesi Matematik ve Fen Bilimleri Eğitimi Bölümü

Öğretim Üyesi Dr. Serkan Özel ile temasa geçiniz. Araştırmayla ilgili haklarınız konusunda Sosyal ve Beşeri Bilimler İnsan Araştırmaları Etik Kurulu'na danışabilirsiniz.

Ben, (katılımcı çocuğun velisinin adı) ...., yukarıdaki metni okudum ve katılmam istenen çalışmanın kapsamını ve amacını, gönüllü olarak üzerime düşen sorumlulukları tamamen anladım. Çalışma hakkında soru sorma imkânı buldum. Bu çalışmayı istediğim zaman ve herhangi bir neden belirtmek zorunda kalmadan bırakabileceğimi ve bıraktığım takdirde herhangi bir ters tutum ile karşılaşmayacağımı anladım.

Bu koşullarda söz konusu araştırmaya kendi isteğimle, hiçbir baskı ve zorlama olmaksızın katılmayı kabul ediyorum.

Ekran görüntüsü ve ses kaydı yapılmasına onay veriyorum. ☐

Ekran görüntüsü ve ses kaydı yapılmasına onay **vermiyorum**. ☐

Katılımcı Çocuğun Velisinin Adı-Soyadı:……………………………………………

İmzası:..

Adresi (varsa Telefon No, Faks No):..

....

Tarih (gün/ay/yıl):...../......./.............

Araştırmacının Adı-Soyadı:...

İmzası:..

Tarih (gün/ay/yıl):...../......./.............

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